# Saint Christopher

## A G.W.R. 29xx $3\frac{1}{2}$ in. gauge

by: DON YOUNG

### PART I

#### Introduction and Frames

I first became aware of the Great Western Railway in the late 1930's, when there was an article in 'Meccano Magazine' on the 38xx County 4-4-0's which had become extinct; I remember my very junior mind had problems imagining Old Oak Common – it didn't sound like a place connected with Locomotives. I was able to indulge myself in 1969 with the series on COUNTY CARLOW as published in 'Model Engineer', and at that time this was the limit of my ambition as regards G.W.R. Locomotives.

Although L.N.E.R. 'Pacifics' will remain my first love, and maybe this is the reason I have yet to publish a design for one of them, I was lucky in Uncle Frank to have someone who appreciated a locomotive for its performance, rather than partisanship for the Works at which it was designed and built, and it was he who opened my eyes that not all good engines had L.N.E.R. stamped on them; some of them that did were right pigs!

My outlook was further broadened by a year at Eastleigh M.P.D. where each day we had at least one G.W.R. engine on Shed; usually an 0-6-0; occasionally a 'Hall' or 43xx 'Mogul'. I found them fascinating to look at, with all the rows of snap head rivets in view, but was not so keen when called to work on them to trace a leak in the vacuum brake system whereby they could not pull 25 in. Hg; this in my opinion was far too high a vacuum, especially when the crosshead pump was removed. Reading Holcroft's 'Locomotive Adventure' I was fascinated to read of his trip to the U.S.A. and how he convinced Churchward on his return of the usefulness of the 2-6-0 wheel arrangement, which led on to the first British 'utility' or 'mixed traffic' engine. Being already a 'Mogul' fan, and having worked on the odd 43xx, this was my second G.W.R. Locomotive for $3\frac{1}{2}$ in. gauge.

Thanks to the support of A. J. Reeves & Co. (Birmingham) Ltd. with the necessary castings and allied to Churchward's policy of standardisation, the means existed to produce another G.W.R. design for $3\frac{1}{2}$ in. gauge, utilising existing castings and a lot of existing drawing details; which one should I choose? The most useful current source of information on Locomotives as far as I am concerned is the print service provided by the Oxford Publishing Company, taken from microfilms of original Works drawings; this to me is a vital service to LLAS readers, yet can I get OPC to advertise in our Magazine? Can I heck! Anyhow, with one of my orders I asked for some prints of the 29xx 'Saint' Class, these then being laid aside for a few months whilst I worked on other designs. I then studied the 29xx drawings, when it was immediately apparent that this was a brilliantly proportioned design, one that was as sure to be successful in $3\frac{1}{2}$ in. gauge as it was full size. Designing SMALL LOCOMOTIVES tends to make one very critical, even of one's own work, yet applying this critical eye to the 29xx, (and remember by no stretch of the imagination am I a G.W.R. fanatic!) I could find just one feature which was less than perfect. This was that to preserve the standard Churchward/Stephenson valve gear arrangement, the intermediate valve rod was bent to clear the leading coupled axle, whereas the gear could have been inclined to avoid this. Other than this it was a real 'Rolls-Royce' engine, but why, oh why, did the crew not get the sort of accommodation such a design deserved? From this one design came the G.W.R. 'Halls', 'Manors' and 'Granges', plus to a large extent the L.M.S. 'Black Fives' and B.R. Standard Class 5's, such was the perfection of the 'Saints' and I hope that readers feel I have done this great design justice in scaling down to $3\frac{1}{2}$ in. gauge, my first offering at $\frac{1}{16}$ in. scale in LLAS, and one that has been long overdue.

#### Mainframes

Let us make the items detailed on Sheet 1, though we cannot progress very far in this first instalment. For such a large machine the mainframes are remarkably straightforward, requiring a very minimum of attention. Take two 2 feet lengths of $2\frac{1}{2}$ in. x $\frac{1}{8}$ in. mild steel flat and square off the ends to $23\frac{15}{16}$ in. overall. Coat one face of one piece with blue marking out fluid, then starting from the front end, mark on the profile and all the holes. To avoid cumulative errors, crosscheck some of the major dimensions for maximum accuracy. Clamp the frames together, drill about six 3/32 in. holes along the full frame length and fasten with snap-head copper or aluminium rivets, hammering well down.

Holes in frames must be drilled properly to avoid problems later on, both in position and squarely through the metal: this calls for use of a drilling machine, with drill pad and 3 jaw chuck on the lathe as a slightly inferior alternative. Carry on and drill all the plain holes and we can next deal with countersinking those so specified. For rivets use a broken Slocombe centre drill or 60 deg. Rosebit; for screws use a 90 deg. Rosebit or grind a drill to the correct angle, and use an actual screw as gauge, the head to come flush with the frames.

Profile is remarkably simple; ahead of the leading coupled axle, saw out the portion to include the radius to clear the rear bogie wheels and complete to line with files, adding a small radius at the back bottom corner. At the top of each horn slot, drill a row of $\frac{1}{8}$ in. holes and open these out until they begin to break into one another. Saw down at each side of the slot and break out the unwanted pieces with pliers; all the rest is machining.

Bolt the vertical slide to the boring table and attach the machine vice in turn, then grip the frames in the latter to first end mill the leading portion at the cylinders down to $2\frac{7}{16}$ in. width. A sturdier set-up is to substitute your angle plate for said machine vice and bolt through the $\frac{3}{8}$ in. hole, though we cannot do this for the remaining operations. Next concentrate on that $\frac{5}{8}$ in. wide slot to $\frac{1}{8}$ in. depth at the top of the frames, this to restrain the rocker box, a very important function. To complete the frames we have to machine the horn gaps to size, so bring one of these up to the machine vice, facing the chuck, grip a $\frac{5}{8}$ in. or $\frac{3}{4}$ in. end mill in the 3 jaw and first tidy up the trailing edge to line. Move to the leading edge and mill this in turn to a piece of 1 in. wide bar material as your gauge. Tidy up the top edge to line, deal with the other two horn gaps, then separate and remove all burrs and sharp edges.

#### Frame Stretcher

We need another 12 in. length of the $2\frac{1}{2}$ in. x $\frac{1}{8}$ in. frame steel from which to make the frame stretcher, plus a simple jig to ensure our frames really are $2\frac{7}{8}$ in. apart, more important are parallel to each other, so saw first into 4 in. lengths. For the first piece, mark out as for a horn gap, but instead of being 1 in. wide it wants to be $2\frac{7}{8}$ in. to form a horseshoe.

Drill the row of $\frac{1}{8}$ in. holes along the top of the slot, open out until they break into one another, then saw down the two sides of the slot and break out. Set up in the machine vice, tidy up the top of the slot, then deal with each side with an end mill. The actual $2\frac{7}{8}$ in. dimension is not super-critical, but used as a gauge over all the components which fit between the frames it does ensure the latter will be parallel throughout. Take the next piece of material, square off one end and scribe a line across $\frac{1}{2}$ in. from this end. Grip in the bench vice with this line flush with the top of the jaws and hammer over to 90 deg., using an engineers' square to check. Move on a full $2\frac{5}{8}$ in., scribe another line and hammer over the second flange, checking with your gauge that there is metal to be removed to clean up the flanges to size. Mark off and drill $\frac{3}{8}$ in. holes at the ends of the two slots, add another in the middle of each and file out to drawing. Bolt by these slots direct to the vertical slide table, end mill the two flanges to gauge and mill off the excess flange width to achieve the $\frac{3}{8}$ in. dimension. The second frame stay is dealt with similarly, though minus the slots; you can either clamp to the vertical slide table to machine, or drill a couple of plain holes to bolt direct to the table again.

### Drag Beam

This is a $5\frac{3}{8}$ in. finished length of $1\frac{1}{2}$ in. x $\frac{1}{8}$ in. BMS flat; mark off and drill the eight No. 34 fixing holes. For the 1 in. x $\frac{1}{4}$ in. drawbar slot, drill a row of 7/32 in. holes and file out to a piece of $\frac{1}{4}$ in. thick material as gauge; that was easy!

### Main Horns

These are Reeves smashing hot pressings; their later and slightly heavier pattern is really good! First get a 2BA bolt about $\frac{3}{4}$ in. long, complete with nut, and fit at the bottom of the opening, this to give support for machining at the weakest point. Next carefully assess the machining allowances, as there is not much metal to be removed; over enthusiasm will lead to scrappages! All machining is going to be by end milling, so avail yourself of a really sharp cutter of around $\frac{5}{16}$ in. diameter.

Back to the machine vice and vertical slide and first grip to machine the inside face; that's the one you see on the L.H. view of the detail. Mill all around this inside edge to remove the machining allowance; before we go any further we need a simple clamp. Cut a 1 in. length of $\frac{1}{2}$ in. square steel bar and mill the ends square. Now cut a step at each end, $\frac{5}{16}$ in. deep and about $\frac{1}{16}$ in. wide, so that when both ends have been dealt with, the clamp fits snugly in the axlebox slot, as yet unmachined. Drill a hole through the centre of the bar to bolt directly to the vertical slide table and hold the horns firmly in place for machining, only pack the horn off the table about $\frac{1}{16}$ in. so you can end mill the slot without damaging the table.

Grip the end mill in the 3 jaw chuck and traverse around the horn to check that the set-up is correct; the outside of the pressing is of course facing the chuck at this stage. First tackle the hornstay facings and then continue around the periphery of the frame fixing flange to complete this part to drawing. Next concentrate on reducing the overall thickness to $\frac{3}{8}$ in., only you will have to leave the bits obscured by the clamp for a moment. Advance the carriage by .125 in., this is where the big graduated handwheel at the end of the leadscrew on the Myford lathes comes in handy, and take a first cut around the frame fixing face. Gradually bring the cutter up to the spigot that locates into the frames and machine this to be a tight fit therein, keeping things nice and central, and checking against the frames without removing the horn from the vertical slide. When satisfied, clamp over the two side flanges to the vertical slide table and only then remove the original clamp, so the job will not move; remove the 2BA bolt at this stage. Now you can machine most of the axlebox slot with your end mill, remembering to keep it central again, and checking with your micrometer over the spigot at each side as well as using a piece of $\frac{7}{8}$ in. square material as gauge for the slot. Complete by milling the edges of the spigot that were masked earlier on. Deal with the next horn to be identical with the first, then move on to the next frame slot and machine another pair, stamping each frame and its horn for identification; letters or numbers as you prefer.

### Erecting the Horns

Fit the 2BA bolt in the slot once more and erect the horn to the frames, clamping firmly in place, when the bottom, hornstay, edge should be flush with the bottom edge of the frames. Drill 3/32 in. diameter from the frames through the horn at seven positions and fit three 7BA bolts to hold firmly in place; now you can remove the clamps. Before we can rivet the horns in place we need a 'dolly'; this is a length of $\frac{3}{16}$ in. steel rod of just sufficient length when stood in the bench vice to project about $\frac{3}{8}$ in. above the jaws, to give support for the rivet head. Chuck in the 3 jaw and lightly centre one end, then take a $\frac{1}{8}$ in. drill and produce a hemispherical cup to accept the snap head of the 3/32 in. rivet; this is surprisingly easy to achieve with a hand drill, just rotate the drill guiding handle in circles as you drill; I just hope that makes sense to you! We actually need a second tool, which is a 4 in. length of $\frac{1}{4}$ in. rod with a No. 39 hole drilled $\frac{1}{2}$ in. deep at one end.

Fit the dolly in the bench vice, poke a $\frac{3}{8}$ in. long rivet through one of the top corner holes, sit the head on the dolly, slip the second tool over the projecting shank and give it a couple of sharp blows to ensure the mating surfaces are in close contact. I now crop the rivet shank off with pliers so that when hammered down into the countersink, and this must be done very carefully to avoid damaging our precisely machined spigot, the rivet just about exactly fills the countersink and does not overflow. This does take a little practice, but any surplus you simply file away to finish flush with the outside of the frames. Deal with all the clear holes, then remove the 7BA bolts one by one as you replace them with rivets; complete all horns to this stage.

### Axlebox

The axleboxes are supplied as cast gunmetal sticks and require a lot of machining; they really are vital to the success of your SAINT CHRISTOPHER. Again the machine vice and vertical slide figure prominently, indeed the first operation is to mill one face of each of the castings. Reverse the second piece in the vice and mill the opposite face to the required $\frac{1}{2}$ in. thickness, then repeat on the other casting at the same setting to ensure they are identical; this will be the pattern all the way through. Next deal with one of the edges on both castings, reverse and complete both to give a 1 in. overall width; in all this you can check by micrometer. Leave the last piece in place and change to your $\frac{1}{4}$ in. end mill from the larger one you will have been using. First cut a $\frac{1}{4}$ in. wide slot right down the middle of this face, to $\frac{1}{16}$ in. depth, again checking your dimension by micrometer. Now gradually open up the width of the slot to $\frac{7}{8}$ in., against the horns as your gauge, and checking that the side flanges remain of equal thickness. Make a note of the vertical slide micrometer collar readings when the final cuts were taken, then turn the block through 180 deg. and repeat the process, this time with the additional check as to whether the axle box will enter the horn slot; the ideal fit at this stage is a very tight one. Deal with the second casting in identical manner, when the next job is to saw into individual boxes. Grip one at a time in the 4 jaw to face off one end, then sort out into pairs, stamping to agree with the horn identification, then chuck each pair in the 4 jaw to face off to length. Find the centre of one axlebox by the 'X' method, centre pop and scribe a circle at ½ in. diameter. Cut four 1 in. lengths from ⅜ in. x ⅛ in. BMS flat and fit in the axlebox slots, then chuck in the 4 jaw as a pair, with the scribed circle outermost.

Chuck a scriber under the toolpost and set the job so that the scriber follows the ½ in. circle; this you can do very accurately. Centre, drill through both boxes at 7/16 in. diameter, change to a small boring tool and open out to around .495 in. diameter; complete to size with a ½ in. reamer. The oil hole, from the top, is drilled around No. 51 and then countersunk before poking the reamer through the bore again to remove any burr.

### Hornstay, Spring Pin and Spring Plate

Before we can go any further with the axleboxes, we need the hornstays, six 1½ in. finished lengths of ⅜ in. x ⅛ in. BMS flat. Grip all six in the machine vice on the vertical slide, when you will be able to position and drill all the holes accurately by use of the vertical and cross slide micrometer collars. Drill those two holes specified at No. 28 to No. 30 only at this stage. Offer up to the horns, spot through, drill No. 43 and tap 6BA for hexagon head bolts. The next job is to ease each axlebox just sufficiently so that it will push into its horn. Spot through the No. 30 holes, drill the axleboxes No. 40 and tap 5BA. Next use a hornstay as a drill jig for each of the spring plates, then cut to length and radius the ends with a file. The spring pins are 1⅝ in. lengths of ⅛ in. steel rod, screwed 5BA at each end, this latter operation being carried out in the lathe using the tailstock die-holder.

The short end of thread goes into the axlebox, so fit two 5BA brass nuts at the other end, tighten together and screw hard into the axlebox using the outer nut. Change to the inner nut and continue tightening until it breaks free, then remove the pair. Open out the hornstay to No. 28, then assemble the box with its spring pins, followed by Reeves standard axlebox springs for 3½ in. gauge, then the spring plate; finally a nut and locknut on each spring pin. The axleboxes still need final relief, but this will have to await assembly of the frames.

### Bogie Wheel

The bogie wheels are entirely out of context at this juncture, but as they are detailed we may as well tackle them; wheel turning I find most pleasureable anyhow!

Grip by the tread in the 3 jaw and at the lowest direct drive speed, face right across the back of the casting. Turn the flange down to 2⅝ in. diameter and radius the sharp corner with a file. Centre very deeply and drill through at 3/16 in. diameter, then if the hole is not running true you can correct the error with your ¼ in. end mill; this really does work. Open out to 19/64 in. and finally to 5/16 in. using a reamer or drill for the final operation as available.

Lately I have discovered a novel way of completing small wheels without a lot of bother; I came across it by accident. Find a length of 5/16 in. diameter material that is a close fit in the wheel bores, you can slightly knurl it if you like to get a tighter fit. Screw both ends 5/16 in. BSF or whatever screwing tackle you have and bolt a pair of wheels together, back to back. Now you can grip by the tread of one wheel in the 3 jaw to completely machine the other, and vice versa. Face across the tyre to get the correct 7/16 in. thickness, then turn down to 2⅜ in. tread diameter, using a round nosed tool to produce the root radius between tyre and flange, taking note of the cross slide reading at which the final cut was taken. Produce the chamfer with a file, then reverse and repeat. The final operation is to chuck each wheel by its flange and complete the boss to stand proud of the tyre by 1/16 in.

### Axles

All five axles are 4 9/32 in. finished length, the bogie ones from ⅜ in. BMS rod and the coupled ones at ½ in. diameter. Chuck a bogie axle in the 3 jaw and check with a d.t.i. it is running true; correct any error by changing to the 4 jaw. Turn down over a ½ in. length to a good fit in the wheel. Centre the axle end, reverse and repeat the process. The main axles are dealt with similarly, except we have no wheels, in fact I have run out of drawing details, so must call a halt to the proceedings.

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# Through Don's Letter Box

Dear Don,

There must be many modellers who read LLAS or other well known periodicals who do not belong to any club or society. Some may make a conscious decision not to belong preferring to plough their own furrow. Others may feel that clubs would not welcome them until they had a completed locomotive and were able to participate on the track. It is a great pity that many beginners and I was one once, do not appreciate that we are all in the same boat. Most beginners if they do not already have a committment to build a particular locomotive may look in one or other of the journals and decide to build 'a locomotive suitable for a beginner'. Much of the advice is completely wrong and leads to frustration and abandoned or long drawn out projects. If they were only to attend a local club's running day they might pick up several tips on the advantages and drawbacks with certain designs in discussion with club members.

To build a steam locomotive takes more than a year rather than a few months if you start from scratch and already have a full time job. It is my opinion that the two frequently recommended 3½" gauge designs, TICH by the late LBSC and ROB ROY by Martin Evans involve far too much time consuming work for the size of locomotive they produce.

I have built two complete locomotives, repaired others and have two in various stages of construction. From my experience in building these I would thoroughly recommend Don's MARIE E design as described in LLAS, in fact I have stopped all other work to build one. From the beginners point of view most of the chassis can be built with the minimum of machine work. The design is straightforward and produces a locomotive that looks like a locomotive.

The entire chassis is held together with 4BA screws. This requires one clearance drill, one tap and a tapping drill. Buying screws by the 100 is much cheaper even if you have cut some to shorter lengths. If you can't find 4BA hexagon head screws at a reasonable price, long countersunk or round head screws are often available from surplus suppliers. These can be converted to hexagon head by running a steel nut on to the thread, applying a drop of loctite and cutting the original head off. The old fashioned way of course was to rivet over the thread on to the top of the nut. So the investment in tools to build this locomotive is not excessive in taps and dies.

I found Dennis Hill's article on building the prototype MARIE E most useful. I have had a little difficulty in obtaining some of the steel sections specified in the drawings as industry is gradually changing over to metric size stock. The advantage of MARIE E from both the beginners and the more experienced model engineers point of view is that there is plenty of fresh air in the design. If you cannot buy the exact size material or have something handy the next size up in the surplus box can be used without difficulty.

DES ADELEY

# Saint Christopher

by: DON YOUNG

### PART II

COUNTY CARLOW when described in 'Model Engineer' had piston valve cylinders and an overscale boiler, or rather firebox, both owing much to the late maestro LBSC, this being his centenary. At that time I was writing for fun, something that is equally true today, the difference being that what was a hobby has now become my livelihood, and at the transition it was prudent to look at the then commercially disappointing COUNTY CARLOW with a view to improving things. Generally among you builders, slide valve cylinders are more popular than the piston variety, with such notable exception as LBSC's DORIS (a 3½ in. gauge BLACK FIVE), so in 1977 I introduced alternative slide valve cylinders. This in turn led to a revision of the smokebox and I added the built-up chimney as the original cast one had come in for much criticism, even though a genuine G.W.R. pattern and as originally fitted. To tidy up the whole design and produce a MKII COUNTY CARLOW, I redesigned the boiler to be slimmer, and thus again more authentic, at the firebox.

As SAINT CHRISTOPHER mirrors these later practices, Sheet No. 2 which appears with these notes is a bit of a hotch-potch of bits and pieces, which after completion will not greatly advance the chassis assembly, though will in fact break the back of the whole engine, containing all the 'meat'. It also means that for once I can preach what I practised in building the boiler first, then the cylinders, when I was confident that the project could then be successfully completed, this in the days of limited equipment and finance – things don't seem to change much! Before getting on to the boiler/cylinder theme, and we shall not be able to complete all the items detailed of Sheet 2 in this session, let me first take the chassis along as far as we can progress it.

**Drag Box**

This is our first fabrication in steel and as there are several specified for SAINT CHRISTOPHER, let me take this one step by step. Start with the back plate, from 2 in. x ⅛ in. BMS flat, squaring off to about 2 29/32 in. overall to provide a small machining allowance. Mark off the drawbar slot, drill four 7/32 in. holes down the centre of the slot and then file to line, this to match the slot already cut in the drag beam. Next cut the two side members from the same flat bar and square off to 2⅛ in. long. At $\frac{1}{16}$ in. in from the side edges of the back plate and at about ⅝ in. spacing, drill three No. 44 holes each side. Offer up the side plates, spot through the No. 44 holes, drill the side plates No. 50 to about $\frac{3}{16}$ in. depth and tap 8BA; secure the side plates to the back plate with round head screws.

We now need the horizontal stiffener plates to complete and these again can be from the 2 in. x ⅛ in. BMS flat, to come hard against the back plate and leaving ⅛ in. short to drawing at the front – this latter is of no consequence. Cut two pieces and square off to be a good fit between the side plates, then mark out one of them for the drawbar pin hole and slots as shown. Clamp together and drill ½ in. holes at the ends of the slots, then saw down to remove most of the unwanted metal before completing with files; drill the ¼ in. hole for the drawbar pin. Take a length of ½ in. steel rod, chuck in the 3 jaw, face centre and drill ¼ in. diameter to about 1¼ in. depth before parting off at 1 in. Use this as a spacer between the two horizontal plates, bolting them firmly together, assemble to the side plates and clamp over the latter to hold the assembly firmly together for brazing.

Brazing (silver soldering) steel is easy provided steps are taken to avoid oxidation at the joints, which necessitates mixing Easyflo flux to a stiff paste and applying quite liberally. Now take your propane torch, the one we shall be using for the boiler very shortly, and heat up the whole drag box as quickly as possible to a dull red; apply Easyflo No. 2 and watch it flow into all the joints. Wash off in hot water, using an old tooth brush to scrub off the excess flux, then dry and clean up with files before applying a zinc coating from an aerosol can, this to prevent rusting. Next file away the screw heads protruding from the back plate, then chuck in the 4 jaw and face across one of the side faces. Reverse in the chuck and face off the second side until the frame gauge is a proper fit.

Erect the frames stretchers and drag box to the frames, the orientation of the former will become clear to beginners when Sheet No. 3 is published; pack each axlebox hard down onto its hornstay and push the main axles through the boxes. Sit the frames, upside-down, on the lathe bed and eliminate any twist, then adjust until the axles turn sweetly. Spot through, drill the drag box and frame stretchers No. 43, tapping 6BA; fit screws. The drag beam can also be fitted to the drag box at this stage, using 6BA round head screws to represent rivet heads.

**Driving and Coupled Wheels**

Turning cast iron for me is most pleasurable, a good excuse for taking them out of context, though there is another reason in that the 'solid backed' wheel castings of Messrs. Reeves' origin, to whom grateful acknowledgement, have raised a number of queries as to how does one arrive at the finished article. First though let me justify these castings as I feel that some criticism that has been levelled against them is unfair.

A wheel with oval section spokes, the way mine are produced, requires master metal patterns and 'oddsides'. Half the wheel is moulded, by hand or machine in one box and the other half in a second box, so not only is this a rather labour-intensive job, and expensive, but the marrying of the two halves accurately depends both on the moulder's skill and the registers on the pair of moulding boxes. By making the backs of the wheels solid, the pattern becomes 'single sided' and can be machine moulded complete in one box only, also finer spoke detail can be produced at a very high success rate, so the whole job becomes a much more economic proposition, which is in the customer's favour. Anyone who has chucked a wheel to run true at the back and then turned it over only to find the front was not true to the back will appreciate this cannot happen with a 'single sided' wheel, though I would stress that 'Skipper', who moulds almost all of my wheels at the iron foundry, is a real artist in sand; it is an inspiration both to watch him at work and to see the finished result. Now for machining.

As with every casting, measure first to establish the machining allowances; despite the weight of the 'solid back' castings there is little metal to be removed. Chuck by the tyre in the 4 jaw and set the flange to run true, taking care at the projection where metal was fed into the casting; face across the back to remove the machining allowance and turn the flange to 5¼ in. diameter. Do this with the lathe running in back-gear, then switch to direct drive and use a file to produce the radius between back and flange. Still in direct drive, centre, drill through in stages to 27/64 in. and ream out for the axle at $\frac{7}{16}$ in. diameter – the reaming operation should be carried out at a lower speed. Now take a round nose tool and take cuts across the back, starting at about $1\frac{1}{2}$ in. diameter and finishing around 4 in., this until the individual spokes appear. Complete by turning outwards to mate with the tyre and then inwards to match the centre boss, this latter at around $1\frac{1}{4}$ in. diameter. Bring all six wheels to this stage; next we need a mandrel.

Take an old drill of at least $\frac{1}{2}$ in. diameter and with taper to suit your headstock mandrel and saw off just beyond the end of the flues; this is easier to do than you might imagine. Fit to the headstock and turn down the projecting spigot to a good fit in the $\frac{7}{16}$ in. hole in the wheels. Fit the faceplate, slip a wheel over the mandrel and bolt through the spokes to the faceplate; countersunk screws are best here, then the heads won't get in the way of your turning tool. In back-gear, first face off the tyre to give the correct $\frac{7}{16}$ in. overall thickness, then on all but the leading coupled wheels, move the tool out by $\frac{1}{16}$ in. and tackle the crank boss; face the balance weights flush with the tyre. Concentrate now on the tread, using a round nose tool that will produce the $\frac{1}{16}$ in. root radius between tyre and flange, and taking a single light cut as there is very little metal to play with. If chattering occurs as you reach the flange, stop the lathe and pull round by hand, applying a drop or two of paraffin as a further aid.

Get all wheels to this stage, leave the last one in place and take a final cut to size. Leave the tool setting strictly alone and deal with each wheel in turn to be of identical diameter, the exact size to within a few thous being unimportant. Remember in full size that the wheel diameter could change by as much as 3 in. between a new tyre being fitted and that at which it was scrapped, so you have a bit of latitude here and still be perfectly authentic. To complete the turning, produce the chamfer at the edge of the tyre, again pulling round by hand if there is tool chatter, and then file the radius to complete the flange.

Next we must turn attention to the crankpin holes, which requires a simple jig. Take a 2 in. length of, say, 1 in. x $\frac{3}{8}$ in. BMS bar and grip in the machine vice, on the vertical slide. On the centre line of a 1 in. face and about $\frac{5}{8}$ in. from one end, centre and drill through at $\frac{1}{4}$ in. diameter. Move on exactly 0.9375 in. by use of the cross slide micrometer collar and repeat the dose. If you have a short piece of in. $\frac{7}{16}$ silver steel rod and it is a close fit in the wheels, chuck it in the 3 jaw and reduce for $\frac{3}{8}$ in. length to $\frac{1}{4}$ in. diameter, a press fit in one hole in the bar. If you are not so lucky, start with a length of $\frac{1}{2}$ in. BMS rod, turn this down to suit the wheel initially, then the bar; press home. Fit the jig over the front of a wheel, spot through the $\frac{1}{4}$ in. hole for the crankpin, then remove the jig and check that the 'dimple' is central in the crank boss. Adjust as necessary and when all is well, clamp the jig firmly in plate and drill right through at $\frac{1}{4}$ in., using the drilling machine for the hole must be perfectly square through the wheel.

### Crankpins and Caps

Two general points concerning the crankpins; first the use of 'solid back' wheels means the $\frac{1}{2}$ in. dimension, $\frac{7}{16}$ in. for the leading crankpins, is in error by the amount by which the back of the wheel was recessed to reveal the spokes, so these dimensions need to be adjusted to place. Secondly I recommend the method of securing the crankpins, also the wheels to their axles, be Loctite No. 601 allied to Primer 'T' degreaser/catalyst, from which the spigots need to be turned to a good sliding fit in the wheels; use either bright mild or silver steel and part off to leave the correct length of bearing surface. Reverse in the chuck, centre, drill No. 34 to a full $\frac{3}{16}$ in. depth and tap 4BA. Degrease with Primer 'T', apply a couple of drops of Loctite No. 601 to each pin and fit.

For the crankpin caps, chuck a length of $\frac{1}{2}$ in. bright steel rod in the 3 jaw, face, centre and drill No. 27 to about $1\frac{1}{2}$ in. depth. Countersink the outer face at 90 deg. to suit a 4BA screw then part off a $\frac{1}{16}$ in. slice and repeat. For the leading and trailing caps, reduce to 27/64 in. diameter and repeat the dose another four times. To take the assembly one stage further, fit one wheel to each main axle, using Primer 'T' and Loctite No. 601; we can now turn our attention, literally(!), to the eccentric sheaves.

### Eccentric Sheaves

This is where I can begin to save both time and space, for MARIE E uses to some degree the SAINT CHRISTOPHER valve gear, and cylinders for that matter, so for machining the sheaves I can refer builders to LLAS No. 8, Page 20, this to avoid repetition in such a short interval of time.

### Connecting Rod

For these again I can refer builders to MARIE E for the basic procedure, material being two 10 in. lengths of 1 in. x $\frac{5}{16}$ in. BMS flat. There is one additional operation, fluting the outside of the rods, so after milling the edge to line, change to the Woodruff key cutter with the rod still set over and cut half the flute as shown; set over the other way, use said key cutter to profile the second edge of the rod, then complete the fluting.

### Cylinders

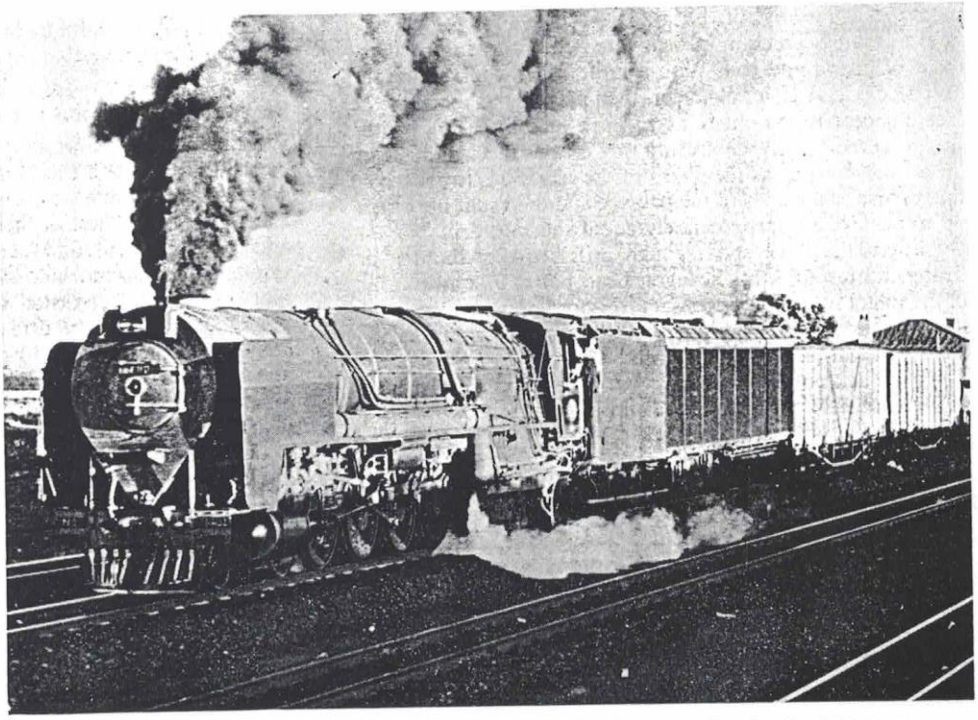
Again these will look familiar to builders of MARIE E, only the steamchests and its ends are different, and as the remainder owe their origin to LBSC, there is a lot of pleasure in perpetuating their use, or rather extending same. Let us start with the blocks.

### Cylinder Block

Assess the machining allowances as a first step, then chuck in the 4 jaw and machine the bolting face to give 1 3/64 in. to the centre of the cylinder bore. Turn through 90 deg. and tighten the chuck jaws, with soft packing between that and the freshly machined bolting face, then machine the portface. This is one of the most important faces on the whole engine and requires a good surface finish, so get your tool really sharp and use some cutting oil or paraffin to achieve said finish. Turn again to bring the front end face towards the tool and machine this to finished size, stamping with an 'F' or number to identify same; deal with the other block to be of opposite hand.

Now bring the back end of the block towards the tool and pack the front face clear of the chuck body by about $\frac{1}{8}$ in., so the boring tool will pass right through. I should have said at the outset that a hardwood bung be driven into this end of the bore, end face rubbed with a file and marking off fluid applied; complete the marking out by scribing a circle at $1\frac{1}{8}$ in. diameter on the block to represent the finished bore size. We are back at the present, so clamp a knife edged tool or scriber under the toolpost and get the scribed circle running true to same; drill out the bung. Change to the boring tool, a stout one of sufficient length to pass right through the bore at one pass; with the lathe running at the lowest direct drive speed, take a cut of around 1/32 in. through the bore. Leave the tool at this setting and still in the finest automatic feed, traverse back, then use cuts of around 1/64 in. per double pass to open out the bore to approaching $1\frac{1}{8}$ in. Now apply a cut of only 0.005 in. and traverse at this setting at least 6 times, removing the last whisker of metal to get the bore really parallel, and running at medium speed. Using an 'O' ring of Viton grade, the bore must be 1.125 in. diameter

**The Ultimate in 3′ 6″ Steam Locomotive Design?**



South African Railways Class 25 No. 3481 "Belinda" leaves BRITSVILLE for DE ARR in the KAROO on 20th April, 1973.
The 50 ft. long engines with their 57 ft. condensing tenders (compare original Royal Scot engine and tender at 63ft.) have a range of 600 miles without watering in the arid Karoo. In terms of mechanical features such as cast steel engine beds and roller bearings throughout on both axleboxes and motion these 4-8-4 locomotives, built by North British and Henschel and introduced in 1953 represent the ultimate in SAR steam locomotive design. Tractive effort (at 75%) is 45,360 lbs. As these locomotives now work mainly the 146 mile DE AAR – KIMBERLY section where water supplies are less critical the condensing equipment has been removed from all but one of the 90 locomotives of this class and the tenders modified to a somewhat ungainly Vanderbilt type.
In addition to the 90 locomotives of Class 25, a further 50 locomotives (Class 25NC) with 12-wheel non-condensing tenders were supplied by the same makers.

within 0.005 in., calling really for use of an internal micrometer, and of the best possible surface finish to give a good service life, so beginners are advised to opt for the soft packing alternative as for MARIE E. Face the rear of the block to the correct overall length of 2½ in., when this face will be perfectly square with the bore, another important requirement.
Back to the vertical slide, only this time instead of fitting the machine vice we need an angle plate. Apply marking off fluid to the portface and mark out the ports to drawing, then stand the rear end of the block on the angle plate. A long bolt, or stud, is required to pass through the bore and down through a slot in the angle plate, with a large washer and nut at the top end to secure same firmly. Open out the 3 jaw chuck and push the portface hard against the jaws, this to ensure the latter is square across the lathe axis; traverse the block to make sure that all the ports can be cut without disturbing the set-up. Centre and drill a row of 3/32 in. holes to $\frac{3}{16}$ in. point depth along the centre of each steam port, then do likewise at $\frac{3}{16}$ in. diameter at the exhaust port.
Change to a 3/32 in. diameter end mill, a very flexible tool that needs care in use, and running the lathe at top speed, take a cut of about 1/32 in. depth along the centre of a steam port. Deepen the slot to $\frac{3}{16}$ in., still 3/32 in. wide, a little at a time, then a few thous at a time, open up one side of the slot to line, taking care not to 'dig in' at the ends of the slot. Do the same at the other side of the slot, using a piece of ⅛ in. thick material as gauge to achieve the correct port width; deal with the second steam port in identical fashion. Use a $\frac{3}{16}$ in. end mill to rough out the exhaust port, then change back to the 3/32 in. one to complete to line. Turn the block through 90 deg. to bring the bolting face towards the chuck and mark out the position of the ⅜ x 32T exhaust tapping. Centre, drill 11/32 in. diameter to $\frac{5}{16}$ in. depth and tap. The connecting passage from port to tapping is ¼ in. diameter at an angle of roughly 45 deg., so if you feel clever, swing the block around to this setting, centre and drill to connect. Those of us with less confidence will take the block to the bench vice, soft clams please, centre pop and drill a pilot hole of around ⅛ in. diameter from the port, opening out in stages to ¼ in.

**Steam and Exhaust Connectors; Steam Union Body**

All these items are plain turning from hexagon bronze bar, though steel will do at a pinch; use the exhaust connector to fasten the block to its frame. Most G.W.R. cylinders are horizontal, yes I do admit there is a lot to be said in their favour(!), so all you have to do is use a square from the top edge of the frames onto the back face of the block to set correctly, when you can spot through the No. 30 holes in the frames, drill the blocks No. 40 to $\frac{3}{16}$ in. depth and tap 5BA. To achieve perfectly horizontal cylinders, the axis of the cylinder bore on some Churchward engines does not pass through the centre of the driving axle; for COUNTY CARLOW in full size it was 1 in. above. Now for the MK1 piston valve version in 3½ in. gauge, I emulated this feature exactly, to be besieged with queries and correspondence, with reams of figures highlighting my 'error'; for the slide valve version my drawing is incorrect and everyone is happy!
Steam passages come next, so file a chamfer at the inlet to the bore at each end, $\frac{7}{16}$ in. long and extending inwards from the top centre line. Set over in the bench vice and drill a $\frac{1}{16}$ in. pilot hole at one end of the chamfer into the steam port. If there is a slight error in your judgement and the passage comes too near the top or bottom of the port, countersink the outer end of the hole to 3/32 in. diameter and use the end mill in the hand brace to correct same; unlike another drill it will quite happily produce a new alignment. Get a row of four holes up to this stage, then open them out to No. 34. Beginners can leave their passages at this stage, they will be perfectly satisfactory, though by use of the 3/32 in. end mill in the hand drill, or a dental burr in the electric drill, they can be opened out to form a slot; repeat the other three passages to bring the blocks to as far as we can advance them for a moment.

**Cylinder Covers**

The covers are next in line for treatment, so chuck the front ones by their periphery and clean up the chucking spigot, then reverse in the 3 jaw, Turn down to 1⅝ in. diameter then face across before producing the $\frac{1}{16}$ in. step to 1⅛ in. diameter, a good fit in the cylinder bore. Actually it does not matter if

these are a 'rattling' fit, but it is a good exercise for the rear ones to follow, which must be a very good fit to ensure alignment of piston and rod. With a knife edged tool, scribe the bolting circle at $1\frac{3}{8}$ in. diameter, then machine as much of the face adjacent to the chuck as you can before parting off the spigot; reverse in the chuck and tidy up this face. In marking off for the cover bolts the object of the exercise is to get a hole fairly close to the ends of the passage and then split the others up to achieve an aprpxomiately equal spacing; drill No. 34. Offer up to the block, spot through, drill No. 43 to about $\frac{3}{16}$ in. depth and tap 6BA for hexagon head bolts. File away a bit of the spigot in way of the passage, this for uninterrupted steam flow; the recess in the periphery of the cover to suit the steamchest end will have to wait awhile.
For the back covers, chuck by the periphery, face the boss, centre and drill through at 7/32 in. diameter. Follow up at 11/32 in. diameter to $\frac{1}{4}$ in. depth, 'D' bit to $\frac{5}{16}$ in. depth and tap $\frac{3}{8}$ x 32T. Chuck an odd end of $\frac{5}{8}$ in. rod in the 3 jaw and turn down for $\frac{1}{4}$ in. length to $\frac{3}{8}$ in. diameter before screwing 32T; fit a cover to same. Now you can turn the periphery, face off to thickness and machine the spigot as for the front covers, going on to scribe the bolting circle. Complete machining by taking a light cut on the outside of the cover in way of the bolt heads. Mark off, drill the No. 34 holes, countersinking where shown, offer up to the block, drill and tap; the slide bar facings will be dealt with later.

### Piston and Valve Spindle Glands; Piston and Rod

Piston and Valve spindle glands are both straightforward and a repeat of MARIE E, so on to the pistons. First clean up the chucking spigots, then reverse in the 3 jaw and rough out to within about 1/32 in. of finished sizes. Centre and drill No. 11 to $\frac{1}{2}$ in. depth, following up at 7/32 in. diameter to 7/32 in. depth; tap the remainder 7/32 x 40T and part off the spigot.
Chuck a 4 in. length of 7/32 in. stainless steel rod in the 3 jaw, face and then screw 40T for about $\frac{1}{4}$ in. length; screw on an embryo piston. Face off to length then turn down to a close sliding fit in the bore. For the 'O' ring groove a special tool is required to produce the profile as shown, used at a low speed, or pulled round by hand, to get a good surface finish; beginners can ignore this last bit and proceed as for MARIE E.

### Steamchest and Cover

We can now move upstairs and deal with the 'controlling mechanism', though the steamchest and its cover are simply a box to contain the steam.
Chuck the steamchest in the 4 jaw and face off, then reverse and complete the second face to $\frac{3}{4}$ in. thickness. Revert to the vertical slide and machine vice to first mill the frame face so that the sloping, opposite, one mates up with the cylinder block; mark off, centre, drill and tap the $\frac{5}{16}$ x 40T steam entry hole. On to the front face which is pure milling, then reverse and do likewise at the back end. Mark off for the 9/32 in. hole; centre, drill and ream this to size. Tidy up the inside with files then mark off and drill the eleven No. 34 holes, noting that the outer ones are inclined to suit the steamchest wall.
Chuck the cover, by its spigot, in the 3 jaw and face off both sides to thickness. Offer up to the steamchest, drill through the No. 34 holes and bolt together, then file the edges of the cover to mate with the steamchest. Final fixing is with countersunk screws, so deal with the countersinks in the cover at this stage. Next offer the steamchest up to the cylinder block, spot through, drill and tap the latter 6BA to $\frac{3}{16}$ in. depth; 1 in. long screws will then secure the assembly.

### Front and Back Steamchest; Bush

The front and back dummy steamchest ends are cast integral and the first job is to chuck by the main body and clean up the chucking spigot; rechuck by same. The front steamchest is now outermost, so complete turning this to drawing and then deal with the main bobbin of the rear steamchest. Part off the front steamchest and if you use a Junior hacksaw to part the two when the spigot is about $\frac{3}{16}$ in. diameter, you can then drill a blind hole in the front of the steamchest proper as positive location, then you won't have to hold the front steamchest in place to spot through the No. 44 fixing holes before tapping the steamchest for the three 8BA bolts as shown.


**WORKING STEAM IN THE EIGHTIES – "THE LILIPUTIAN"**

South African Railways two-foot gauge Garratt Class NGG 13 No. 78 gets ready to head the 6 days-a-week mixed on its 46km run from WEENEN to ESTCOURT in NATAL. Early-type passenger coaches are attached to the train which, in addition to having become a popular tourist attraction, serves the farming community of WEENEN. The 2-6-2 plus 2-6-2 locomotives of Class NGG13 built in 1928 by HANOMAG are a similar but earlier version of Class NGG16 also used on the four 2′ 0″ gauge lines in Natal.
Note the swing-out seat for crew comfort during the summer months.

Clean up the face of the rear steamchest end, then reverse in the chuck and part off the chucking spigot, to leave at $\frac{1}{2}$ in. overall. Centre and drill through at 7.0mm, following up with a 9/32 in. reamer and then a $\frac{5}{16}$ x 40T tap to $\frac{5}{16}$ in. depth; mark off and drill the three No. 44 holes.

For the bush, chuck a length of $\frac{5}{16}$ in. bronze rod in the 3 jaw, face and then turn down to 0.284 in. diameter, a micrometer dimension, over a $\frac{1}{2}$ in. length. Centre, drill No. 24 to $\frac{5}{8}$ in. depth and ream at 5/32 in. diameter before parting off at $\frac{7}{16}$ in. and repeating. Grip the bush in the 3 jaw once more, clean up the parted off face and lightly chamfer with a file so that the end enters the hole in the steamchest; press home. Lightly countersink the mating hole in the rear steamchest end so that it accepts the bush and press this home in turn; poke the reamer through the 5/32 in. hole to clean to size.

### Valve, Buckle and Spindle

The valve spindle is a 2 in. length of 5/32 in. stainless steel rod at this stage and screwed 40T at each end, this operation being carried out in the lathe and using the tailstock die-holder.

Chuck the valve castings in the 4 jaw and first machine the working face, to a good surface finish, reverse and machine the top face to $\frac{1}{2}$ in. overall depth. Back to the machine vice and vertical slide; pack the working face of the valve away from the vice body so that you can mill the upper part of the valve to $\frac{11}{16}$ in. square as shown. Reverse in the vice and mill around the edges to arrive at the dimensions shown, with the cast-in cavity nice and central; complete by tidying up the cavity edges to size with the 3/32 in. end mill. That reminds me that I should have said earlier that the ports as machined have rounded ends as against the square ones drawn. Experienced builders can arrive at the square corners by careful use of a small chisel; beginners should leave well alone as any improvement in performance will be very minimal; the chances of disaster great!

For the valve buckle, chuck in the 4 jaw and face one side; reverse and face to $\frac{5}{16}$ in. thickness, keeping the valve spindle boss central. Bring the boss towards the tool, tidy this up and the face of the buckle, then centre, drill through at No. 30 and tap 5/32 x 40T. For the remaining faces I recommend you return to vertical slide and machine vice to mill to size, then file out the centre to a close fit to the valve to complete. That takes the cylinders as far as we can go this session; a short break before the boiler.

### Illustration

I thought the SAINT CHRISTOPHER series would start without the first example having been track tested, but right on cue last Saturday, 23rd January, came an exciting telephone call from Mr. Howarth in Rochdale telling me of his successful steaming, so all is well. Readers can guess that a plea was entered for photographs with which to illustrate this series and hopefully some may materialise, though at the moment the engine is stripped down for painting. This is by no means the only SAINT CHRISTOPHER being built ahead of the series, but until the 'photographic evidence' begins to arrive I can take the opportunity to include a few photographs for which it has been previously impossible to find space. Some of these are by Don Baker, of Howick, in South Africa and have been filed away for more than 2 years, which as I think you will agree from looking at them is far too long. Some magazines I know have a 'Picture Gallery' and I am sometimes tempted to follow suit, but my professional conscience is against this, for I now know from experience that this is a cheap way of filling space, and to my mind not giving value for money to the reader. So I just hope you will excuse me dropping in the odd unrelated photograph from time to time, as the other half of my conscience tells me that if a reader is kind enough to send me photographs, then I must not keep them all solely for my private enjoyment.

## THE BOILER

It is difficult to realise the impact of the Churchward 4-6-0's on the British railway scene at this distance in time, but from inspection of old photographs of them hauling rakes of diminutive coaches they look positively enormous; the tenders that later came to be regarded as rather puny did not look incongruous then. Remember that 2-4-0's were still busily engaged in hauling expresses on the L.N.W.R. 'Premier' route and Stirling 'Singles' were still in evidence on the G.N.R. out of Kings X; the Midland Railway had in fact not long built their famous 4-2-2 'Spinners'. Churchward must have had problems in convincing the G.W.R. Board that such large, and expensive, engines were necessary. Luckily for us Small Locomotive builders, Great Western engines are hardly any more expensive to construct than any others, but they do involve more hours, as one would expect with such sophisticated designs, and nowhere is this more apparent than in the boiler. Compared with the round-backed variety as for GLEN, even my script will be somewhat extended. There is no doubt that a better boiler results performance wise, so the extra time will be well spent, so let us take up the reins again.

### Outer Shell

For previous tapered barrel designs, like COUNTY CARLOW and BLACK FIVE, I have used a short length of parallel tube at the front end, as per prototype, though it has been criticised as over-complicated. I found this practice very useful as it gave an assured circular end to the barrel to mate with the smokebox, also there is something positive to fit the front end of the tapered barrel to. Anyhow, one of the critics of my over-complicated boilers is none other than Alec Farmer and I have a great deal to thank him for in arriving at my humble boiler designs – all the good features are Alec's; the bad ones are mine! I once had the treat of watching Alec produce a taper barrel as now drawn, this for LBSC's $3\frac{1}{2}$ in. gauge BRITANNIA, and although Alec can no longer practice his skills so frequently, as a Director of A. J. Reeves & Co. (Birmingham) Ltd., the Company will supply a ready-rolled and brazed barrel, a must for all who invest in a boiler kit from this source. If this opening gambit has already frightened you, then don't despair, Reg Chambers is there to help you with one of his finely built and tested boilers.

For those still with me, take the throatplate formed plate and file the top flange to fit the bottom of the boiler barrel. Rough up the two side flanges then clamp to said barrel, scribing on centre lines so that they coincide. Next take the backhead and rough right around the flange with a fairly coarse file then pick up the outer wrapper plate and scribe on the top centre line. The $7\frac{1}{2}$ in. radius can best be achieved by hand pressure, using the top of the backhead as your gauge, then at $1\frac{9}{16}$ in. on each side of the centre line, scribe further lines to represent the start of the $\frac{3}{8}$ in. radius. Pull round a length of $\frac{3}{4}$ in. diameter bar held in the bench vice, tightening the radius by hand to the backhead as gauge and starting to form the 5 in. radius at the same time. At this stage you can offer up the wrapper to the barrel, with $\frac{3}{8}$ in. overlap as shown, drill through on the top centre at No. 42 and fit a 7BA bolt. Slide the backhead along as gauge, this for the top profile only, and when satisfied that all is well, drill further No. 42 holes where the wrapper again comes into contact with the barrel; again fit 7BA bolts. Remove the throatplate when it begins to get in the way and tackle each side individually to achieve a full fit with throatplate and backhead, adding more 7BA bolts as you go. The back of the throatplate is finally positioned $\frac{3}{16}$ in. in from the end of the barrel; locate this and scribe onto the barrel, also scribe further lines where the outer wrapper overlaps the throatplate on the side flanges. Take apart and cut away this excess metal, then re-assemble and drill about four No. 42 holes through throatplate flange and barrel; countersink the outside of all the No. 42 holes drilled at 60 deg.

One at a time, remove the 7BA bolts and replace with 3/32 in. snap head rivets. For this we need about a 1 foot length of 1 in. square steel bar as the 'dolly' to support the rivet heads, this protruding horizontally from the bench vice. We also need the means to draw the two surfaces at the joint into intimate contact, a 4 in. length of $\frac{5}{16}$ in. steel rod drilled No. 39 for about $\frac{1}{2}$ in. depth at one end. Support a rivet head on the dolly, fit the tool just made over the protruding shank, give it a couple of sharp taps then go on and splay the shank into the countersink; repeat until the outer wrapper/throatplate/barrel is a sound assembly. For the top corners, cut these to place either from 5mm copper plate, or $\frac{1}{2}$ in. x $\frac{3}{16}$ in. bar; you will have to bend the latter to fit the barrel as you proceed, so using plate will be easier. Try to get these corner pieces a good fit, splaying out locally if necessary to achieve this, then no other fixing will be required before brazing. We are nearly ready for the first braze, but we may as well make and fit the safety valve bush as it is located near the scene of operations, as are the pair of top feed bushes.

If you have no suitable drawn gunmetal bar, resort to phosphor bronze and chuck a length of $\frac{3}{4}$ in. diameter in the 3 jaw. Face and turn down to $\frac{11}{16}$ in. diameter over a $\frac{1}{4}$ in. length then part off at a full $\frac{5}{8}$ in. overall. Reverse in the chuck, face off to length, then centre, drill out to 29/64 in. diameter and poke the $\frac{1}{2}$ x 32T taper tap in, forming only about four full threads. The rest can await the rigours of boilermaking, after which you will be able to complete tapping out the bush squarely; all bushes are dealt with in this fashion, so why not have a session? Drill the barrel at around $\frac{9}{16}$ in. diameter and file out until the bush fits; a large drilled hole in this thin sheet is bound to be anything but round(!), then deal with the pair of top feed bushes.

**Brazing the Outer Shell**

For brazing gear I would refer builders to my notes for MARIE E, procedure too. Flux the bush and all around the wrapper and throatplate joints, stand on the brazing hearth and get the propane torch going. Start at a bottom corner of the throatplate after warming up the whole job, feeding in C4, B6 or Easyflo No. 2 spelter as you decide, the latter is much the easier to use and can be employed throughout. Work right round the joint, tackling the bushes as you come to them, then deal with the throatplate to barrel. Pickle, wash off and inspect for full penetration of the spelter, when we can move on to the firebox.

**The Firebox**

Take the ready-formed tube and back plates and rough up the flanges with a coarse file, then mark on the tube centres. It is a good plan to clamp the smokebox tubeplate to that for the firebox and drill $\frac{1}{8}$ in. pilot holes through both, in fact deal with all the tube holes together. Clamp a plate to a block of wood, then drill for all the $\frac{3}{8}$ in. firetubes; drilling into the wood will ensure round holes result. For the 1 in. flue holes, open out as far as your drills will allow, fit a bung and scribe out the 1 in. circle, then file out until the flue tube is a tight fit. Next chuck the smokebox tubeplate by the inside of the flange in the 3 jaw and turn down to be a drive fit in the end of the barrel, facing off the flange at the same setting. Drive into the end of the barrel, when it will fall through due to the taper and all is well. Drill for the steampipe bush, which is identical to that for the safety valve, fit this and braze in with B6 or C4 spelter as a separate operation, pickling and cleaning.

Back to the firebox, where back is the operative word, for we next have to make and fit the firehole. Chuck the tube provided by its bore in the 3 jaw, face and turn down over a $\frac{3}{16}$ in. length to about 1 13/32 in. diameter, Reverse. face off to about 23/32 in. overall and turn down again to leave $\frac{5}{16}$ in. at the original tube diameter. Mark off the firehole position on the back plate, scribing a circle; chuck the plate in the 4 jaw and get this circle running true. Centre, drill and bore out until the firehole is a close fit, stand on a lead block and peen over the projecting spigot.

Next I suggest you cut a $5\frac{7}{8}$ in. length of 4 in. x $1\frac{1}{2}$ in. section hardwood and clamp the firebox end plates to same, so that you can form the firebox shell over same. You will have marked the centre lines on the end plates, so now do the same for the firebox wrapper plate; get these lines to coincide and drill No. 42 holes through for 7BA bolts. Now you can begin bending the wrapper around the two end plates, drilling No. 42 holes and fitting 7BA bolts as you go, this at about $\frac{3}{4}$ in. pitches. If the wrapper is too stubborn to bend by hand pressure, then anneal it, but it is best to have a bit of springiness in same if you can cope with it. Because of the 'waisting', the back edge of the wrapper will now need trimming, the same remark of course applying to the outer wrapper, after which the firebox wrapper can be rivetted to its pair of end plates, again removing one bolt at a time.

Cut the front section of the foundation ring from $\frac{5}{16}$ in. square copper bar and file the ends to a close fit inside the throatplate. Fit in place, followed by the firebox and set the latter true to the outer wrapper. The height from the firebox crown to the outer wrapper is a nominal $1\frac{9}{16}$ in., but more important is that the outer tubes in the bottom row are at least $\frac{1}{8}$ in. clear of the boiler barrel; use the latter as your critical dimension. Now, using inside calipers, gauge the height of the crown stays; you will note these are radial to both inner and outer wrappers, so that they are almost purely in tension with minimal bending stresses; this is important.

Flange up the crown stays from 1.6mm copper to be a good fit and rivet them back to back in pairs as shown, trying in place and scribing lines along the firebox crown to position. At this stage you can mark off and drill the outer wrapper for the cross stays, spot through onto the girder stays, and drill $\frac{1}{8}$ in. clearance holes in the latter. Cut away the back end of the girder stays, the minimum dimension being $\frac{1}{8}$ in. to clear the backhead flange, then remove the firebox, clamp the girder stays to same and drill a hole in each corner of the flange, securing each girder stay to the firebox top with four 3/32 in. snap head copper rivets; tap down the flange onto the wrapper ready for brazing.

Flux all the joints, stand the firebox on the hearth on its back end, dealing with the tubeplate joint first and keeping the flame clear of the tender spots between the tube holes, so the copper does not burn. Next stand upright and deal with the girder stays, then move on to the back plate, not forgetting the firehole; cool, pickle, wash off and inspect.

**Fitting the tubes**

Take each firetube, chuck in the 3 jaw, face off squarely and polish the end $\frac{1}{4}$ in. or so bright with emery cloth, then reverse in the chuck, face off to length and polish this end also. The flue tubes will have to be squared off and ends cleaned by hand. If the 'Coulson method' of locating the firetubes is to be used, the firebox tubeplate must be drilled at 9.0mm diameter instead of $\frac{3}{8}$ in. and a step turned for $\frac{3}{16}$ in. length on each firetube to suit. Otherwise, select a taper pin that fits the bore of the tube, smear it with Vaseline, fit the tube, followed by the taper pin and use the latter to expand the tube firmly into the tubeplate. A sideways tap will release the taper pin; carry on and fit the remaining 12 tubes. The flues you have already ensured are a good fit, so now cut rings from Easyflo No. 2 spelter and drop one over each tube, allowing them to fall onto the firebox tubeplate. At the outer end, pick up the tubes in the smokebox tubeplate, then check the tube-stack is square to the firebox tubeplate.

Mix the Easyflo flux to a fairly runny paste, applying around the tubes, stand in the brazing hearth and get the propane torch going with a diffuse flame. The tubes will warm up very quickly, so concentrate the flame away from them to prevent burning the copper and work instead from inside the firebox. When the Easyflo rings melt, feed in more spelter if indicated, carefully playing the flame around the tubes, then allow to cool, pickle, wash off and inspect that there is evidence of spelter around each tube on the inside of the firebox, indicating full penetration. If this is not the case, now is the time to rectify by reheating and applying a drop more spelter – do not proceed past this point until you are certain. Knock off the smokebox tubeplate and anneal the tube ends, either as a separate operation or after silver soldering the tubes at the firebox end.

### Assembling the Firebox

Fit the leading portion of the foundation ring and erect the firebox inside the outer shell, the most important point to watch being that the top flanges of the girder stays are in intimate contact with the outer wrapper. Rivetting these flanges to the outer wrapper is not the easy task that LBSC used to describe, at least to this ham-fisted oaf(!), but if you get the proper initial contact then Easyflo No. 2 will do the rest. When satisfied, drill through in two positions, at about $\frac{3}{4}$ in. centres and at $\frac{1}{8}$ in. diameter, from throatplate through foundation ring into firebox tubeplate, this for $\frac{5}{8}$ in. long snap head copper rivets, with heads inside and hammered down into countersinks in the throatplate. Before doing this though it is a good idea to mark off and trim the bottom profile of both outer and firebox wrappers. The side sections of foundation ring are also from $\frac{5}{16}$ in. square copper, each in two pieces, held in place with a minimum number of $\frac{1}{8}$ in. rivets; three per piece if possible. Drill $\frac{7}{16}$ in. holes for the blow-down valve bushes in the outer wrapper and fit these. To complete the firebox end for the next braze, cut six cross stays from $\frac{3}{16}$ in. copper rod, each at least 6 in. long, flattening slightly about 1 in. from one end so that when pushed through the outer wrapper they won't fall out.

Moving to the smokebox end, first insert the tubeplate, align the tubes and get them about $\frac{1}{16}$ in. proud of the plate, then expand a few to hold the tubeplate firmly in place. To finish this end we need the ring on the barrel to mate with the smoke-box shell; it starts life as a 1 foot length of $\frac{1}{4}$ in. x 1.6mm copper strip. Fully anneal the strip then wrap around the barrel, trimming to length and then securing with a few $\frac{1}{16}$ in. snap head copper rivets, heads inside.

We had better deal with the brazing as a two-stage affair, so flux around the foundation ring, cross stays and girder stay flanges. Lay the boiler on its back in the brazing hearth with the firebox projecting, weighting it down at the front end to prevent a disaster. Cut 6 in. lengths of Easyflo No. 2 spelter and lay along the girder stay flanges, then light the propane torch and get a good flame going, play this on the outside of the outer wrapper at the top, only you will be working from underneath. Provided the girder stay flanges are in correct contact, heat will transfer from the wrapper, the whole will become dull red and the Easyflo will flash right through giving a perfect joint. Move on to the cross stays, dealing with one side at a time, then on to the foundation ring, not forgetting the pair of blow-down bushes; cool, pickle, wash off and inspect. Now flux the smokebox tubeplate and joint ring, play the flame on the outside of the barrel and apply Easyflo No. 2, including of course the tubes which needs careful use of the flame; again pickle, clean and inspect.

### The Backhead

Take the backhead and fit all the bushes, brazing them in as a separate operation with either C4 or B6 spelter. Next hold the backhead to the outer wrapper and scribe back through the firehole tube. Drill at about No. 30 around inside this circle, opening out until the holes begin to break into one another, then tap out the centre and carefully open out the hole with a round file until it is a close fit over the firehole spigot. Tap the outer wrapper down into contact with the backhead flange then mark off and drill for the top water gauge and turret bushes in the outer wrapper, scalloping the backhead flange to suit. Sit the inside face of the firehole tube on a stout piece of bar and peen over the outside spigot onto the back-head.

The rear section of the foundation ring seals the whole thing up and if this is made to a close fit, and of slightly tapering section, it can be tapped home and requires no further support for brazing.

Stand upright in the brazing hearth, flux around the backhead, top bushes, firehole and rear foundation ring, then get the propane torch going to good effect. Warm the whole area then starting at a bottom corner of the backhead, work right around the joint with Easyflo No. 2, taking in the bushes as you come to them, then the firehole and finally the foundation ring. Allow to cool, pickle, wash out thoroughly, clean up with wire-wool or the later plastic equivalent and inspect.

### Preliminary Air Test

Complete tapping out all the bushes, make and fit hexagon head plugs for all of them, drilling out that for the safety valve and sweating in a cycle tube valve stem; tap a soft-wood bung into the regulator bush, or use a rubber cork. Immerse the boiler completely in water, rocking it about until all the trapped air is released, fit the cycle pump and apply about 10 pumpsful of air. Inspect for any tell-tale stream of bubbles, though I very much doubt if there will be any, and at this successful stage in the proceedings we can take a well earned rest.

## Book Review

TRAVELLING BY TRAIN IN THE 'TWENTIES AND THIRTIES by Philip Unwin

One of the 'Steam Past' series published by Allan & Unwin at £6.95

This book is largely personal reminiscences by author Philip Unwin of rail travel within the U.K. between the wars, and interests arising from same. Conveying the author's own impressions of the period, there can be no criticism of any bias of opinions on the various aspects of railway travel in this golden age of steam, plus a lot of the atmosphere of one life-style in these good/bad years is conveyed to the reader and as such this book can be recommended.

Chapter 2 on the Locomotives was obviously that which interested me most and here I found two flaws, both in reference to Stanier. The first was that the BLACK FIVES had cylinders of 'exceptionally large dimensions of $18\frac{1}{2}$ x 28 in.', whereas many of us would say they were extremely modest. This, however, is small fry compared to 'Stanier's great **four** – cylinder 2-8-0', which for me called into question the whole authority of the book, though subsequently it appeared to be an isolated discrepancy, one which I trust will be corrected in future editions.

# Saint Christopher

by: DON YOUNG

**Part 3 – Boiler completion and Smokebox**

Let us make further progress on the boiler, though first I have to admit to an omission in my earlier description in brazing up the boiler of the single solid longitudinal stay, which should have been fixed to both smokebox tubeplate and backhead in the manner of the cross stays. This meant brazing the front end at the same time as the smokebox tubeplate to the barrel, then lining up when fitting the backhead, with about 1 in. protruding, and tackling this at the final braze. Anyone who like me forgets about the longitudinal stay at the material time can simply tap out at $\frac{5}{16}$ x 40T as for the blower stay and use screwed end fittings as described for GLEN.

**Firebox Stays**

For the firebox stays, first mark out the outer wrapper and drill one of the top row of holes right through into the firebox at No. 34. Poke another drill into this hole and use as a 'sight' for drilling the rest of the row. Always invest in a new set of carbon steel taps when making a boiler, this as added insurance against tearing the soft copper. Use a good tapping compound such as 'Trefolex' and with sighting drill still in place, align the taper tap to this and form the threads in the outer wrapper. Withdraw the tap and thoroughly clean it, follow up with the plug and then use the taper tap again to deal with the firebox shell. Tackle the whole of the top row, then screw in the copper or phosphor bronze stay rod, add a full brass nut on the inside, tighten this up and crop off the outside of the stay about $\frac{1}{16}$ in. proud of the outer wrapper. You can tidy up the stay head within 1/32 in. of the wrapper surface after sealing the stays if you wish, this by filing, but never try to finish them flush. Carry on and deal with one row of stays at a time until each side of the firebox is complete, then deal with the throatplate and backhead in turn, not forgetting the top row above the firehole ring.

The stays will be sealed with Comsol or SX2 spelter, so mix the appropriate flux and apply, lay the boiler on its side and fit a neck burner to the propane torch. Start inside the firebox, far less heat than for brazing the boiler itself is required, and tackle the job stay by stay. Move to the outside and deal with these in turn, then roll the boiler over and repeat the dose, before finishing with the throatplate and backhead; wash, clean and inspect.

**Hydraulic Test**

Although the official hydraulic test should in my opinion await the complete fitting out of the boiler, it can at least be described here. Fill the boiler completely with cold water and attach the tender hand pump to its check valve. Pump up to 40 p.s.i.g. and inspect, then go on in 40 p.s.i.g. increments until you reach twice the intended working pressure; hold this for around 30 minutes and your boiler is passed fit for service. These are of course this designer's recommendations as I feel in this I have a great responsibility for the safety and well being of our hobby, though in most cases these days the ultimate responsibility rests with the Club Boiler Inspector, in whom I have the greatest confidence. I view boilermaking as an exercise in 'honest workmanship', so if you have a problem during construction, don't try to hide it, but confide in your Boiler Inspector. It is highly likely in return that you will receive sound advice which will retrieve the situation and save expense. For remember in industry that things do not always go 100% as they should and my experience around 20 years back was that Lloyds Surveyors were the most practical of men and would proffer advice to retrieve situations which otherwise would have resulted in the loss of many thousands of pounds.

**The Smokebox**

On Sheet No. 2 we have the three most important features of any Stephensonian Locomotive – the Cylinders, Boiler and Smokebox, only I would place them in reverse order for their effect on performance. A perfect boiler will not steam unless properly draughted and cylinders perform effectively only if sufficient steam is available plus a low back pressure to exhaust; a good smokebox ensures these conditions are met and that for SAINT CHRISTOPHER is pure Swindon thanks to S. O. Ell. I have related to Ell's great work in 'What makes a Steam Locomotive tick?' and it is good to apply same to a genuine Swindon product.

**Smokebox Shell**

The first requirement is a $4\frac{5}{8}$ in. length of 4 in. o.d. x 16 s.w.g. brass tube; grip by the bore in the 3 jaw and face off at the chuck end, then reverse and face to length. Chuck roughly true in the 4 jaw, fit a scriber under the toolpost, pull the job round until a chuck jaw touches the scriber, then wind the carriage along to scribe on the top centre line; repeat 180 deg. apart for the bottom centre line. Lay the smokebox shell aside for the moment whilst we go on to the saddle.

**Smokebox Saddle**

This is a fairly straightforward steel fabrication, the only problem being bending the top plate, though with bending rolls even this will not be difficult. Full size, half the saddle was cast integral with each cylinder, there being a flanged bolting connection on the vertical centre line; this may be represented if you wish. The bolting flange to the smokebox shell is quite substantial and if you can both acquire and form this from 4mm plate, this is the ideal, otherwise use 3mm material. The plate should be $2\frac{3}{4}$ in. wide for rolling, then at least two faces will be finished to drawing, length being at least $3\frac{1}{4}$ in. at this stage. Mark on the centre lines and drill a $\frac{9}{16}$ in. hole; now cut the front and back plates to fit; these want to be $2\frac{11}{16}$ in. wide. The side plates complete the box and are flanged up to place from 2.5mm material; you can assemble the whole for brazing with a few 8BA screw.s Mix Easyflo flux to a stiff paste and apply quite liberally at both sides of all the joints, this to help stave off oxidation, then get the propane torch going, heat up quickly, apply Easyflo No. 2, allow to cool, quench and clean. A coat of zinc from an aerosol can, not only stops rusting, but improves the appearance quite dramatically.

With the base of the saddle facing the chuck, bolt through the $\frac{9}{16}$ in. hole directly onto the vertical slide table, then mark off and drill the other pair of $\frac{9}{16}$ in. holes to clear the steam unions. Change to an end mill of at least $\frac{3}{8}$ in. diameter and clean up the two side flanges to $2\frac{7}{8}$ in. overall, then go on and tidy up the ends of the top flange, pulling the cutter back $\frac{1}{8}$ in. to achieve finished size and packing the flange away from the vertical slide table to avoid any unfortunate accident.

Although you can scallop out the side faces in way of the steam connector with an end mill, I would saw out a rough 'V' and complete with a round file. Mark off and drill the 24 holes at No. 44 for 8BA bolts in the top flange, all holes being tangential, then offer up to the smokebox shell with centre lines coinciding and drill through.

Despite all your efforts to ensure the shell is a good match with the top flange on the smokebox saddle, I am sure you will be dispapointed by the gap which showed when you brought the two together; this was also common in full size and is no problem at all. For inside the rectangle of fixing bolts drilled in the shell, we now make a rectangular cut-out approximately $1\frac{7}{8}$ in. long x $2\frac{1}{4}$ in. wide; this of course weakens the tube locally so that when bolted to the top flange of the saddle the shell adjusts to the shape of the latter and gives a really strong and air-tight assembly.

Offer the saddle up to the frames in the position shown, drill through from the No. 44 holes in the frames, tap the latter 6BA and then open out the plain holes to No. 34 in the saddle; secure with hexagon head bolts.

### Chimney and Petticoat Pipe

On the top centre line of the smokebox shell, scribe a 1 in. circle, drill small holes around the inside of same to break into one another, tap out the redundant piece and file to line. Chuck a $\frac{3}{8}$ in. nut in the 3 jaw, bolt the petticoat pipe casting to same through its bore and set to run true; turn the outer profile. Now chuck by the parallel portion of the outside, drill through the core-hole and bore out to $\frac{11}{16}$ in. diameter, then set the tool over 2 deg. on the topslide and complete the upper part. Rough out the bell-mouth by turning, then change to a file and finally emery cloth to get a nice smooth and polished surface; reverse in the chuck and tidy up to $1\frac{3}{8}$ in. overall height.

For the flange, cut a $1\frac{1}{2}$ in. square from $\frac{1}{16}$ in. (1.6mm) brass sheet, find its centre by the 'X' method, chuck to run true in the 4 jaw, centre, drill through and bore out to fit over the petticoat pipe. Bend to suit the smokebox shell, file the hole to fit the petticoat pipe once more, stand in your brazing hearth, pack the flange to its correct position, flux and silver solder; pickle and clean up.

The chimney is a quite substantial casting, especially for $3\frac{1}{2}$ in. gauge, and is not the easiest to machine, though of course we shall succeed! Chuck a $\frac{3}{4}$ in. length of $1\frac{1}{4}$ in. diameter steel bar in the 3 jaw, face across, reverse in the chuck, face again then centre, drill and bore through to $\frac{7}{8}$ in. diameter. File the top of the chimney flat then braze or soft solder on the steel sleeve to act as a chucking spigot. Change to the 4 jaw and chuck by the spigot for the chimney to run true then profile to drawing. Change to a boring tool and open out the centre cored hole to a plain 23/32 in. diameter as a first step. Next open out for $\frac{3}{16}$ in. depth to 29/32 in. diameter, a push fit over the petticoat pipe. Set the top slide over 2 deg. and bore out the upper part of the chimney to match the bore of the petticoat pipe. Grip the chucking spigot in the bench vice and first tidy up the base of the chimney to suit the smokebox shell, this with a half-round file, then complete the bottom flare to leave a 3/64 in. thick flange. Back to the 4 jaw to part off the chucking spigot, then file away as shown at the top to form the capuchon.

### Exhaust Piping and Blast Nozzle

Moving downstairs we have to complete the exhaust circuit to the blast nozzle before we can erect the chimney, the first requirement being those 90 deg. bends. If you are unable to obtain suitable ready-made bends from a heating system supplier or a plumber, get a 'Terry' extension spring that is a good fit in $\frac{3}{8}$ in. o.d. x 22 s.w.g. copper tube. Anneal the tube, pull round by hand and tap the soft copper to release the spring. The blastpipe is a 2 in. finished length of $\frac{1}{2}$ in. o.d. x 16 s.w.g. copper tube screwed 32T for $\frac{3}{8}$ in. at its upper end; scarf the two 90 deg. bends to fit into the base of the blastpipe and then trim off the outer ends of the bends to fit neatly between the exhaust connections. Turn up two $\frac{1}{2}$ x 32T union nuts from $\frac{5}{8}$ in. A/F brass or steel hexagon bar, slip them over the bends and we need two plain olives, or ferrules, to complete. Chuck a length of $\frac{1}{2}$ in. brass rod in the 3 jaw and turn down for $\frac{1}{2}$ in. length to an easy fit in the $\frac{1}{2}$ x 32T union nuts. Face, centre and drill $\frac{3}{8}$ in. diameter to $\frac{1}{2}$ in. depth, then part off two 3/32 in. slices. Fit one to each bend, not forgetting the union nuts, then braze up the whole assembly and erect to the cylinder exhaust connections.

As alignment gauge for the chimney we need a 6 in. length of $\frac{3}{8}$ in. steel rod that will drop down the blastpipe, only fit the petticoat pipe inside the smokebox first. Next fit the chimney and with inside calipers, centralise chimney and petticoat over the alignment gauge. You may alternatively use 'washers' to obtain alignment, these being $\frac{1}{16}$ in. thick and $\frac{3}{8}$ in. bore to suit the gauge rod, one of the pair being 45/64 in. o.d. and the other around $\frac{13}{16}$ in. Check by eye that the chimney is upright and if this is not so, use the alignment rod to move the blastpipe, only before doing do turn up and fit a nut over the fragile $\frac{1}{2}$ x 32T threads at the top of the blastpipe to prevent their distortion. Once satisfied, remove the chimney, drill through smokebox shell and petticoat pipe flange in four positions as shown, countersink the shell and secure with screws.

For the blast nozzle, chuck a 1 in. length of $\frac{7}{8}$ in. diameter brass bar in the 3 jaw, face, centre and drill through to No. 4. Follow up with a $\frac{7}{16}$ in. drill to $\frac{5}{16}$ in. depth, 'D' bit to $\frac{3}{8}$ in. depth and tap $\frac{1}{2}$ x 32T; turn down to $\frac{5}{8}$ in. diameter over a $\frac{3}{8}$ in. length. Set the top slide over about 10 deg. and bore out roughly as shown, to leave about $\frac{1}{16}$ in. of the original No. 4 hole. Next chuck a length of $\frac{1}{2}$ in. rod, steel or brass, face and screw 32T for $\frac{7}{16}$ in. length; fit the embryo nozzle. Now you can face off to length, poke the No. 1 drill into the top of the nozzle and then turn the remainder of the outer profile to drawing; a parting off tool will produce the 'blower belt' very quickly. The 25/32 in. diameter flange is to suit the bore of an odd end of $\frac{7}{8}$ in. o.d. x 18 s.w.g. copper tube, this latter being finished to $\frac{5}{16}$ in. length. For the union connection, chuck a length of $\frac{1}{4}$ in. brass rod in the 3 jaw and turn down for $\frac{5}{16}$ in. to 7/32 in. diameter before screwing 40T for $\frac{3}{16}$ in. length. Centre deeply to form the cone seating, then drill for $\frac{3}{8}$ in. depth at No. 41. Start parting off, but when you reach about 5/32 in. diameter, move the tool along 3/64 in. to leave a spigot. Measure said spigot by micrometer, drill a hole in the blower belt surround tube a press fit to suit, erect the whole to the blast nozzle and silver solder; pickle and clean. To complete, we need three No. 70 holes in the top flange as the blower, so centre pop lightly and drill them through by hand, with care of course! I should have said before silver soldering to assemble to the blastpipe to check orientation of the blower union, this as per the front view on the smokebox.

### Smokebox Door, Ring and Hinges

Chuck the front ring casting by its periphery and just clean up the inside, then rechuck in the 3 jaw by the inside of the flange. Turn down the outside to a light drive fit in the smokebox shell, face across the front, radius the corner with a file and bore out to $2\frac{5}{8}$ in. to complete turning. The hole on the top centre line is for a handrail stanchion and should be drilled to suit; mark off and drill the other pair for the hinge blocks. For the latter, chuck a length of 5/32 in. square steel bar truly in the 4 jaw and turn down for $\frac{1}{4}$ in. to 3/32 in. diameter; screw 7BA. Cross drill at $\frac{1}{16}$ in. diameter, or No. 51 as shown, then saw off to length and radius the end; erect to the front ring with 7BA nuts.

The hinge pin is best made in two pieces, the first a $1\frac{9}{16}$ in. length of $\frac{1}{16}$ in. steel rod with one end tapered as shown; chuck in the 3 jaw and use a file to achieve this. Next chuck a length of 5/32 in. rod, centre and drill No. 52 to $\frac{1}{8}$ in. depth and part off a full $\frac{1}{16}$ in. slice; silver solder this to the $\frac{1}{16}$ in. pin. To complete, chuck the pin in the 3 jaw and file the head to drawing, polishing it well.

Chuck the door by its periphery and clean up the chucking spigot, plus as much of the front of the door as you can manage without fouling the chuck jaws; rechuck by the spigot and complete the front before facing off the important sealing surface with the front ring. Centre and drill through at No. 29 before parting off the spigot. Centralise the door on the front ring, both by eye and careful measurement, then clamp securely. The door hinges start life as $1\frac{3}{16}$ in. lengths of $\frac{1}{4}$ in. x $\frac{1}{8}$ in. BMS strip and need careful filing, this as a pair and to suit the profile of the door; they want to finish up $\frac{1}{16}$/3/32 in. thick over the door itself. The dimension then increases to 5/32 in. out to the hinge blocks and when you reach this stage, drill three No. 52 holes through hinge and door, countersink the hinge and fit snap head copper rivets, heads inside. For additional security the hinges can be silver soldered to the door; re-erect, drill the holes through from the hinge blocks then radius the ends of the hinges and fit the hinge pin.

## Dart, Crossbar, Brackets and Handles

The next step is to secure the door, the first part being the crossbar. Cut two $3\frac{1}{2}$ in. lengths from $\frac{1}{4}$ in. x $\frac{1}{8}$ in. steel strip, clamp together and at $\frac{5}{8}$ in. from each end drill through at No. 41. Chuck a length of 5/32 or $\frac{3}{16}$ in. steel rod, centre and drill No. 41 to $\frac{5}{8}$ in. depth and part off two $\frac{3}{16}$ in. slices. Use these as spacers between the two bars and complete the assembly with 3/32 in. snap head iron rivets.

How many darts have been scrapped over the last 14 years I ask? The detail was drawn first for COUNTY CARLOW in 1968 and as with all things that receive no adverse comment, the detail was simply repeated for both the 43xx and SAINT CHRISTOPHER, thus perpetuating my original error. I am indebted to Mr. Phelps for pointing this out to me, and on the very day that I sat down to pen these notes, and I am able to tell him that the scrapped dart, thrown from Bradford-on-Avon, did not reach me! The error is a dimensional one in that $\frac{9}{16}$ in. bare should in fact read $\frac{11}{16}$ in. bare and it looks as if I omitted to include the thickness of the front ring; I will make amends in these notes.

Chuck a length of $\frac{7}{16}$ in. steel rod in the 3 jaw, face and then reduce the outer $\frac{3}{16}$ in. to .086 in. diameter, screwing 8BA. Move on and at about $\frac{5}{16}$ in. increments, reduce the next 27/32 in. bare to $\frac{1}{8}$ in. diameter. Leave the square for the moment as it is best to tackle this to suit the handle rather than the reverse, so part off to leave 5/32 in. of the original $\frac{7}{16}$ in. material. Saw and file away the flanks of this end piece until it slides easily through the crossbar, shaping the corners as shown.

The handle bosses are from 5/32 and $\frac{3}{16}$ in. steel rod, the smaller drilled No. 51 and the larger at No. 40 initially; lay aside for the moment. The handles themselves are from 3/32 in. steel rod and the best way I know to tackle them is to chuck in the 3 jaw with the total required length projecting and lightly file to profile with the lathe running at top speed. Use emery cloth for a polished finish, then with the lathe still running at top speed, file on a wee spigot at the outer end over about $\frac{1}{16}$ in. length. Mike this spigot, drill a hole to match in the boss, press home and silver solder; only the merest touch of spelter is required here or you will spoil the effect. Tap the outer handle 8BA and rough out the square hole in the inner one with a Swiss file. To complete the square hole, take a 1 in. length of 3/32 in. square silver steel and harden it, which means heating to bright red and quenching, then press it through the boss; there is so little to do it is not worth making up a proper punch. Now file the dart to suit and erect to the door to check is closes tightly.

## Buffers

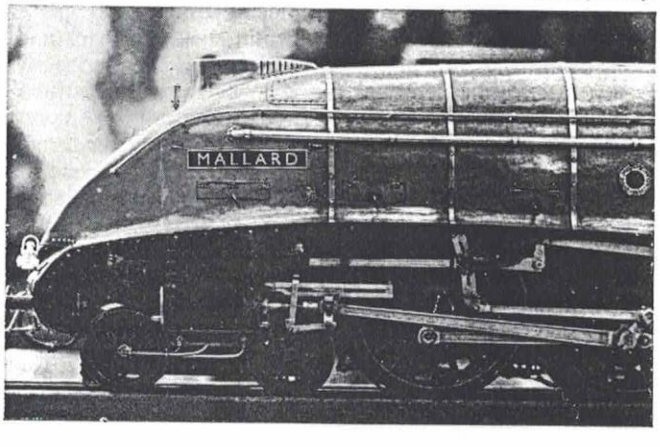
The buffers too are totally out of sequence, but they fitted the last bit of space on Sheet No. 2 so I will deal with them as the last item in this session, when we shall have broken the back of the whole project; everything will be downhill after this I promise you.

The stock comes first in line for treatment, so chuck the casting by its spigot and reduce to $\frac{7}{16}$ in. diameter over $\frac{7}{16}$ in. length. Rechuck by this turned portion and turn the spigot down to $\frac{3}{8}$ in. diameter, facing across the flange, then screw 32T. Screw hard into a buffer beam and note the orientation, calculating how much you have to face off the flange for the stock to be square on the beam; one turn is 1/32 in. so 45 deg. as $\frac{1}{8}$ of this works out at .004 in. approx; do this and mark the buffer stock as identification. Use a knife edged tool to lightly mark out the pitch circle for the four 8BA fixing bolts. Next chuck an odd end of, say, $\frac{5}{8}$ in. diameter steel bar in the 3 jaw, face, centre, drill through at 11/32 in. diameter and tap $\frac{3}{8}$ x 32T; screw in an embryo stock. Face off to length them complete the profile before centreing and drilling right through at No. 30; follow up to $\frac{3}{4}$ in. depth at $\frac{1}{4}$ in. diameter. Mark out the flange and I guess the easiest way is to file to line rather than resort to machining. Radius the corners then mark out and drill the four No. 44 holes.

Chuck the buffer head casting in the 3 jaw and turn down over a $\frac{1}{2}$ in. length to $\frac{1}{4}$ in. diameter, a nice sliding fit in the stock. Face, centre and drill No. 40 to $\frac{3}{16}$ in. depth before tapping 5BA. Rechuck by the shank, and I should have said to use a round nosed tool to achieve the blend with the head, set the top slide over 10 deg. and machine the back chamfer. Turn the head to $\frac{13}{16}$ in. diameter, face off to thickness, and I again think the front face is best dealt with by filing, with the lathe running at speed; polish to complete.

The centre studs are full 1 in. lengths of $\frac{1}{8}$ in. steel rod, screwed at 5BA for $\frac{1}{8}$ in. at each end; screw hard into the buffer shank. For springs, use the stiffest available, which probably means 20 s.w.g. and $\frac{5}{8}$ in. free length. I usually crop these from a length of standard spring and then grind the ends square; the ends soften during grinding and become quite neat and presentable; in any case they are well hidden! Assemble the complete buffer, compress in the bench vice, soft clams please, fit and tighten up the 5BA nut and that is as far as we can go this time.

I just had to include this front end shot of Ron Price's $3\frac{1}{2}$ in. gauge MALLARD to remind me of another memorable day at the 'North London', this on the occasion of the LBSC Centenary Rally.



# Saint Christopher

by: DON YOUNG

### Part 4 – Chassis and Motion

This is the session where a comparatively small amount of work brings a lot together, as will be seen by a glance at the details, also time spent absorbing the 'Chassis and Motion Arrangement' should make a lot of those things that have gone before much clearer in your mind. Let us make progress to complete the front end as a first step, this to remove the stunted look from SAINT CHRISTOPHER.

### Front Frame and Beam

On COUNTY CARLOW, the 38xx 4-4-0 that was my first excursion into G.W.R. territory back in 1969, I made the front frames simple pieces of plate attached to an angle buffer beam, the latter an LBSC standard. There was criticism of the four 6BA bolt attachment to the mainframes on a question of strength, though standing my considerable weight on the chassis I had by me which had been made by the late Stan Slade failed to wreak the predicted havoc! Nevertheless I did take heed of this, fair, criticism and for both the 43xx and SAINT CHRISTOPHER have designed a rigid structure, which now draws criticism for its complexity, a case of not being able to win(!), though I hope by description to show that the front frame as illustrated is quite straightforward to construct.

For the frames, take two 6 in. lengths of $1\frac{1}{2}$ in. x $\frac{3}{16}$ in. BMS flat, square off one end of each piece, apply marking off fluid, mark out one face, then drill a couple of the No. 30 holes right through and secure together with $\frac{1}{8}$ in. copper or aluminium rivets. Offer up and spot the remaining five holes from the mainframes, drill them No. 30 then carry on and complete the profile, except at the front edges. Clamp firmly in the vice, at the bend line which is $2\frac{1}{4}$ in. from the back edge and hammer over to get the $\frac{1}{4}$ in. set as shown. Bolt together again, back to back, and grip the whole in the machine vice, attached to the vertical slide, with the frames across the lathe axis. First with a large diameter end mill and using the side teeth, mill the front edges to arrive at $5\frac{3}{4}$ in. overall length, then change to a slitting saw and deal with the $\frac{1}{8}$ in. slot to $\frac{5}{8}$ in. depth to accept the gussets, cutting these latter to a tight fit in the slot. Next take each front frame and bolt it to the mainframes via the cylinder fixing bolts.

Let us tackle the front beam next to make the whole assembly a rigid one, so cut a length from $1\frac{3}{4}$ in. x $\frac{1}{8}$ in. BMS flat and square off to $6\frac{3}{8}$ in. overall, adding an $\frac{1}{8}$ in. radius at the bottom corners. Mark off and drill the holes to drawing, tapping $\frac{3}{8}$ x 32T for the buffers which we have already made, and filing out the coupling hole to a piece of $\frac{1}{8}$ in. square bar as gauge. Offer up to the front frames, spot through the No. 44 holes, drill No. 50 to $\frac{3}{16}$ in. depth and tap 8BA; secure with countersunk screws. Next cut the intermediate stay from $\frac{3}{8}$ in. x $\frac{1}{8}$ in. BMS flat, file the ends to be a close fit between the frames and secure with a couple of 8BA screws just as for the front beam.

For the bogie fulcrum, chuck a length of 1 in. diameter steel bar and turn down for $1\frac{1}{8}$ in. length to $\frac{3}{8}$ in. diameter; part off at $1\frac{3}{4}$ in. overall. Grip in the machine vice, if you take out the tilting top jaw then the recess will give good support, and mill the two flats to complete. Cut two stays from $\frac{1}{2}$ in. x $\frac{1}{8}$ in. BMS flat to be a tight fit between the front frames, slide in the bogie fulcrum and you may drill right through and secure for brazing with a 3/32 in. copper or iron rivet. Release the front frames from the mainframes and cramp over them again to hold the bogie fulcrum assembly firmly in place, now we can silver solder all the joints. Mix some Easyflo flux to a stiff paste and apply liberally to all said joints. Heat up quickly, I use the Sievert 2941 nozzle for this type of work, and apply Easyflo No. 2 or equivalent specification spelter. Wash off and scrub well to remove the excess flux, inspect carefully then rub over with a file and apply a zinc coating from an aerosol can, this to prevent rusting; assemble to the mainframes.

### THE BOGIE

The Churchward standard bogie as applied to the 'Counties' and 'Saints' was very much of American origin and I recall vividly the initial problems it caused me with COUNTY CARLOW in translating the bar frames down to $\frac{1}{16}$ th scale without making the whole thing too flimsy. Cutting the top frame from one piece of plate was my answer then and as the whole bogie has proved so successful in service, there is no need to change anything the second time round, though I was tempted to replace the coil springs on the equalisers with more realistic and working leaf springs, but decided against it in the end, though of course individual builders can make their own decision on this particular feature.

### Top Frame, Bottom Bar, Spring Plate & Horns

For the top frame, cut an 8 in. length from 3 in. x $\frac{1}{8}$ in. BMS flat and mark off to drawing. First reduce to $2\frac{7}{8}$ in. width and square off to $7\frac{15}{16}$ in. overall length then drill all the holes as specified. Clamp to the vertical slide table, packing clear so that you can drill around and then mill out the two large openings, then concentrate on the $\frac{3}{4}$ in. slot for the bogie centre, milling this to a piece of $\frac{3}{4}$ in. square bar as gauge, then filing the corners of the slot square. Saw two lengths from $\frac{1}{2}$ in. x $\frac{1}{2}$ in. x $\frac{1}{8}$ in. BMS angle and square off to $1\frac{7}{8}$ in. overall, these for the bogie centre guides, but do not attach them to the top frame as yet. The spring plates can also be dealt with, drilling the No. 34 holes from the top frame and securing with 6BA bolts; the bottom bar is very straightforward, especially if you can obtain the correct section of material, 8mm x 3mm being equally acceptable.

With the knowledge I have gained of American Locomotives over the interim period since 1968, there is no way I could repeat the crude horns/pedestals used on COUNTY CARLOW's bogie; those depicted although calling for a little more work are a definite improvement as far as appearance is concerned. I recommend them to be made from $\frac{3}{4}$ in. x $\frac{5}{16}$ in. BMS bar, sawn off at $1\frac{1}{16}$ in. lengths, then chucked in the 4 jaw with the centre used in the headstock mandrel acting as a 'back stop' to face all off to identical 1 in. length. Drill the No. 34 hole in the outer horns, that's four out of a total of eight I guess(!), then grip in the machine vice, on the vertical slide, either in pairs or one at a time, to end mill away as much of the unwanted material as you can, completing with files. Before we can attach the horns to the top frame and bottom bars we need the axleboxes, wheels and axles having already been tackled from Sheet 1 during our initial session.

### Axleboxes

Staying with the machine vice and vertical slide set-up, take the cast stick for the bogie axleboxes and mill all four sides to complete at $\frac{3}{4}$ in. square, a good start. Move over to the 4 jaw, fit a scriber under the toolpost, and use the latter as an aid in setting the square bar to run true – just touching the four corners. Face across, centre and drill through in stages to $\frac{3}{8}$ in. diameter, though you may ream the bore if you wish. Apply marking off fluid to one face and mark off for individual boxes and their slots, then grip again in the machine vice, clamping a piece of bar to the vertical slide table as a register so that you can push the machined end of the bar hard against it.

With a $\frac{1}{4}$ in. end mill, deal with each slot in turn to $\frac{1}{16}$ in. depth, making a note of the cross slide micrometer collar reading when the final cut was taken over the width of slot. Rotate the bar through 180 deg. and repeat the dose, when the slots will be opposite one another. Use a hand or slitting saw to arrive at individual boxes, facing off to $\frac{11}{16}$ in. overall thickness and keeping the slots central, then grip each in turn in the machine vice and with a $\frac{1}{2}$ in. diameter Woodruff key cutter, deal with the scallop to accept the equaliser beam end, which latter can also form the oil reservoir, with No. 60 hole conveying same to the journal; we are ready to assemble.

### Assembly; Cross Tie and Bracket

Clamp each axlebox hard under the top frame, fit a pair of horns to each and clamp over these also, then try the axles in place, getting them to turn sweetly and checking with an engineer's square that they are square across the frames, then clamp on the bottom bars as a further check. When all is well, drill through, tapping the top inner holes in the horns and secure with 6BA bolts. Next thing is to get each axlebox to lift independently by about 5/32 in. so the wheels can follow any track irregularities, one of the most important safety features of the whole Locomotive, to prevent derailing. To achieve this you simply relieve the flanks of the slots as shown on the drawing detail, checking to place as you proceed. Once this operation is complete, degrease the wheel seats and axle ends with Loctite Primer 'T' and apply a drop or two of Loctite 601 before assembling, with axleboxes in place of course!

The cross ties are plain turning and with the outer horns already in place, you can check the $2\frac{1}{4}$ in. dimension, erecting with 6BA nuts. The wee brackets are again bent up from $\frac{5}{16}$ in. x $\frac{1}{16}$ in. BMS flat and attached with 6BA bolts.

Guard irons can be a real pest in miniature, indeed I don't think they could be very effective even in full size, and builders of SAINT CHRISTOPHER will note that I have changed the design between Sheets 1 and 3 in that on the G.A. the guard irons are shown from $\frac{1}{4}$ in. x $\frac{1}{8}$ in. BMS strip interposed between bracket and top frame, whereas on Sheet 3 they start life from $\frac{1}{2}$ in. x $\frac{1}{8}$ in. strip and attach to the top face of the top frame; this latter I now feel to be more practical. Either way they are best bent up to place, using the front view on Sheet 1 for guidance, and securing with my pet standard 6BA bolts.

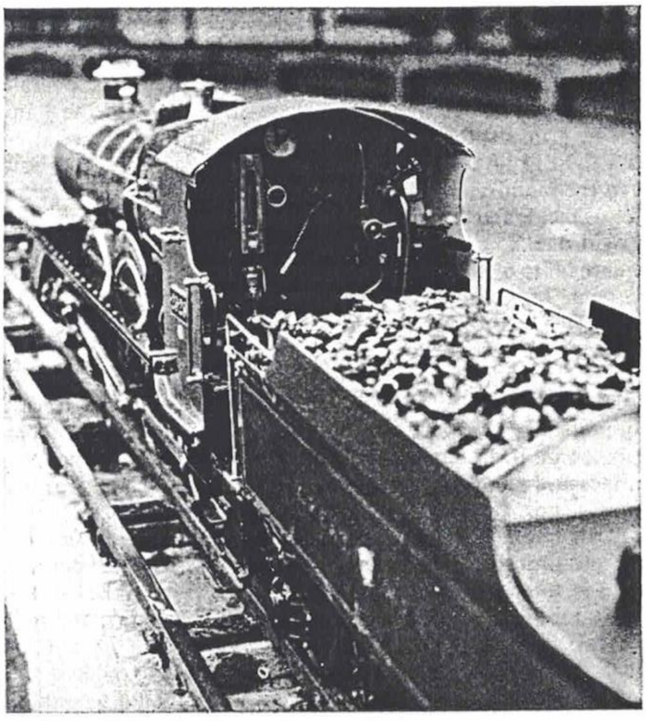
### Bogie Centre and Side Control details

Chuck the bogie centre casting in the 4 jaw as truly as possible, face across and deal with the raised face to 1 in. diameter, then centre and drill through to $\frac{3}{8}$ in. diameter; reverse and face off to 49/64 in. overall depth. Back to machine vice and vertical slide to first mill all four faces to arrive at 1 in. square, then tackle the $\frac{1}{8}$ in. step on one face, rotate through 180 deg. and repeat to a good fit in the slot in the top frame. The retaining plate is also 1 in. square from 2.5mm brass sheet; chuck in the 4 jaw, centre and drill through at $\frac{3}{8}$ in. diameter, then mark off, drill and countersink the four fixing holes. Offer up to the bogie centre, align with the $\frac{3}{8}$ in. drill, then spot through the No. 44 holes, drill the centre No. 50 to $\frac{1}{4}$ in. depth and tap 8BA. Erect the centre to the top frame, clamp the angle slides to same, drill through at 3/32 in. diameter for snap head rivets, hammering down into countersinks in the upper face of the top frame. Ease with files as necessary so that the centre slides freely, this after fitting the side control spring blocks, our next task.

For these latter, cut two $\frac{13}{16}$ in. lengths from $\frac{1}{2}$ in. x $\frac{1}{4}$ in. BMS bar and square off to a tight fit between the centre guides; mark off, drill and tap the four 7BA fixings. There can be difficulty in alignment of two blind holes, like those in the centre and side control blocks, and the side control springs want to be in good alignment to be really effective, so I will deviate from drawing slightly to achieve this. Mark off and drill the $\frac{1}{4}$ in. hole right through a side control block, then clamp the centre to it and drill further to $\frac{3}{16}$ in. point depth; repeat the other side. Complete the holes in the centre with a $\frac{1}{4}$ in. 'D' bit, then cut $\frac{1}{4}$ in. discs from $\frac{1}{16}$ in. steel and silver solder into the side control blocks to arrive back at blind holes.

The prime reason for a bogie is to guide the locomotive into curves at speed and relieve side loading on the leading coupled wheel flanges; to do this requires positive and effective side control springing of the bogie, so that it really pulls the front of the engine into a curve and out of it. Release the side control blocks, insert springs into the bogie centre, slip on the blocks and clamp up in the vice to re-insert the 7BA bolts. Even though each axlebox of the bogie on my favourite Gresley 'Pacifics' was independently sprung, I still prefer the classic Adams bogie with its equalisers, so the Churchward bogie meets with my approval in this respect. For the equaliser beam profile, I suggest you cut this from cardboard, or stiff plastic, initially and check to place before using as a template for profiling the actual beams. Clamp these together to drill the 3/32 in. rivet holes, separating into pairs and countersinking the outside faces.

This is the sort of view that makes me want to climb aboard and get the regulator open – wide!



The equaliser blocks are 1½ in. lengths from ½ in. x ⅜ in. BMS bar; clamp the spring plates to them and drill the 3/16 in. holes, completing with a 'D' bit. Fit the spring plates, then the beams and offer up the equaliser blocks complete with their coil springs, clamping over the beams in way of the blocks. Check operation, drop the wheels out, followed by the complete equaliser beam assemblies and drill each side from the beams into the blocks, securing with 3/32 in. countersunk soft iron rivets. Assemble the bogie complete, erect to the fulcrum, followed by a ⅜ in. washer and then cross drill for a 3/32 in. split pin; that takes care of another large slice of SAINT CHRISTOPHER.

### Chassis and Motion Arrangement

With the publication of the Chassis and Motion Arrangement we now know all the ingredients to make SAINT CHRISTOPHER tick, having already dealt with cylinders, smokebox and boiler. Very little comment is called for on my part hereabouts and we can soon take the plunge again and make more parts, but just two features I would like to mention. Firstly, on COUNTY CARLOW I had great difficulty in siting the lubricator, finally deciding on an LBSC inverted 'V' pattern as he used for HEILAN LASSIE and located between the valve gear on the centre line of the engine; it was less than ideal. For the 43xx 'Mogul' and SAINT CHRISTOPHER there is room to install a pair of our standard mechanical lubricators inside the mainframes and ahead of the valve gear, which is far more sensible, though I reckon the ultimate solution for all three Locomotives is a hydrostatic lubricator with sight feed to each cylinder, and to this end we have recently developed a more compact oil tank which is very suitable for 3½ in. gauge Locomotives.

The other feature of note is one reproduced from full size and one which I mentioned earlier, namely the set in the intermediate valve rod to clear the leading coupled axle. Maybe I am thick, nothing new for me(!), but I can see no reason why the whole valve gear could not be inclined, when the intermediate valve rod could have the set removed. I was sorely tempted to do just that I must admit, but it is such a prominent feature, albeit hidden between the frames, that it was retained for the realism it gives – let us press forward again.

### Coupling Rods, Knuckle Pin and Bushes

We have already tackled the connecting rods so know basically what is involved and this means some needless repetition can be avoided, the main difference with the coupling rods being in technique to establish centre distance between the rod ends. First remove the leading and coupled axles and pack the axleboxes hard down onto their hornstays. Next chuck a length of ½ in. diameter steel bar in the 3 jaw, face, centre and drill to 7/16 in. diameter for ⅝ in. depth; part off a ½ in. slice. This is our drill bush for the front end of the leading coupling rod, so push it into the leading axlebox.

For the leading rods themselves, cut two 7 in. lengths from 1 in. x 5/16 in. BMS bar and scribe a line along the 1 in. face of each about 9/16 in. from one edge. Starting ½ in. from one end, scribe another line across the bar, then move on 5⅜ in. and repeat, this to roughly represent the rod end centres. Bring one of the embryo coupling rods up to the L.H., say, leading and driving axleboxes, look down the bore of the latter and line up the '+' you will see to be central in the bore, this by eye; clamp firmly in place and drill through at ½ in. and 7/16 in. respectively as per drawing. Remove and measure, by rule, for the knuckle bush and drill this at 9/32 in. diameter.

We now need an 8 in. length or so of 1¼ in. x 1¼ in. x 3/16 in. bright steel angle, a piece that is nice and square. Drill holes at approximately 2 in. intervals in one face to accept the 'T' bolts for the vertical slide table and two ⅜ in. holes in the other face to accept the embryo coupling rod; fit the latter and bolt in turn to the vertical slide. Using the side teeth of a ½ in. end mill, remove 1/16 in. from the driving rod end right forward as per drawing, clamping over the excess portion at the front end and removing the fixing bolt as you come to it. Turn the rod over and starting from the leading rod end, reduce first to 5/32 in. thickness for the rod, fitting packing between rod and angle to prevent bowing, then remove the driving rod end fixing bolt and reduce this in turn to ¼ in. thickness. For the knuckle portion, fit the machine vice to the vertical slide, clamp over the rod end and mill away one face at a time to form the knuckle. Remove all burrs and sharp edges, there will be quite a few of them, then apply marking off fluid and scribe on the rod profile. Saw away as much metal as you can, completing the main section of rod either with files, or go back to the angle set-up and end mill to line. For the rod ends, grip the appropriate diameter mandrel in the machine vice, these may be pressed into steel blocks if you wish for additional security, fit the ½ in. end mill in the 3 jaw, bring the work up to it and pull towards you, against the rotation of the end mill, never towards it. Take care not to mill away the oil bosses, completing with files and drilling the No. 51 oil holes.

For the trailing coupling rod, cut two pieces 6 in. long from the 1 in. x 5/16 in. section material, scribe on the 9/16 in. line and at 5/16 in. from one end, centre pop and drill through at No. 30. Do this with the rod clamped in the machine vice, then change to a No. 12 drill and follow up to 3/16 in. depth. Turn the rod over and ¼ in. in from the centre of the hole just drilled, cross drill at No. 22 as the bottom of the slot. Saw down carefully to this latter hole, using two hacksaw blades in the frame, then either end mill the slot to suit the knuckle end of the leading rod, or file to place.

The knuckle pin I recommend be from 3/16 in. silver steel rod turned down to ⅛ in. diameter over a 7/32 in. length and screwed 5BA. For the bush, chuck a length of 5/16 in. bronze rod in the 3 jaw and reduce to .284 in. diameter over a ¼ in. length, forming a wee taper at the outer end to just enter the rod eye. Centre and drill No. 12 to ¼ in. depth then part off a 5/32 in slice and press into the leading rod; poke a 3/16 in. reamer through the No. 12 hole. Assemble the rods, pack the trailing axleboxes hard down onto their hornstays, poke a length of ½ in. rod through the driving box and rod end, a 7/16 in. rod at the leading end, then make another drill bush and tackle the trailing rod eye; complete the trailing rod in like fashion to its leading partner. Turn up all the coupling rod bushes to the table dimensions, getting the same .003 in. interference fit as at the knuckle bush, press these home and ream in situ after drilling the oil holes through into the bore; tackle those for the connecting rods in like manner.

### Wheeling the Engine

Take the driving axle with its wheel attached, slide through the first axlebox, fit the eccentric sheaves and slide right home. I would now degrease the other wheel journal and axle end with Primer 'T', apply a drop or two of Loctite 601, fit the second wheel and orientate it at 90 deg. to its partner by eye to a sufficient degree of accuracy. For those requiring a more scientific method of quartering, lift out the whole assembly from the frames and set up on a flat surface, a sheet of plate glass is ideal. Use either 'V' blocks or pieces of packing to stop the wheels rolling about, then set one crankpin vertical above the axle centre by use of an engineer's square. For the second wheel, set a scribing block up to the centre of the axle and then line the crankpin up in turn to same; degrease, apply Loctite, slide right home, check the settings again and leave to cure. Replace the driving axle in the frames, pack down the axleboxes on to their hornstays once more, then fit the coupling rods to the side already wheeled. Take the remaining two wheels yet to be fitted, either individually or together, degrease, apply Loctite 601, slide on and fit the coupling rods to obtain correct crankpin orientation before the Loctite cures; choose a cool evening to carry out this operation as this will extend the curing time.

We now have to relieve the main axleboxes to gain independent lift of wheels as for the bogie, this you can do, but there is still the restraint imposed by the close fitting bushes over the crankpins, which must also be eased. Take the appropriate sized drill to suit the bush being tackled, grip it upright in the bench vice, feed the rod over it and poke a length of $\frac{1}{16}$ in. wire down one of the drill flutes. Now rotate the rod very carefully around the drill, paring away a few thous of metal from the bush and repeating for all of them until with the side rods fitted, there is the same amount of independent wheel lift as without them, 5/32 in. approximately; your SAINT CHRISTOPHER will now be safe on the track.

### Crossheads, Slide Bars and Motion Plates

Where to next? Well I guess we may as well finish off the cylinders which means our next job is the crossheads, smart Reeves standard castings. Rub a file over the edges of the slippers and clean up the face away from the feed point, then grip in the machine vice, on the vertical slide and mill the other surfaces to line, having checked the machining allowances as the first step; reverse and clean up the second face to arrive at the $1\frac{1}{8}$ in. overall dimension. Turn through 90 deg., clean up the slipper edges and take a minute cut across the centre, then turn through 180 deg. and repeat to arrive at $\frac{1}{2}$ in. over slippers, $\frac{3}{8}$ in. over the centre. Mark off for the crosshead pins, centre and drill through at No. 27, following up at $\frac{7}{16}$ in. diameter through the outer flange, only it becomes the inner one on assembly; 'D' bit to $\frac{5}{16}$ in. depth. Leaving the vertical slide at this setting, rotate its base on the boring table through 90 deg. and tighten up the holding down bolts, this to bring one of the piston rod bosses towards the chuck; centre and drill at No. 3 or 5.5mm, then reverse and repeat. Put the vertical slide back to its original position with table across the lathe axis and grip the pair of crossheads with a slipper face towards the chuck. With a $\frac{1}{4}$ in. end mill, produce a slot to $\frac{1}{16}$ in. depth along the centre of the face, then widen it to $\frac{3}{8}$ in. to leave $\frac{1}{16}$ in. at each side and to suit the slide bar material as gauge. Make a note of the vertical slide micrometer collar readings when the final cuts were taken, turn through 180 deg. and repeat. To complete the crossheads, cut the casting in halves and clean up each to drawing dimensions with files and emery cloth.

The crosshead pins require careful machining to be a good fit, so chuck a length of $\frac{1}{2}$ in. diameter steel bar in the 3 jaw and first reduce for $\frac{1}{4}$ in. to 9/64 in. diameter, a good fit in the No. 27 hole, and screwing the outer $\frac{3}{16}$ in. at 4BA. Reduce the next .26 in. to 7/32 in. diameter as the working face of the pin, then move on and reduce the next $\frac{1}{4}$ in. or so to $\frac{7}{16}$ in. diameter, a tight push fit in the crosshead; part off then reverse and clean up the head to complete.

Cut four pieces from $\frac{3}{8}$ in. x $\frac{3}{16}$ in. BMS flat for the slide bars and square them off to 4 in. length. Grip each in turn in the machine vice and reduce to $\frac{1}{8}$ in. thickness over a $\frac{1}{4}$ in. length, this by end milling; the tapered portions can also be milled to drawing, taking trial cuts and setting the bar over until the desired result is achieved.

Mount the vertical slide on the boring table with its own table along the lathe axis; bolt an angle plate to same. Make up a special $\frac{3}{8}$ x 32T bolt to pass through the angle plate and fasten to the exhaust tapping in the cylinder block. To ensure the cylinders are correctly aligned, fix a dial test indicator (d.t.i.) in the 3 jaw chuck, bring it up to the piston rod and wind the carriage along so you can check the length of said rod; carry out a further check along the steamchest cover. When all is well, clamp a pair of slide bars to the crosshead and enter the latter in turn onto the piston rod; bring the slide bars up to their boss on the rear cover and mark on how much metal has to be removed from the latter. Take the crosshead away, chuck a $\frac{3}{8}$ in. end mill in the 3 jaw and remove metal from the rear cover boss, checking with crosshead and slide bars as you go; the ideal fit is when you can just push the slide bars over the boss, though any slackness of fit can be cured by use of shims, just as was done in full size. Push the slide bars hard against the cover, spot through the No. 41 holes in the slide bars, I didn't even tell you to drill the latter(!), then drill the boss No. 48 to $\frac{3}{16}$ in. depth and tap 7BA; secure with hexagon head bolts. Release the clamp and check the crosshead slides sweetly between the slide bars from end to end, shimming between cover boss and slide bar if indicated, then erect the completed cylinder assembly to the frames, fit the bushes to the connecting rod and assemble in turn.

We now have to take the cylinder 'bumps', a simple procedure to avoid the pistons ever striking the end covers in service. Turn the engine to front dead centre, then push the piston forward via its rod until it strikes the front cover; scribe a line where the piston rod enters the crosshead. Move on to the back dead centre, remove the front cover and push the exposed piston until it strikes the back cover, making sure that you do not get a false reading here through an overlong piston rod striking the small end of the connecting rod first; scribe a second line at the point of entry of the piston rod into the crosshead. Bisect these two lines with another and bring this up to the entry into the crosshead, remove any surplus length of rod then cross drill and ream for an $\frac{1}{8}$ in. taper pin, fitting same but not driving it home for the moment.

For the motion plate stay, cut a piece from $\frac{3}{4}$ in. x $\frac{1}{8}$ in. BMS flat and square off to 2 21/32 in. overall. Cut two end flanges from the same action material, square them off to $\frac{5}{8}$ in. length and fasten to the centre piece with 8BA screws; braze up. Grip in the machine vice, on the vertical slide and mill the end flanges to your $2\frac{7}{8}$ in. frame gauge; erect and drill through the No. 34 holes.

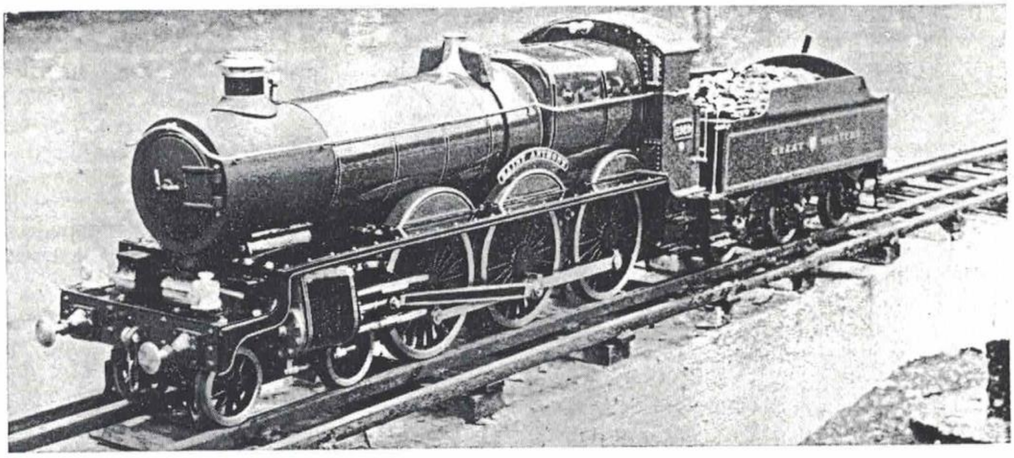
Take a motion plate casting and grip in the machine vice over the flange at the jaw, tidying this latter with files in the first instance if the edges are uneven. Mill across the frame fitting face and around the edges, then grip by said flange and mill the two jaws of the opening to fit neatly over the slide bars. Clamp in place after drilling the No. 41 slide bar fixing holes, spot through these holes, and those from the frames, drill the flange No. 43 and tap 6BA, the slide bars No. 48 and tap 7BA; erect with hexagon head bolts.

### Brake Cylinder Stay

Whilst in this area we may as well tackle the brake cylinder stay and except for being from $1\frac{1}{2}$ in. wide material, construction is identical to that for the frame stretchers. Drill the $\frac{3}{8}$ in. hole, bolt directly to the vertical slide table and mill the end flanges to gauge. Erect to the frames, clamp in position, spot through the No. 34 holes, drill No. 43 and tap 6BA. Incidentally, if when you fit a 6BA hexagon head bolt as specified, you find it is very close to fouling a wheel, remove it and subsitute with a countersunk screw – this wee comment may save me much correspondence!

## VALVE GEAR

Except for the reversal of direction of motion on MARIE E, which latter caused me that wee spot of bother over decreasing lead approaching mid gear, the valve gear for SAINT CHRISTOPHER is identical in respect of eccentric straps and rods, plus expansion links and die blocks, so I can save a big chunk of description; the die block pin is identical except for length, as are the lifting links, so we are well on the way.



Cliff Howarth's pristine SAINT ANTHONY looks every inch a gentleman – will somebody please tell me what the position of the lamps signifies on the G.W.R.?

The beauty for me of Churchward's policy of standardisation is that having worked out his version of the Stephenson link gear once, as I did so successfully for COUNTY CARLOW around 14 years back, then the design can be repeated with its detail variations in the sure knowledge that all will be well. Let us next get some of the 'anchor points' established.

### Weighshaft Bearing, Pendulum Bracket and Rocker Box

One of the most vital features of this valve gear is that the 'anchor points' be rigid and secure, the three items we are about to tackle, for they contribute much to the success of SAINT CHRISTOPHER, the rocker box being first in order of importance, for if it can move then it will destroy the whole valve timing – let us make sure it cannot.

Take a length of $\frac{5}{8}$ in. square BMS bar and try it in the frame step for tightness of fit; if at all slack then change to $\frac{3}{4}$ in. square section and first mill down to acheive the correct fit. Unless you are absolutely determined to be authentic, I would recommend the cap be integral with the rocker box, it serves no useful purpose in this instance and can be a source of unwanted movment if the cap holding down bolts slacken, as these things have a nasty habit of doing. So carefully mark out, cross drill and ream the fulcrum pin hole at $\frac{3}{16}$ in. diameter, this at $\frac{7}{8}$ in. from the end of the bar, an improvement being to drill out to 9/32 in. diameter and fit a bronze bush, an elongated version of that for the knuckle pin in the coupling rods.

If you cross drilled with the bar held in the machine vice and using the vertical slide, then move the bar so you can mill away to leave the $\frac{1}{8}$ in. frame fixing flange, tidying up its bottom edge. Saw away from the bar at the top end and start forming the cap to drawing, then grip a length of $\frac{3}{16}$ in. steel rod in the machine vice, grip the rocker box with a Mole wrench, slip over the mandrel and use a $\frac{3}{16}$ in. end mill to fashion the cap. Mark off, drill and tap for the 6BA dummy bolts, these having 8BA heads, and use a 'D' bit to spot face so that the bolt heads sit nice and flat; drill the No. 41 oil hole. Offer up to the frames, spot through, drill No. 43 and tap 6BA; secure with hexagon head bolts. Check with the Mole wrench that the rocker box is really secure and if at all unhappy, drill a couple of No. 43 holes right through frame and flange on the vertical centre line and press in $\frac{1}{4}$ in. lengths of 3/32 in. silver steel rod as dowels.

For the weighshaft bearings, chuck a length of $\frac{5}{8}$ in. square brass bar, or the phosphor bronze that will be preferable for the pendulum bracket, truly in the 4 jaw; face and turn down to $\frac{7}{16}$ in. diameter over a $\frac{1}{4}$ in. length. Centre and drill $\frac{1}{4}$ in. diameter to $\frac{1}{4}$ in. depth, then part off at a full $\frac{1}{2}$ in. overall. Revert to the 3 jaw chuck to face off to length and then turn the $\frac{1}{4}$ in. spigot to a tight fit in the frame; spot through, drill and tap the flange at 6BA to complete. The second bearing is similar, and simpler, so we can dispense with its description except for the fixing bolts, where an odd length of $\frac{1}{4}$ in. rod is used as an alignment gauge with the frame, when you can spot through, drill and tap 6BA as before.

Chuck the bar again truly in the 4 jaw for the pendulum bracket, face and turn down to 7/32 in. diameter, a 'mike' dimension, over a $\frac{5}{16}$ in. length; centre, drill No. 44 to $\frac{3}{16}$ in. depth and tap 6BA. Part off at a full $\frac{9}{16}$ in., rechuck in the 3 jaw, face and turn the $\frac{3}{16}$ in. spigot to a tight fit in the frames, then deal with the fixings.

### Pendulum Lever, Retainer and Spacer

For the pendulum lever we first require a simple building jig, so take a 2 in. length of, say, $\frac{1}{2}$ in. x $\frac{1}{4}$ in. BMS bar and grip in the machine vice, attached to the vertical slide; at about $\frac{1}{2}$ in. from one end and roughly central in the $\frac{1}{2}$ in. face, centre, drill through at No. 31 and ream at $\frac{1}{8}$ in. diameter. Move the cross slide on by .750 in. using the micrometer collar, centre again, drill through at No. 13 and ream at $\frac{3}{16}$ in. diameter; cut $\frac{3}{4}$ in. long pins from silver steel to fit these holes.

For the boss, chuck a length of $\frac{7}{16}$ in. rod, face, centre and drill No. 12 to $\frac{1}{2}$ in. depth then part off a full $\frac{7}{16}$ in. slice; rechuck and face to length. The lever is from $\frac{1}{2}$ in. x $\frac{1}{8}$ in. BMS flat; drill and ream $\frac{1}{8}$ in. diameter a full $\frac{1}{8}$ in. from one end, mark out the profile, saw and roughly file to shape, then radius the end over an $\frac{1}{8}$ in. mandrel with an end mill. Saw off overlong, fit the boss to the building jig, then scallop the rod to suit the boss until it slips over its pin on the building jig; file the flanks to mate with the boss. Coat jig and pins with marking off fluid, this to stop spelter adhering, then flux the joint, standard steel procedure, heat and silver solder. Whilst still hot, tap out the pins, then wash off and polish up the levers. Chuck by the boss in the 3 jaw, open out to No. 3, ream 7/32 in. diameter, then 'D' bit at $\frac{5}{16}$ in. diameter to $\frac{1}{8}$ in. depth, checking when fitted to the pendulum bracket that the spigot protrudes a couple of thous into the recess.

Chuck $\frac{5}{16}$ in. bronze rod for the retainer, face and ease the outside to an easy fit in the lever recess. Centre and drill No. 34 to $\frac{1}{4}$ in. depth, following up with a 90 deg. countersink to suit a 6BA screw; part off a 3/32 in. slice and erect the pendulum lever to its bracket.

Later on we shall have to make up and fit the spacer between the intermediate valve rod and die block, nominally $\frac{1}{16}$ in. thick and from $\frac{1}{4}$ in. brass rod drilled centrally at No. 30; I mention it here as it might be forgotten in the excitement as we approach valve setting.

### Valve Rocker and Rocker Arm

Rocker arm next, which uses the same building jig as for the pendulum lever; how's that for economy(!), that for the valve rocker being at $\frac{13}{16}$ in. centres. Chuck a length of $\frac{3}{8}$ in. steel rod

# Saint Christopher

by: DON YOUNG

### Part V – Chassis Completion and Steam Circuit

Again apologises for the 'break in transmission' of the SAINT CHRISTOPHER series, though certainly not for Les Clarke's fine contribution which provided the interlude; take a look too in the following pages at the rest of the COUNTY of GLOUCESTER that he has put round those cylinders. Inspired by this, let me set about getting our 29xx one step nearer steaming, a big step at that!

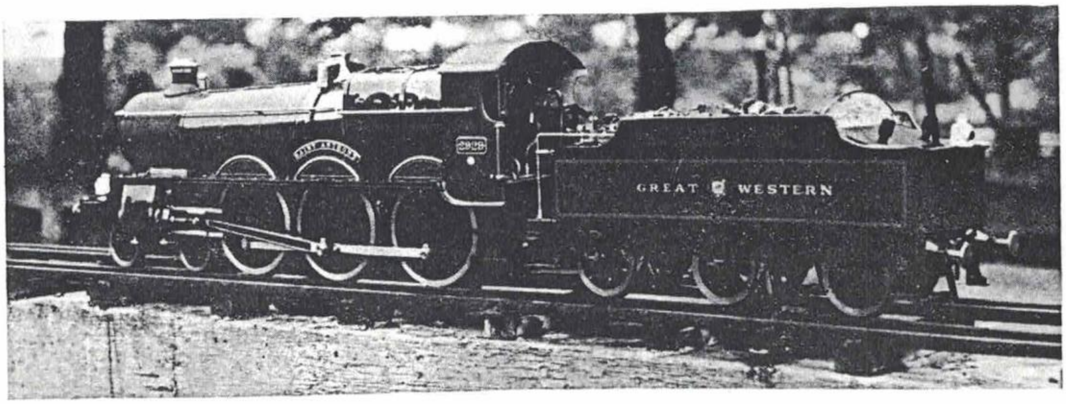
### Reverser and Reach Rod

It was the little group of components at the top L.H. corner of Sheet 4, illustrated now, that denied my completing the valve gear and its setting in Part 4; chief among them the reverser stand and backplate, so let me pick up the proceedings here. For the stand, square off a length of 1 in. x $\frac{3}{16}$ in. BMS flat to 1$\frac{3}{4}$ in. overall. Grip in the machine vice, on the vertical slide, and mill away for 1$\frac{9}{16}$ in. length to $\frac{9}{16}$ in. depth, as shown; do this in about three stages to keep the overhang from the vice jaws to a minimum. To complete the profile, mark on the sloping, bottom line and set up once more in the machine vice. For this sort of milling operation, I do not spend time in setting up accurately, but take a trial cut or two, then ease the vice jaw and give the workpiece a gentle tap, take another cut and repeat the process, until the final cut is to line. Carefully mark off for the No. 35 hole, turn this face towards the chuck, centre and drill through. The base is a full 1$\frac{3}{4}$ in. length of $\frac{5}{8}$ in. x $\frac{1}{8}$ in. BMS flat; either clamp to the stand for brazing or fit screws like we did for the front frame earlier on; remove any excess flux and polish. The backplate is from $\frac{5}{16}$ in. x $\frac{1}{8}$ in. BMS flat, squared off to 1$\frac{1}{8}$ in. overall and if you grip in the machine vice you will be able to drill all the holes accurately, using the cross slide micrometer collar to arrive at the required dimensions. Before we can assemble to the stand we need a few more pieces.

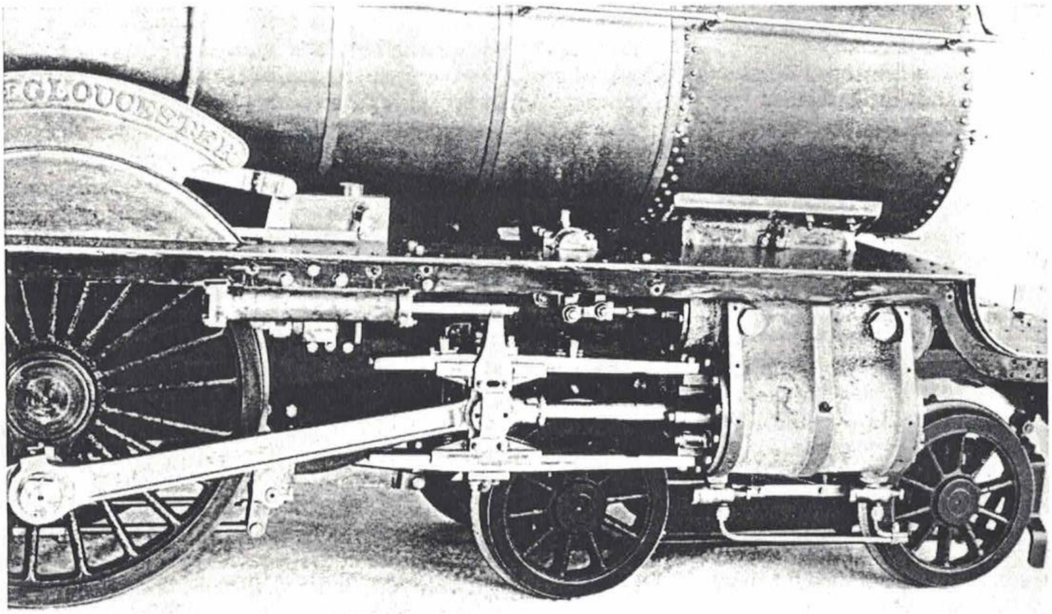
For the screw, I recommend purchase of a length of 2BA steel studing from Reeves, as this solves the major problem in machining a long length of thread. Chuck lightly in the 3 jaw, no great pressure is required, face off and then turn down over a $\frac{3}{16}$ in. length to 7/64 in. diameter, a running fit in the No. 35 hole in the stand. Saw off at 2$\frac{1}{16}$ in. overall and face to 2 1/32 in., then starting at this end, reduce to 3/32 in. diameter for 3/32 in. length and screw 7BA; reduce the next $\frac{3}{8}$ in. length to 5/32 in. diameter, checking this latter in the backplate. If you are a little heavy-handed with the silver solder, leave this portion at around 11/64 in. diameter for the moment, turn up and braze on the collar, then complete turning; you can also use a 2BA die to remove any spelter from the threads. Leave the $\frac{1}{8}$ in. square for the moment and we will next concentrate on the nut, which starts life as $\frac{5}{16}$ in. square bronze bar. Square off a $\frac{3}{4}$ in. length and then mill down to $\frac{1}{4}$ in. thickness. Mark off, drill and tap the 2BA hole, then mill the $\frac{3}{16}$ in. wide recess at the bottom, a little at a time, until when fitted to the screw, the spigot on the end of the latter enters the No. 35 hole in the stand sweetly. At this point, erect the backplate, clamping firmly in place, check that the nut traverses from end to end of its travel without binding, then spot through from the backplate, drill and tap the stand 7BA and secure with round head screws, only we have yet to finish the nut! Back to the machine vice and vertical slide to first cross drill at No. 31 and ream $\frac{1}{8}$ in. diameter for the reach rod pin, then mill away at the top to leave a bare $\frac{1}{8}$ in. projection, which goes through the indicator plate; the little notch as detailed is a job for a Swiss file.

The indicator plate starts life as a 2 in. length of $\frac{3}{8}$ in. x $\frac{1}{16}$ in. brass strip. Mark off the slot 1$\frac{3}{8}$ in. long and drill a row of No. 35 holes down the centre line. Carefully grip in the machine vice, but if there is distortion, sweat to a piece of $\frac{3}{8}$ in. square brass bar. For this you heat both pieces, dip in Bakers fluid, warm again and apply a little tinmans soft solder; with molten solder on both faces, squeeze together in the bench vice. Now you can use a 3/32 in. end mill to deal with the slot, checking against the nut; unsweat and file the ends of the slot square. Offer up to the stand, mark off and drill the No. 50 holes, carrying on at No. 55 and tapping 10BA: I have shown these tapped holes right into the bearings as 10BA blind holes are tricky to say the least, but do remove the screw before this operation. Set the nut in the middle of its travel, remembering to make due allowance for the little thrust collar, and scribe across the indicator plate to coincide with the notch at the top of the nut; this is mid gear.

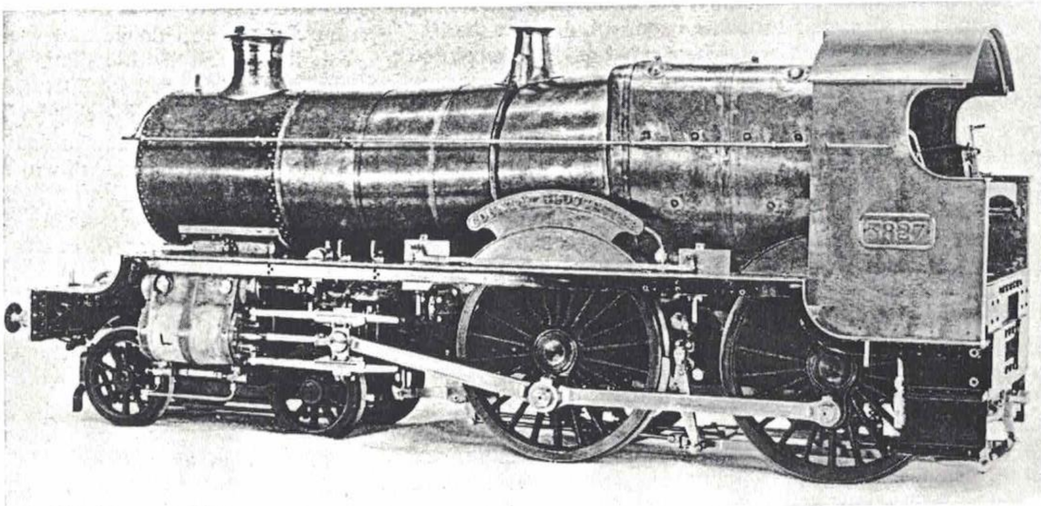
Only the handle to complete the reverser, so chuck a length of $\frac{1}{4}$ in. steel rod, face, centre and drill No. 30 to $\frac{5}{16}$ in. depth. Reduce to 7/32 in. diameter over a $\frac{1}{16}$ in. length and part off at a full $\frac{3}{16}$ in.; reverse and clean up the parted off face. Measure the spigot diameter by micrometer and drill an appropriate number sized hole in the middle of a 1$\frac{1}{2}$ in. length of $\frac{5}{16}$ in. x $\frac{1}{16}$ in. steel strip. Turn up handles from $\frac{1}{8}$ in. steel rod, only I usually produce these with files, running the lathe at top speed. Start parting them off, but when you have a

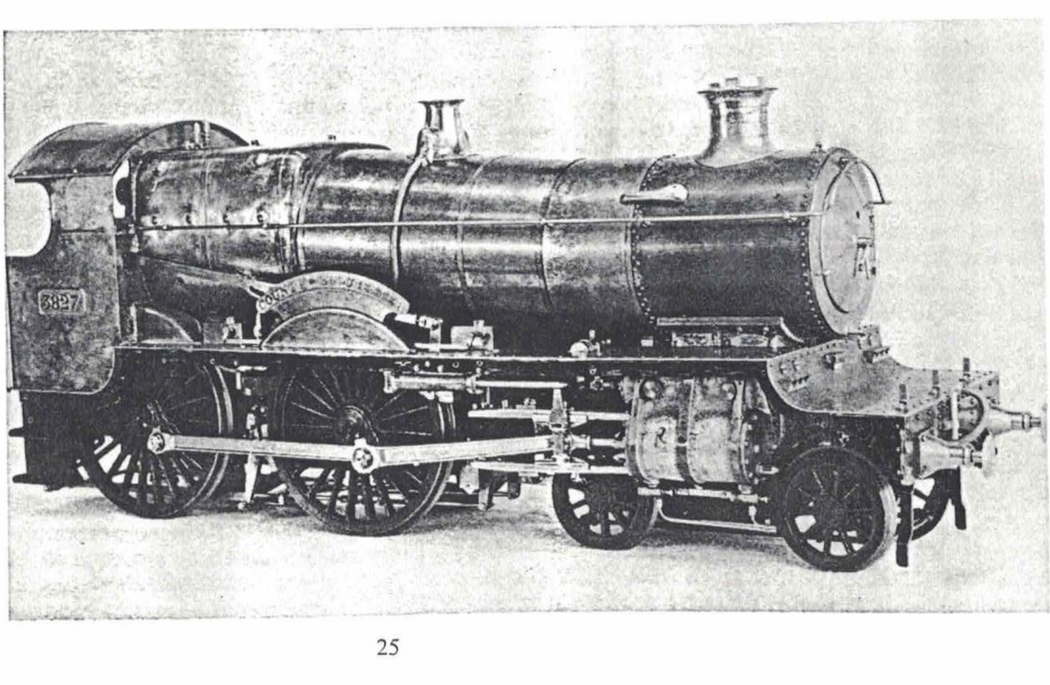



Over lunch at the Brighton Show with Laurie Lawrence, Editor of 'Model Engineer', we enthused over the design features of Churchward's SAINT Class, one of the most successful Locomotives of all time, which is some admission from this Doncaster Plant man!



# County of Gloucester




In LLAS No. 14 we were privileged to have description by Les Clarke in Australia of the cylinders for his $3\frac{1}{2}$ in. gauge COUNTY OF GLOUCESTER. Since then the cylinders have been joined by the rest of the engine to make an impressive whole, complete now except for a few details like cylinder cleading and ready for the paint shop. That my humble COUNTY CARLOW series published in 'Model Engineer' back in 1969 could simply be the inspiration of such a masterpiece makes me very proud, a fine tribute by Les to his earlier years at Swindon.

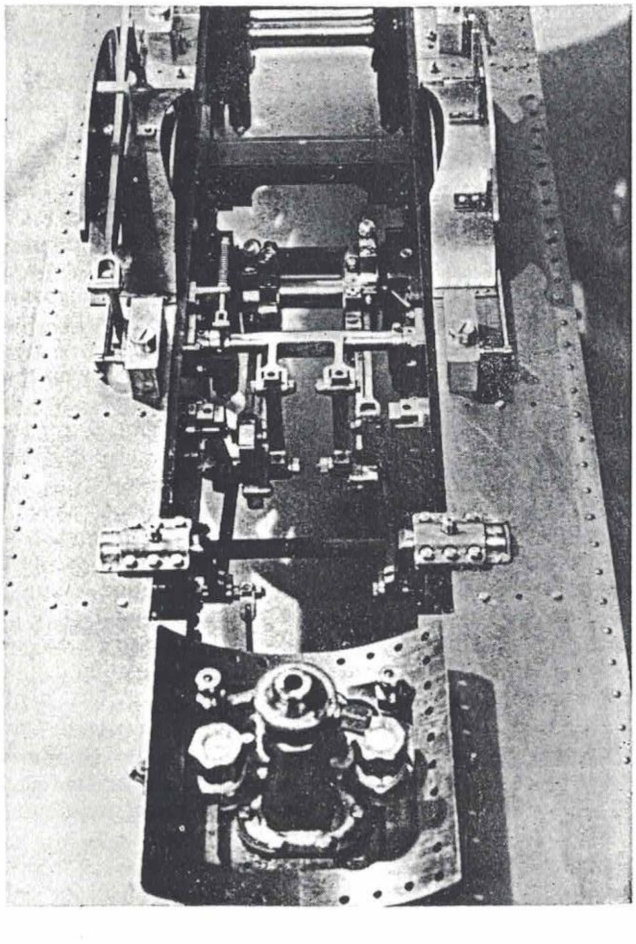
The photographs were taken by son Terry Clarke, using equipment whose normal purpose is for astronomy – though still pointed at a star attraction!

in the 3 jaw, face, centre, drill No. 13 to $\frac{5}{16}$ in. depth and part off a full 7/32 in. slice. Rechuck, clean up to 7/32 in. thickness and then ream through at $\frac{3}{16}$ in. diameter. For the pin, chuck a length of $\frac{1}{8}$ in. silver steel rod, face and turn down to 3/32 in. diameter over an $\frac{1}{8}$ in. length before screwing 7BA; part off at $\frac{3}{8}$ in. overall. Use this as your second pin when building up the rocker arm, employing the same technique for the arm itself as for the pendulum lever already made; silver solder together, not forgetting the pin this time. Deal with the valve rocker in exactly similar fashion then cut a $1\frac{1}{16}$ in. finished length from $\frac{3}{16}$ in. silver steel rod for the rocker shaft. Nowadays I much prefer to use a spring dowel pin rather than the tapered variety as it means a plain drilled hole, but beware that there can be deflection under load with spring dowel pins, which can be avoided either by use of a smaller spring dowel pin down the bore of that first fitted, or a plain piece of rod; each will give the required stiffness. Fit the rocker arm to the shaft with 1/64 in. of the latter projecting, drill right through and secure. Erect to the rocker box, align the two arms, by eye is sufficiently accurate, then fix the valve rocker.

### Intermediate Valve Rod

Start by silver soldering a $\frac{3}{4}$ in. length of $\frac{5}{16}$ in. square bar to the end of a 6 in. length of $\frac{1}{4}$ in. x $\frac{1}{8}$ in. BMS strip. At a full $\frac{1}{8}$ in. from the end of the block, drill No. 31 and ream $\frac{1}{8}$ in. diameter, then turn the bar over and drill No. 30 at the bottom of the slot. Use the double hacksaw blade technique to start forming the slot, completing with a key cutting file to the pendulum lever as gauge. Radius the fork ends over a mandrel with an end mill then file down the rest of the block to match the rod itself, tidying up the inner end of said block on its inner face to also blend into the rod. Next job is to produce the $\frac{1}{4}$ in. set, which need not be exact, but for appearance sake at least both rods should be identical. To complete, mark off at $5\frac{3}{16}$ in. centres, drill and ream this second hole at $\frac{1}{8}$ in. diameter to suit the rocker arm pin, then saw off the surplus and radius the end. Erect to the rocker arm, fit the die block and spacer to the die block pin, slide through the forked end of the intermediate valve rod, taking in the pendulum lever, and complete with 6BA washer and nut.

Prelude to something rather special. This is actually 38xx 4-4-0 COUNTY OF GLOUCESTER under construction by Les Clarke in Australia, but she has much in common with SAINT CHRISTOPHER



### Valve Crosshead and Link

These two items complete the 'operating' part of the valve gear, what follows will be the 'control' components, so take two $1\frac{5}{16}$ in. lengths of $\frac{1}{4}$ in. x $\frac{1}{8}$ in. BMS strip and grip them in the machine vice. At a full $\frac{1}{8}$ in. from one end, centre, drill No. 31 and ream $\frac{1}{8}$ in. diameter; move on 1.000 in. by cross slide micrometer collar and repeat. Put a 5BA bolt through one end of the pair, grip with a Mole wrench, then use the mandrel/end mill technique to fashion the other ends; reverse and repeat. To complete, file the centre section down to $\frac{3}{16}$ in.
The valve crosshead is from $\frac{5}{16}$ in. square material, so chuck truly in the 4 jaw, face and turn down for $\frac{1}{8}$ in. to $\frac{1}{4}$ in. diameter, using a round nose tool to finish as per drawing. Centre, drill No. 29 to $\frac{3}{16}$ in. depth and tap 5/32 x 40T. Next mark off, cross drill and ream at $\frac{1}{8}$ in. diameter, then saw off at $\frac{1}{2}$ in. overall, sawing and filing the slot to accept the valve link. Radius the fork end over a mandrel with an end mill, using a length of 5/32 in. rod screwed 40T as your lever, then assemble to the valve spindle and erect the link. For valve gear pins I recommend you make them identical except in length of plain pin to that for the die block and of course you can check said length to place.

### Weighshaft

The lifting arms are identical to those for MARIE E and the shaft itself a plain $3\frac{11}{16}$ in. length of $\frac{1}{4}$ in. steel rod, which leaves only the reversing arm. For this latter we need another building jig, again $\frac{1}{2}$ in. x $\frac{1}{4}$ in. section BMS, with $\frac{1}{8}$ in. and $\frac{1}{4}$ in. reamed holes at $1\frac{5}{16}$ in. centres; cut and fit $\frac{1}{2}$ in. long silver steel pins to suit. Turn up the boss and mark off the arm on $\frac{3}{8}$ in. x $\frac{1}{8}$ in. BMS flat. Drill and ream the $\frac{1}{8}$ in. hole, roughly file the end to line and complete by the end mill/mandrel technique, then saw off to length and scallop this end to suit the boss, file the flanks to line, assemble and silver solder together.
Erect the lifting arms and links to the expansion links, slide in the weighshaft and position the lifting arms axially by scribing on the shaft. Taper pins are best here, so drill and/or ream for one arm and fit a taper pin, push fit only. Bring the other arm into its axial position and poke a length of $\frac{1}{8}$ in. rod through the pair for alignment, then deal with the second taper pin.
The reversing arm is at 90 deg. to the lifting arms and can be set up by eye, this is sufficiently accurate, when you can also pin this arm to complete the weighshaft assembly.

### Reverser

Many times have I been asked to inspect valve gears which have been 'set' when in fact everything stops at the reversing arm, which is then variously clamped to frames, running boards, etc., etc. As in full size practice, it is not possible to accurately and permanently set any valve gear without the presence of reverser and reach rod to give positive settings, those that can then be reproduced in service; for this reason valve setting will not be dealt with in this session. This applies equally to the reverser itself, as lack of space prevented all the details appearing on Sheet 3, so we shall pick up the reins at this point next time.

spigot roughly 3/32 in. diameter, move on a full $\frac{1}{16}$ in. before parting right off, then you can drill further holes in the $\frac{5}{16}$ in. x $\frac{1}{16}$ in. steel strip to accept same before brazing up the whole assembly. Use a square Swiss file to deal with the $\frac{1}{8}$ in. square, I use the end of a tap as a gauge for this, then complete the profile to drawing with files. To complete, file a square on the screw to accept the handle boss, checking that there is a minimum of end float in the backplate, then apply a washer and 7BA nut to hold things in their proper place.

Erect on the reverser box, which unfortunately is detailed with the platework on Sheet 5, then cut two $6\frac{1}{2}$ in. lengths from $\frac{3}{8}$ in. x $\frac{1}{8}$ in. steel strip, or the nearest available section. In both pieces, drill a No. 31 hole at one end and press in $\frac{3}{8}$ in. lengths of $\frac{1}{8}$ in. silver steel rod. At the opposite ends, drill one piece No. 30 and mill a 1 in. long slot in the other to accept a 5BA screw; tighten this up and erect with one pin in the reversing arm and the other in the reverser nut. Set the nut in the mid-gear position, slacken the 5BA screw and bring the reverser arm upright. Now, looking down into the motion, it is very difficult to check if the die block is in the mid-point of the expansion link, but if you set up the valve gear as shown on Sheet 3, then you can screw the reverser down into full fore gear, measure the clearance between die block and end of the expansion link slot, repeating in full back gear, adjusting the length of temporary reach rod to centralise the die block and finally checking that there is no visible error at the mid-gear position.

Take an 11 in. length of $\frac{1}{2}$ in. x $\frac{1}{8}$ in. BMS flat and braze a $\frac{9}{16}$ in. length of $\frac{1}{2}$ in. square bar to one end, a $\frac{1}{2}$ in. length of $\frac{1}{2}$ in. x $\frac{1}{4}$ in. section to the other, orientating to produce the correct end result. Press out the $\frac{1}{8}$ in. pins from the temporary reach rod, offer up to the embryo permanent one and drill through at No. 31. Now it is a question of completing the fork ends and profiling, just as we have done for other valve gear components, the big lump at the back being a straightforward milling operation. That really awkward slot towards the middle of the rod, in way of the stirrup, has no real meaning in $3\frac{1}{2}$ in. gauge, so I suggest you mark it off, drill No. 30 closely spaced along the centre line and then file out to line.

Although manufacture of the reach rod stirrup has to await the splasher being erected, I will describe it here. Cut two $1\frac{1}{4}$ in. lengths from $\frac{1}{4}$ in. x $\frac{1}{16}$ in. steel strip, clamp together and drill through at No. 50, this $\frac{5}{16}$ in. from one end. Cut the base $\frac{1}{2}$ in. square from 3/32 in. thick material and fashion to fit the curved splasher, then saw and file the bottom end of the side supports, still as a pair, until the No. 50 hole align roughly with the centre of the slot in the reach rod, clamp together and braze up. With the boiler erected, you will have to bend the reach rod very slightly to gain working clearance, but this will have a negligible effect on overall length, such that we can ignore same; press in lengths of $\frac{1}{8}$ in. silver steel rod as pins.

**Valve Setting**

Really the notes as they appear on Pages 14/15 of LLAS No. 9 apply almost in their entirety, but there are pitfalls as Terry Phelps discovered, plus this one operation can cause more frustration than everything else lumped together, so let me run through the procedure again.

The one real advantage of slide valves is that by removing the steamchest cover we can see plainly what is happening at all times, nothing is secret or mysterious. So the first job is to remove those covers and refit the nuts to at least the four corner studs, this to hold the steamchest firmly in position. Let us deal with the L.H. side of the engine first, so remove the front cylinder cover and rig up a dial test indicator to be clamped firmly to the front frames and with business end touching the piston, turn to front dead centre, which will be indicated when the pointer stops moving; that is the only function we require from such a sensitive piece of measuring equipment. Put the engine into full fore gear, ease the securing screw on the fore gear eccentric sheave, that is the one closest to the frame, and turn it until the valve just 'cracks' the port; you should just be able to enter a .003/.005 in. feeler to verify this. Tighten up the eccentric sheave screw and turn the engine to back dead centre, again using the d.t.i. to establish when the piston stops moving; check the port opening. To centralise the valve over the ports, if there is any error, screw or unscrew the valve crosshead $\frac{1}{2}$ turn, giving a .0125 in. movement, so the **maximum** setting error will be half of this, which is still well within accepted tolerance; the norm of course will be much less even than this.

Put the engine into full back gear, bring to front dead centre on the L.H. side again, release the back gear eccentric sheave and turn again to 'crack' the port. Move to back dead centre, check the setting and again centralise the valve over the ports by turning the valve crosshead. A builder of one of my Locomotives thought at this stage his valves should be set and was annoyed that this was not so, but I guess readers and builders alike will realise that in moving the valve in the back gear position, the setting in full fore gear has been upset. So now it is a case of full fore gear and centralise valve, then full back gear and ditto, gradually progressing towards equality in all positions. The last little bit is usually difficult to trace and involves both time and patience to get as close as humanly possible, in fact I vividly remember a Saturday evening spent with Gordon Chiverton setting my modified valve gear on his MAID OF KENT. At the end of the evening we were in fact going backwards, though to be fair we did have one more variable to contend with than on SAINT CHRISTOPHER, with dark mutterings of things being consigned to the dustbin! On arrival in some trepidation on the Sunday morning, it was to find the job done and boxed up, so do take your time as it is a 'once only' job.

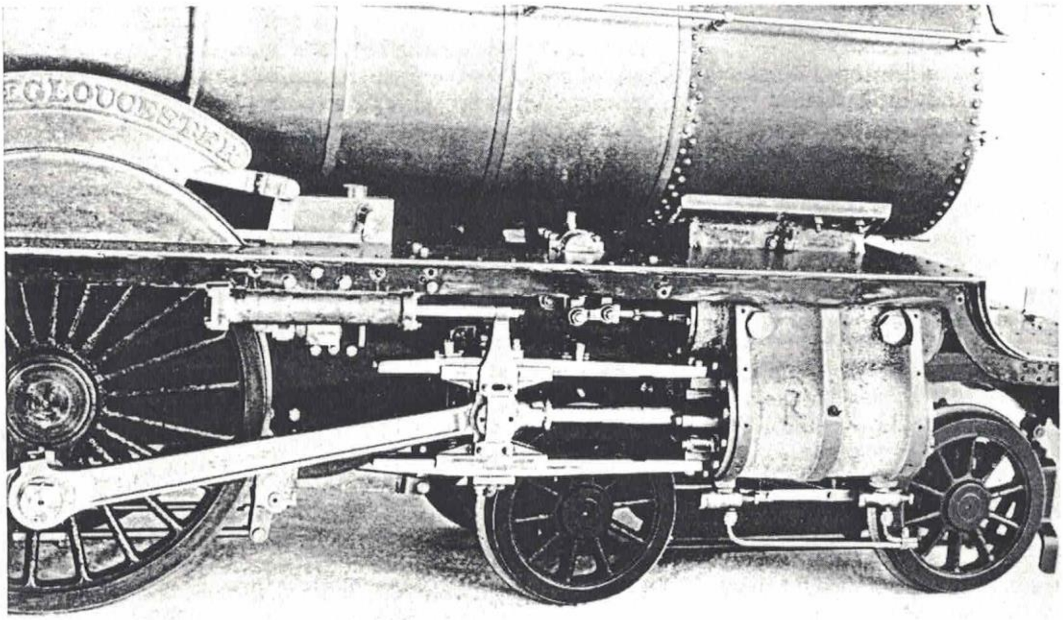
In sorting out the last little discrepancies, if your valve rocker/rocker arm assembly is not finally pinned, move these arms slightly relative to each other and check its effect. The final checks are to notch up the valve gear, in fore gear, and check that the increasing leads are approximately the same, equalising any marked error to the detriment of full fore gear, back gear too, as your SAINT CHRISTOPHER will spend most of its working life I guess notched up and running forwards, though be it understood this is not a license to skimp the whole operation; any error introduced should be less than .010 in. at the valve, a very fair specification. The moral here is that the better the timing, the better your SAINT CHRISTOPHER will sound, and we all want her to sound good!

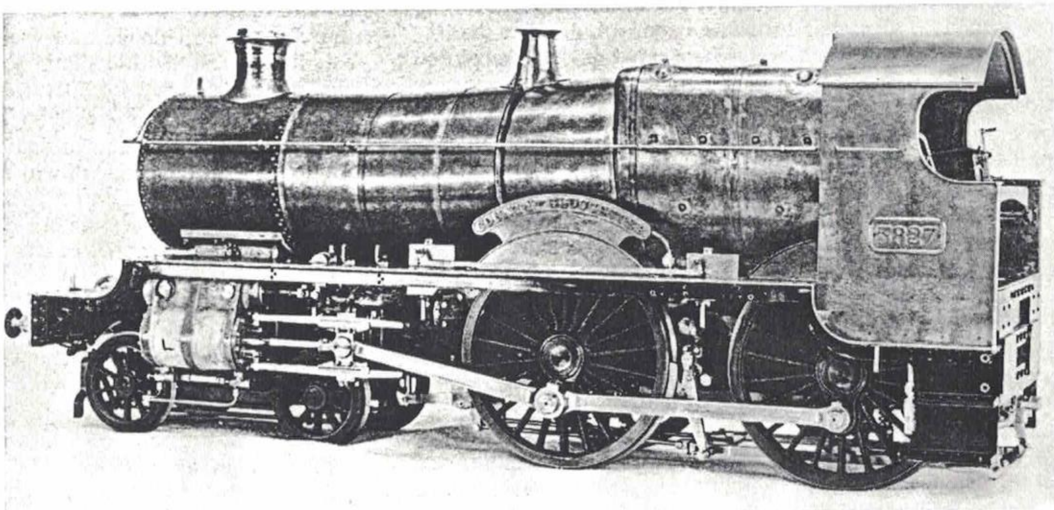
**Brake Gear**

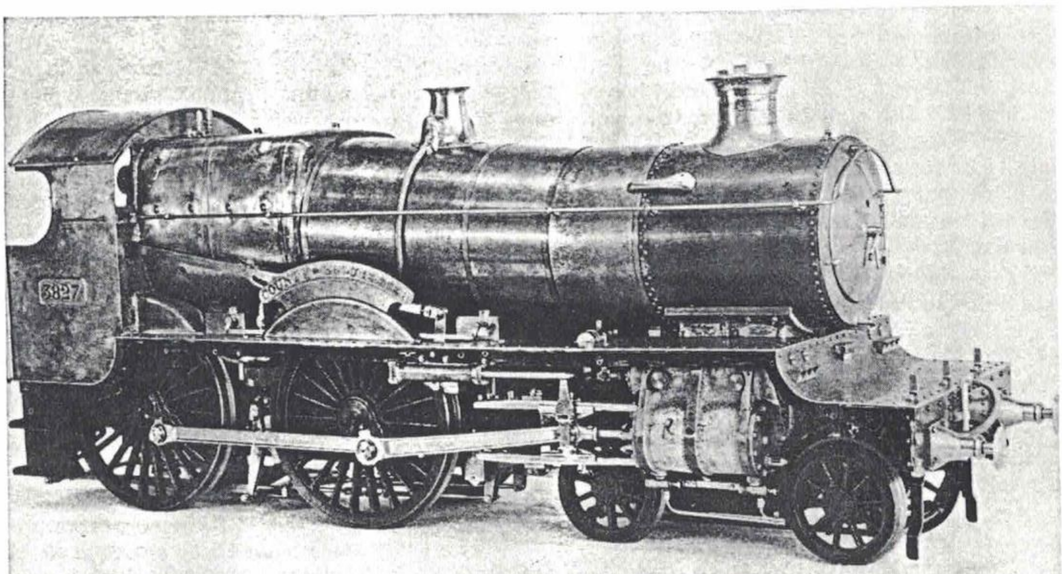
After all the fine work that has gone before, the specification for the brake gear is that, save in the matter of the steam brake cylinder, all fits should be on the sloppy side, so that the brake shoes are free to follow the wheels without restriction, though again this is not a license for poor workmanship, it all being visible!

Brake hanger brackets are plain turning and cross drilled for a 3/64 in. split pin on assembly, which brings us on to simple components such as brake hangers, compensators and links. Here I will digress for a moment to a time when I was able to build Locos rather than describe them, in particular the 02 Class 0-4-4T FISHBOURNE, when my working day was filled with steam and gas turbines, their manufacture involving millions of pounds of investment in jigs and fixtures; we also machined some of the intricate press tools for motor car body panels, this at a time when they were becoming flambouyant. After struggling say with a broaching problem for turbine blade roots all day, with thousands of unfinished ones glaring at me from their skips, it was nice to relax with a 'one

# County of Gloucester



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The photographs were taken by son Terry Clarke, using equipment whose normal purpose is for astronomy – though still pointed at a star attraction!

off' situation, knowing that with drill and file I could fashion a lump of steel to the shape I wanted it to be, and not having to worry about the odd .001 in. Also I was a fitter by trade, and a leopard does not change his spots very easily, at least this one. So when I came to an item such as the brake hangers, requiring more than a single similar item, this is how I proceeded.

First mark out one hanger on a piece of $\frac{1}{8}$ in. thick BMS strip, as accurately as possible; drill the appropriate holes and saw away as much unwanted material as you can. For the end radii, chuck an odd end of 7/32 in. silver steel rod, turn down to $\frac{1}{8}$ in. diameter for $\frac{1}{8}$ in. length, heat and quench. If silver steel is not available, use mild steel in lieu and caseharden; all you need for the latter operation is a tin of crushed charcoal; heat the pin, roll it in the charcoal, and repeat if necessary until a glass-like skin is obtained. You now poke the $\frac{1}{8}$ in. spigot in the No. 30 hole and file the radius, using the 7/32 in. diameter as your filing jig. Do this at both ends of the hanger, file the rest to line and case harden this 'master' hanger. You now have a drill jig for as many other of the same parts as you require, a filing jig too, for after drilling from the master you just bolt it to same and file down to the casehardened surfaces. Simple, easy, and at the end of the day your drilling/filing jig becomes a part of the Locomotive instead of a useless piece of junk. Oh, I know there are useful accessories to aid building, but I used to reckon that people like Myford could make a better job of these than I; my role was to put them to good use. That remains my philosophy and I recommend it to all builders of miniature steam Locomotives – those engaged in the renovation/preservation of large Locomotives too.

For brake gear pins, chuck a length of $\frac{3}{16}$ in. steel rod, face, centre and drill No. 42 to about $\frac{3}{4}$ in. depth, then part off full $\frac{1}{16}$ in. slices. Cut the pins themselves a full $\frac{7}{16}$ in. long, face off and slightly chamfer both ends. Push a collar over one end, silver solder in place, chuck by the shank and clean up the heads to drawing; much easier than turning from solid bar.

Brake beams which have the same diameter end spigots as the beam thickness can be a wee bit difficult to chuck in the 4 jaw to run true enough to avoid a flat after turning, though this latter is of no real consequence, so take a $4\frac{3}{16}$ in. length of $\frac{1}{2}$ in. x $\frac{1}{8}$ in. BMS flat, saw away most of the metal in way of the spigots and finish turning to size. Drill the No. 41 hole and complete the profile with saw and files; again you can produce a 'master' for this if you wish, then you only have to concentrate and get things right once!

Cast iron brake shoes are now rather prohibitive in price for their size, and they can just as easily be fabricated from mild steel. Mill about a foot length of steel bar to $\frac{5}{16}$ in. x $\frac{3}{16}$ in. section, heat it to a bright cherry red and pull around a piece of 5 in. o.d. material, preferably not a finished wheel! Saw into $1\frac{1}{4}$ in. lengths and file the working face to fit the wheels, then cut triangular pieces from $\frac{1}{4}$ in. steel bar for the lugs. Braze these in place, drill the No. 41 hole, complete the profile and then saw and file the slot to accept the brake hanger, securing with a brake pin; erect hangers and beams.

The pull rods are far easier than they look. For the rear pair, braze a $1\frac{3}{16}$ in. length of $\frac{1}{4}$ in. square steel bar to a $5\frac{5}{8}$ in. length of $\frac{1}{2}$ in. x $\frac{1}{16}$ in. steel strip. Mark off and drill the two No. 41 holes, then saw and file out the long slot. Radius the ends as per valve gear parts, file each side to arrive at 7/32 in. width and tidy up the end of the block adjacent to the strip to complete to drawing. For the intermediate pair, deal with the fork ends first on fairly long lengths of $\frac{1}{4}$ in. square bar. Saw and square them off, then drill and tap this squared face centrally at 7BA. Now all you have to do is take a 4 9/32 in. length of 3/32 in. steel rod, screw 7BA for about 3/32 in. at each end, and assemble to arrive at 5 13/32 in. centres. On achieving this, silver solder together and build up a decent fillet, when you will be able to finish to drawing with a round nosed tool and paint matt black all over so that the silver solder does not show. The leading pull rod follows the same technique; for the shaft pull rod simply scallop the end of the rod to suit the collar and braze up.

I doubt if many builders have R. & L.H. 5BA taps and dies, it matters not, so chuck a length of 5mm A/F hexagon steel bar in the 3 jaw, face and turn down to $\frac{3}{16}$ in. diameter over a $\frac{1}{4}$ in. length; lightly radius the outer end. Saw off at a full $\frac{3}{4}$ in. overall, reverse and repeat, then centre, drill right through at No. 40 and tap 5BA; do it from both ends if you do not have a long enough tap. Erect all the gear made so far, when it will look like the arrangement I have drawn.

We know all about machining cylinders, so that for the steam brake should now be a piece of cake. Chuck a length of 1 in. diameter brass bar in the 3 jaw, face and then turn on the outer profile. Centre and drill $\frac{7}{16}$ in. diameter to $\frac{13}{16}$ in. depth and part off at 23/32 in. overall. Next clean up the parted off face, then bring this latter towards the chuck. Take a final light facing cut across the bottom, cover, face then bore out to $\frac{1}{2}$ in. diameter, only you can finish the bore with a reamer if you wish. The top cover is a 1 in. disc from 2.5mm brass, to which a 7/32 in. stem is brazed. Grip by this stem and take a light facing cut, then scribe on the bolting circle, Mark this off and drill No. 44 in five positions, then offer up in turn to the cylinder top flange and the stay, drilling through. On erection, smear a little liquid jointing compound over the surfaces and secure with 8BA brass screws and nuts.

The bottom cover is a wee bit tricky, but we shall win of course. Chuck the 1 in. bar again and turn down for $\frac{5}{16}$ in. length to $\frac{7}{8}$ in. diameter, this to match the bottom flange on the cylinder. Face and turn a $\frac{1}{16}$ in. spigot to $\frac{1}{2}$ in. diameter to suit the bore, then centre and drill $\frac{1}{4}$ in. diameter to $\frac{3}{8}$ in. depth. Start parting off to leave a 3/32 in. thick flange, but when you reach $\frac{1}{2}$ in. diameter, move out another $\frac{1}{16}$ in. and then part right off. Lightly grip by the cylinder spigot and complete the outer faces, then drill the No. 50 vent, Mark off and drill the five No. 44 fixing holes, offer up to the cylinder, spot through, drill and tap the latter 8BA.

For the piston, chuck a length of $\frac{5}{8}$ in. diameter bronze bar in the 3 jaw, face and turn down to $\frac{1}{4}$ in. diameter, an easy running fit in the bottom cover, over a $\frac{9}{16}$ in. length, then centre and drill No. 27 to 7/32 in. point depth, before parting off at a full 27/32 in. length. Reverse in the chuck, face to length, then turn down the head to about 33/64 in. diameter before forming the groove with a parting off tool. Incidentally, when I first drew such a groove some 20 years ago now, the idea was to fit soft packing. In the event I forgot to put it in at the first steaming, though the brakes worked perfectly, and I discovered water in the groove on dismantling. From this I have never specified packing this groove, finding that water does the job better, with less friction. Anyhow, continue by reducing the head to a nice sliding fit in the bore, treating the piston with a little molybdenum disulphide grease to further reduce said friction, then centre and drill No. 51 to $\frac{1}{2}$ in. point depth. Follow up at No. 22 to $\frac{1}{4}$ in. depth, 'D' bit at 5/32 in. diameter to 9/32 in. depth, then tap $\frac{3}{16}$ x 40T without the tap bottoming and spoiling the seating you have just formed. Drill a No. 53 hole and press in the wee $\frac{1}{16}$ in. pin, this provides clearance so the piston does not stick to the top cover when the brakes are released, then complete with a No. 51 drill at an angle into the centre bore as shown.

For the ball retainer, chuck a length of $\frac{3}{16}$ in. brass rod, face, centre and drill No. 48 to $\frac{1}{4}$ in. depth. Screw 40T for the same $\frac{1}{4}$ in., still in the chuck, make a slot with a hacksaw for your screwdriver. Start parting off at $\frac{1}{8}$ in. length, but before completing this operation, run the die over the outside again to remove any burrs, otherwise you could play for hours

getting it into the top of the piston, this after dropping in a 3/32 in. stainless steel ball. Said ball is actually a condensate drain, it floats just sufficiently when the bore starts to fill with water to allow it to drip away down the passage, and stops the embarrassment of applying the steam brake, only to find that nothing happens as the cylinder is waterlogged – crunch!
The shaft trunnions are from $\frac{1}{2}$ in. x $\frac{1}{4}$ in. BMS bar, so square off one end of each piece and clamp side by side in the machine vice, on the vertical slide, to mill the $\frac{1}{2}$ in. strip to $\frac{1}{8}$ in. depth. Bring together, with a short length of the $\frac{1}{2}$ in. x $\frac{1}{4}$ in. bar aligning the two steps, clamp tightly together, mark off and drill the No. 12 hole. Saw off to length, start radiusing this end with files and complete over a mandrel with an end mill. For the shaft, cut a 3 5/32 in. length from $\frac{1}{4}$ in. steel rod, chuck in the 3 jaw, face and turn down for $\frac{1}{4}$ in. length to $\frac{3}{16}$ in. diameter, an easy fit in the trunnion, then reverse and repeat to arrive at $2\frac{5}{8}$ in. between shoulders. Erect with the trunnions to the frames, check for squareness, then drill through at four positions No. 44 for 8BA bolts. We now have to complete the brake shaft, starting with the steam brake arm. Grip a length of $\frac{3}{8}$ in. x $\frac{1}{8}$ in. BMS bar in the machine vice, $\frac{3}{8}$ in. wide face towards the chuck, and on the centre line at $\frac{1}{8}$ in. from one end, drill through at No. 41. Move on 1.219 in. by cross slide micrometer collar and drill through again at Letter 'D' or $\frac{1}{4}$ in. diameter; if the latter then squeeze in the bench vice to a tight fit over the shaft. Mill away as much metal as you can to arrive at a 3/32 in. thick arm, then saw down and file the slot in the fork end, tidy up with files and radius the other end over a mandrel, finally filing top and bottom edges, or milling them, to blend into the end radii. The short, pull rod, arms are from $\frac{3}{8}$ in. x 3/32 in. strip, another example where you can make a single 'master' and use it to produce another three identical parts; silver solder the complete assembly, clean it up and paint matt black.
Apart from the larger brake pins, made in exactly the same fashion as the smaller ones, only the push rod remains; as the latter is quite adjacent to condensate it can be made from brass if you wish. Turn up the collar, take a $\frac{5}{8}$ in. length of 3/32 in. rod and radius an end with a file, in the lathe and running at top speed, then silver solder together. The push rod end fits into the No. 27 hole at the bottom of the piston, pin the other end to the brake arm, then complete the assembly and check operation of the whole brake gear. Fit a light extension spring between the brake beam for the leading coupled wheels and the bottom of the frame stretcher to ensure positive brake release if the brakes tend to bind in service.
After what I said earlier about hydrostatic lubrication, I can forget about description of the lubricator drive fork and lug, though they are straightforward anyhow should any builder wish to retain mechanical lubrication; back to the boiler.

**Steam Circuit**

We now come to the important job of getting steam from the boiler to the cylinders, the last major task on the whole Locomotive, so without further ado I will press ahead.
First item into the circuit is the regulator and although for COUNTY CARLOW I did investigate an authentic smokebox type, it posed more problems than it solved in $\frac{1}{16}$ th scale, so I came back to the proven disc-in-tube pattern, and from all accounts it has not been found lacking. It has one tremendous advantage in that steam is taken from the highest, and hottest, spot in the whole boiler, so let us deal with the tube that allows steam from the boiler into the confines of the regulator. In the days of L.B.S.C., most commercial brass was 70/30 whereas nowadays 60/40 is more the order of the day, so brass fittings which used to last for many years in internal boiler service are rather a thing of the past, hence my alternative specification of stainless steel tube. Whichever material is used, square off to $4\frac{11}{16}$ in. overall, removing any burrs at the bore so as not to get a false fit over the end fittings, then mark off and drill the three rows of No. 48 holes, pitched approximately $\frac{1}{4}$ in. apart, and again deburr.
For the regulator valve seat, chuck a length of $\frac{5}{8}$ in. diameter bronze bar in the 3 jaw, face, centre and drill 9/32 in. diameter to $\frac{3}{8}$ in. point depth, following up with a $\frac{5}{16}$ x 32T tap. Scallop the end of the bar as shown, then part off at a full $\frac{5}{8}$ in. length. Chuck an odd end of $\frac{1}{2}$ in. rod in the 3 jaw, turn down for 7/32 in. length to $\frac{5}{16}$ in. diameter and screw 32T; fit the embryo valve seat. Face carefully, then turn down to a press fit in the tube over a $\frac{1}{4}$ in. length; centre, drill No. 47 to $\frac{1}{8}$ in. depth and tap 7BA. To complete, drill two No. 41 holes, spaced 180 deg. apart at $\frac{3}{8}$ in. centres, converging into the steam outlet hole as shown. A simple peg fits into the 7BA tapped hole, so chuck a length of $\frac{1}{8}$ in. stainless steel rod, face and turn down to 3/32 in. diameter over a 3/32 in. length and screw 7BA; part off to give a 3/32 in. head and screw into the seat.
The valve is best made from gunmetal rod, something a little softer than the seat, so chuck a length of $\frac{5}{8}$ in. diameter bar in the 3 jaw and turn down over a $\frac{1}{2}$ in. length to 17/32 in. diameter, an easy fit in the tube. Further reduce to $\frac{1}{4}$ in. diameter over a 7/32 in. length, transfer to the machine vice and use an end mill or slitting saw to cut the 3/32 in. slot to $\frac{3}{16}$ in. depth. Back to the 3 jaw to part off to leave a full 3/32 in. valve face, then reverse in the chuck and carefully finish the working face to thickness. Centre and drill No. 30 to $\frac{1}{8}$ in. point depth. following up with an $\frac{1}{8}$ in. 'D' bit to complete the valve. Mark off the ports and drill No. 48 initially, opening out to No. 41 and then with a Swiss file, elongate them into slots as shown. If you have a little fine grinding paste, apply this sparingly to the valve and grind it into the seat, washing off all excess paste with paraffin.
The two collars are $\frac{1}{8}$ in. thick and 17/32 in. diameter, being cross drilled at No. 53 for $\frac{1}{16}$ in. stainless steel retaining pins; one of the collars has to be scalloped later on to mate with the stop pin.
For the regulator flange, chuck a length of $1\frac{1}{4}$ in. diameter gunmetal or bronze bar and reduce to $1\frac{1}{8}$ in. diameter over a $1\frac{3}{8}$ in. length. Further reduce to $\frac{5}{8}$ in. diameter over a full $\frac{15}{16}$ in. length, then face off before turning the outer $\frac{3}{8}$ in. down to a press fit in the tube; part off at a full $1\frac{1}{4}$ in. Reverse in the chuck, face off to length, then turn down for $\frac{3}{16}$ in. length to $\frac{1}{2}$ in. diameter; use a knife edged tool to lightly scribe on the bolting circle. Centre and drill through at No. 22, follow up at 9/32 in. diameter to $\frac{7}{16}$ in. depth and tap the outer $\frac{1}{4}$ in. at $\frac{5}{16}$ x 32T. For the gland, chuck a length of $\frac{3}{8}$ in. brass rod, face and turn down to $\frac{5}{16}$ in. diameter over a $\frac{5}{16}$ in. length before screwing 32T. Centre and drill No. 22 to $\frac{7}{16}$ in. depth, then part off to leave a 3/32 in. flange. Although the slots may be milled, I would tackle them with a key cutting file, a job which only takes a few minutes.
The last piece to be machined is the regulator rod, starting from a squared $5\frac{7}{8}$ in. length of 5/32 in. stainless steel rod. The spigot to suit the valve is best dealt with by filing, so produce a flat on the end $\frac{3}{16}$ in. of rod, using a micrometer to check until the dimension reads .125 in.; file a second flat directly opposite and use the valve itself as your gauge; the fit does not want to be too tight as this could prevent the valve from seating properly. At the outer end, reduce to 3/32 in. diameter over an $\frac{1}{8}$ in. length and screw 7BA; the square is best produced to suit the regulator handle rather than the reverse, though do remember to orientate it so that the regulator handle is roughly in the position shown on Sheet 1 when closed; we will deal with said handle after assembly.
If you do not have a ready made spring for keeping the valve firmly on its face, wind one over a 5/32 in. mandrel from 22 s.w.g. bronze wire and trim off to around $1\frac{1}{8}$ in. free length.

Fit a collar over the regulator rod, slip on the spring, fit to the valve and bring up to its seat. Check that the loading on the valve is sufficient to hold it firmly, then cross drill from the collar through the spindle, from both sides, and press in a $\frac{1}{16}$ in. pin. Bring the valve seat spigot up to the tube, on the outside, slip the other collar over the outer end and position from the regulator flange, cross drill again. Before fitting the retaining pin, scallop the collar and fit the $\frac{1}{16}$ in. stop pin into the end of the flange, either tapping 10BA or pressing into a No. 53 plain holes; make sure the orientation of this scallop is correct to the valve positions. Now you can press in the two end fittings with the internals in place, to complete but for packing the rod gland.

### Regulator Handle

When refering the builder back to Sheet 1 for the correct orientation of the regulator handle, I surprised myself to see what I had drawn thereon differed a little from the detail as it appears on Sheet 4, which later was lifted directly from COUNTY CARLOW; my preference now is for that which appears on Sheet 1, so I will describe same; it only involves slight changes to the detail dimensions.

Chuck a length of $\frac{1}{4}$ in. x $\frac{1}{8}$ in. BMS or stainless steel flat truly in the 4 jaw, with about $\frac{5}{16}$ in. protruding and reduce this to $\frac{1}{8}$ in. diameter, a shade under if you have to until the flats disappear. Finish the ball end with files and emery cloth, then tackle another $\frac{5}{16}$ in. length to arrive at the finished handle to $\frac{5}{8}$ in. length. At 1 in. from this outer end, grip in the bench vice and produce the first bend, moving on about $\frac{3}{8}$ in. to produce the second, reverse, bend to arrive at about $\frac{3}{16}$ in. offset, this to allow ease of access to the blower and injector steam valves when the regulator is open. Now, at $1\frac{3}{4}$ in. from the end of the handle, as against $1\frac{1}{2}$ in. shown on the detail, drill through at No. 30 and either punch or file the $\frac{1}{8}$ in. square. Now you can offer this up to the regulator rod and file the square on this accordingly, to be a good fit. Saw and file to length, then grip in the bench vice between two pieces of $\frac{1}{4}$ in. square packing to file the flanks to a slight taper, as shown on Sheet 1, starting at $\frac{1}{8}$ in. from the handle itself and growing to 5/32 in. or 11/64 in. approaching the squared end. Do this by eye so that the end result pleases you, for it is well to the fore on the footplate. Fit the handle, offer the regulator up to the backhead, mark off and drill the No. 40 holes in the flange, continuing No. 47 into the bush and tapping 7BA; secure on final assembly with home made bronze screws.

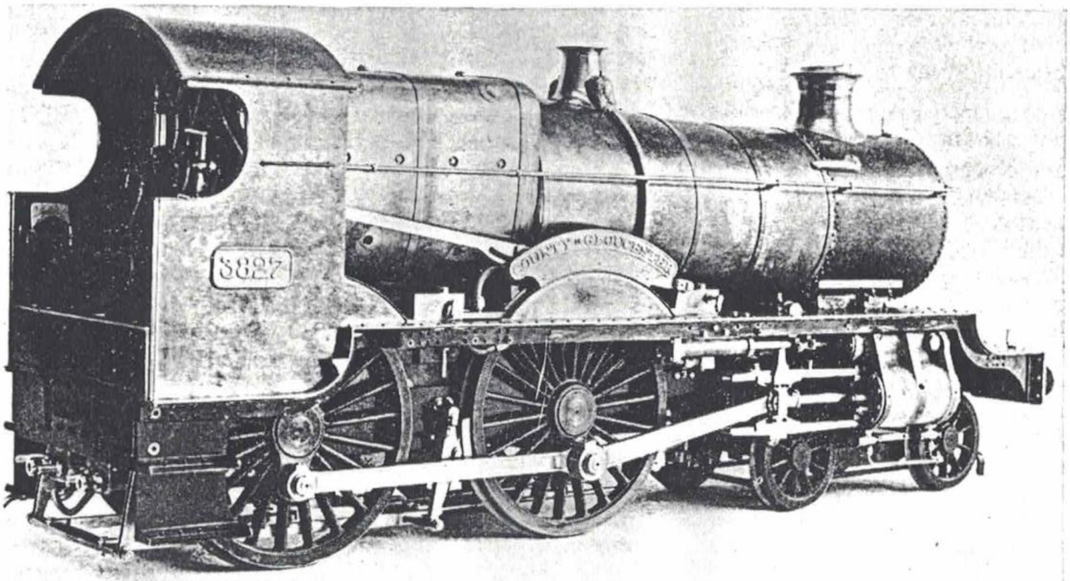
For the steampipe, take a length of $\frac{5}{16}$ in. o.d. x 18 s.w.g. copper tube, square off to 13 in. overall and screw each end for about $\frac{1}{2}$ in. length, then anneal about 6 in. towards one end. Screw this annealed end hard into the regulator, check its orientation and produce an $\frac{11}{16}$ in. set. Insert the whole assembly through the backhead and adjust the set until the steampipe emerges centrally through its bush. You can either apply liquid jointing compound to the flange joint on the backhead, or cut one from 1/64 in. thick CAF gasket material.

The steampipe flange is plain turning from 1 in. diameter bronze bar, as is the superheater flange. Mark off and drill the four No. 33 holes in the latter, then drill from the periphery into the bore at $\frac{1}{4}$ in. diameter for the superheater pipes to clear the No. 33 holes, spacing being roughly 90 deg. Screwing items with circular flanges into holes, I use a miniature pipe fitters gadget using a piece of wood and some string, but it is so difficult to describe, for all its simplicity, that I am going to adopt the coward's approach and suggest you file two small flats on the steampipe flange to accept a spanner. Apply liquid jointing compound to the threads, engage the steampipe, screw up to the bush and take care to get this thread entering correctly, then screw home. Offer up the superheater flange, spot through, drill No. 43 to $\frac{3}{16}$ in. depth and tap 6BA; again home made bronze screws will be used on final assembly, plus you can fit a 1/64 in. CAF gasket, remembering to punch out the central hole to allow steam to pass; I know its elementary, but yours would not be the first red face by a very long chalk!

### Superheater

One of the greatest advances in design since COUNTY CARLOW back in 1969 has been the changeover from double spearhead superheater elements to the coaxial pattern, a re-invention by Alec Farmer of A. J. Reeves & Co. Its advantage is in the ease of cleaning, so this really is a superheater, though against this the surface area exposed to the gases is considerably reduced, hence my option to extend into the firebox, The fact that blockage very rarely occurs when coal is lifted from the fire though, and even then can very readily be removed, means an overwhelming improvement.

Cut the outer sheaths from $\frac{7}{16}$ in. o.d. x 22 s.w.g. stainless steel tube to the length you wish, then drill a $\frac{1}{4}$ in. hole at $\frac{5}{16}$ in. from one end. For the other end, turn up an $\frac{1}{8}$ in. thick disc from stainless steel to fit the bore and weld this in for preference; your local garage should be able to do this for




Gazing at this picture I am reminded of the photographs published in 'Meccano Magazine' in the 1930's which first excited me as to the sheer magic of a 38xx 'County' you if you do not have the facility. A similar disc is wanted at the other end, drilled to suit the $\frac{1}{4}$ in. o.d. return pipe; this latter can be from copper as it is not exposed to the gases at the 'hot end'. Set the boiler in the frames, packing up from the trailing axle to be level, then bend the superheater pipes to match the unions already in the smokebox. Erect the whole superheater on your brazing hearth and silver solder all the joints, including the nipples at the ends of the pipes to the cylinders; pickle, clean and inspect. If you are worried about the return pipes not remaining concentric in the outer sheaths, wind a course spiral from 1.6mm soft copper wire, 2/3 in. long, and lightly silver solder this to the far end of the return pipe, when all will be well.

### Boiler Erection

We already have the boiler packed up level in the frames, so can easily fit the expansion brackets at this stage. Bend them up from $\frac{3}{4}$ in. x 2mm copper strip, locate to the outer wrapper, mark off and drill clearance holes in way of the firebox stays. Drill three No. 34 holes roughly as shown, spot through on to the outer wrapper, drill this No. 44 and tap 6BA. Turn up more bronze cheese head screws to complete, opening the die out a little so that the threads are fairly tight, then erect with some liquid jointing compound on said threads.

### Blow-down Valve

With any luck at all, just below the expansion brackets, the blow-down valve bushes should align with the holes for said valves in the frames, or I am in the mire! Chuck a length of $\frac{1}{2}$ in. bronze rod in the 3 jaw, face and turn down for $\frac{1}{4}$ in. length to $\frac{5}{16}$ in. diameter before screwing 32T; part off at $\frac{13}{16}$ in. overall. Chuck an odd end of $\frac{1}{2}$ in. rod in the 3 jaw, face, drill through at 9/32 in. diameter and tap $\frac{5}{16}$ x 32T; screw in the embryo body. Face off to length and fashion the outside to drawing, then centre, drill through at No. 24, following up with a 7/32 in. drill to $\frac{3}{8}$ in. depth and 'D' bit to form the valve seat. Tap to about $\frac{1}{4}$ in. depth at $\frac{1}{4}$ x 32T, then poke a 5/32 in. reamer through the remains of the No. 24 hole. Mill or file two flats on the $\frac{1}{2}$ in. flange to suit your spanner, then screw hard into the boiler; mark on the bottom centre line and drill No. 22 into the body for the escape pipe; silver solder this in place.

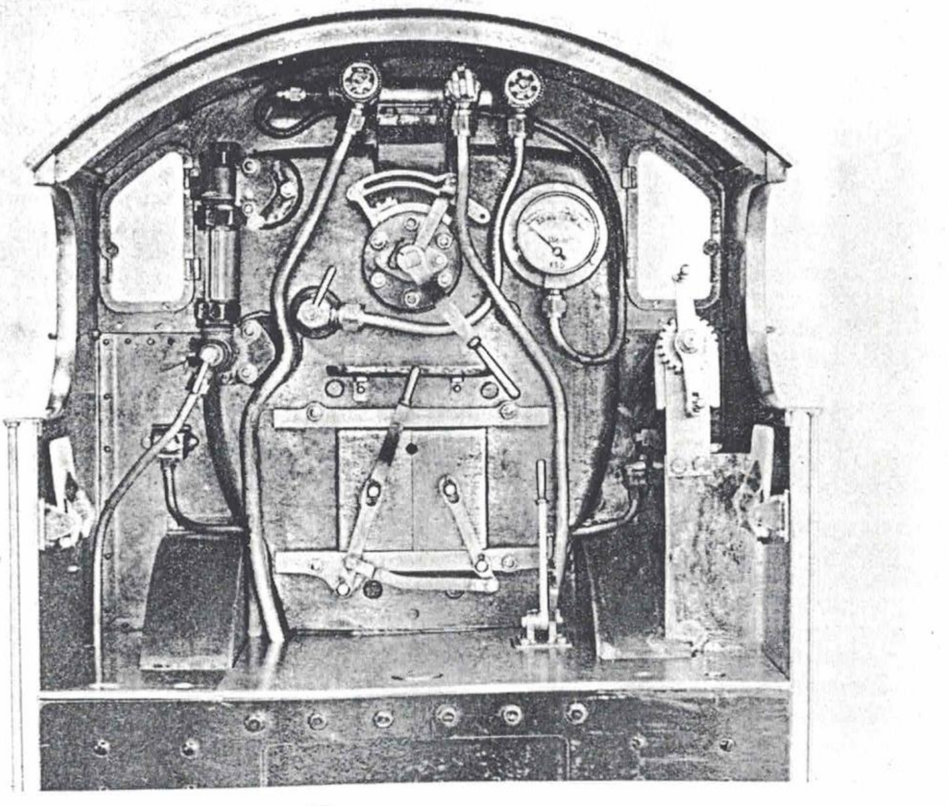
For the valve itself, chuck a length of $\frac{1}{4}$ in. stainless steel rod in the 3 jaw, turn down from $\frac{1}{4}$ in. length to a bare $\frac{3}{16}$ in. diameter, set the tool over and turn the end to roughly 90 deg. Screw the next 7/32 in. at 32T, then reduce a further 5/32 in. to 13/64 in. diameter before parting off. File a square on this outer end to suit a spanner that you will use in your running kit; 4mm A/F if you have gone metric, which in this instance is the same 5/32 in. as specified!

### Safety Valve

This again is one of our standard fittings, and looking at the price of a foot of $\frac{3}{4}$ in. diameter bronze bar, the requirement for the body, to be honest it is far more economic for builders to purchase the finished item, especially as the valve itself is a little tricky, plus ours are tested and proved at boiler working pressure. However, for those wishing to make their own valve, here is the modus operandi.

Chuck a length of the $\frac{3}{4}$ in. bar in the 3 jaw, face and turn down for $\frac{3}{8}$ in. length to $\frac{1}{2}$ in. diameter before screwing 32T; part off at a full $1\frac{3}{8}$ in. overall. Grip in the machine vice and mill two flats over a $\frac{3}{16}$ in. length to $\frac{5}{8}$ in. A/F. Next chuck an odd end of $\frac{3}{4}$ in. bar in the 3 jaw, face, centre, drill through at 29/64 in. diameter and tap $\frac{1}{2}$ x 32T; screw in the embryo body. Face off to length, then set the top slide over a full 5 deg. to turn the taper body, then centre and drill through at 9/32 in. diameter, reaming same if you are able. Follow up at $\frac{7}{16}$ in. diameter to $\frac{7}{8}$ in. depth, then 'D' bit to form the seat, before boring out to 29/64 in. diameter for $\frac{7}{16}$ in. depth and tapping $\frac{1}{2}$ x 32T.

For the valve, chuck a length of $\frac{5}{16}$ in. bronze rod, face and use a centre drill to produce the indent for the spindle. Move on $\frac{1}{8}$ in. and turn down for 5/32 in. length to $\frac{1}{4}$ in. diameter. Now set the top slide over 30 deg. and tackle the working face of the valve, using a round nosed tool of small radius so



Simple, neat and effective is this back-head, one that certainly meets my with approval. There is one concession to age in the size of pressure gauge and its position for ease of reading.

it slightly undercuts the $\frac{1}{4}$ in. spigot already produced. Before parting off, grip by the excess rod in the bench vice and carefully file on the three flats as the steam can escape freely, taking care not to damage the working face.
To grind in small valves, I take a short length of gauge glass rubber and first slide over a length of $\frac{3}{16}$ in. rod, with about $\frac{1}{8}$ in of the tube projecting. This I wet and then push on to the top of the valve, when it adheres; you just apply a weeny touch of grinding paste and twiddle the rod between your fingers to grind in the valve; wash off all excess grinding paste with paraffin.
The spindle is a $\frac{15}{16}$ in. length of 3/32 in. stainless steel rod, turned to a point at one end to engage the valve, with a 1/32 in. thick collar, about 5/32 in. diameter, silver soldered on immediately above the pointed end. For the top cap, chuck a length of $\frac{1}{2}$ in. bronze rod in the 3 jaw, face and screw 32T for $\frac{1}{4}$ in. length. Centre and drill through No. 41, an easy fit over the spindle, then part off a $\frac{3}{16}$ in. slice. File in the four steam escape slots; tidy up the threads with a Swiss file as I doubt if the die will pass over the slots O.K., then assemble with a 20 s.w.g. stainless steel spring and test hydraulically.

### Firehole Door

First cut two discs, $1\frac{1}{2}$ and $1\frac{1}{16}$ in. diameter respectively, from 1.6mm brass sheet and drill centrally at No. 41. On the large disc, drill three more holes at No. 41 on a $\frac{13}{16}$ in. p.c.d. to allow top air over the fire. The little spacer completes this part of the procedure, the baffle being inside the firehole and the three pieces held together with a 3/32 in. snap head copper rivet later on. Tackle the hinge block next, cutting the base to size, drilling a length of $\frac{3}{16}$ in. brass rod centrally at No. 41, sitting it on the base and silver soldering together; trim off any excess length of rod to match the base, then drill the No. 41 fixing holes.
Back to the door itself to deal with the hinges. I suggest you make a base $\frac{3}{4}$ in. x $\frac{1}{2}$ in. and silver solder on a $\frac{1}{2}$ in. length of $\frac{3}{16}$ in. pre-drilled rod as for the hinge block, then cut into two $\frac{3}{16}$ in. wide strips. The hinge pin is a 1 in. length of 3/32 in. stainless steel rod, the head being $\frac{1}{4}$ in. diameter and drilled No. 42; silver solder together and machine the head to drawing.
Assemble hinges and block with the hinge pin, offer up to the door, check against the backhead, then drill for and fit the hinges to the door with $\frac{1}{16}$ in. snap head copper rivets. Bend up the catch and rivet this in turn to the door, then secure the baffle in place. Offer the whole assembly up to the backhead, check that the door opens freely without the baffle fouling the firehole tube, then spot through the No. 41 holes in the block, drill the backhead No. 48 and tap 7BA, securing with home made bronze screws.
Bend up the catch spring from $\frac{1}{4}$ in. x .015 in. spring steel, or phosphor bronze strip, heavily centre punching for the two holes on a lead block, filing off the 'pip' and then drilling out to size. Hold against the backhead so that the spring just touches the catch at its outer limit, then spot through again, drill and tap the backhead 7BA and secure with another couple of bronze screws.
That covers all the boiler details shown, save for the blower union which is plain turning, so let us make a last visit to the chassis.

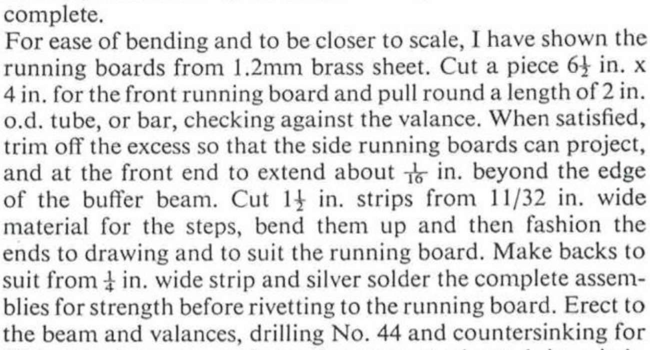
### Drain Cocks

I do not propose to describe manufacture of the drain cocks, they being one of our standard fittings, though the HUNSLET detail is relevant for those who wish to make their own. Also, for slide valve cylinders, there is no real point in taking the operating gear back to the cab, not in $3\frac{1}{2}$ in. gauge anyhow, for if you make opening the drain cocks your first job when lighting up and move the engine a few turns when in steam with the regulator cracked open, condensate will not then be a problem. The connecting link starts life as $2\frac{7}{16}$ in. lengths of 5/32 in. x 1.2mm brass strip, drilled No. 51 to suit the drain cock levers, ends then being fashioned and the centre portion filed down to 3/32 in. width, this latter being optional. I use $\frac{1}{16}$ in. snap head brass rivets as pins, cross drilling for a 1/32 in. split pin to complete; you can add a 10BA brass washer at each side to add to the effect.

### Valance and Running Boards

We will attend to the valance and running boards as the last job in this particular session, in fact we are almost ready for steam! All the dimensions shown are very much 'check to place', indeed it is a good plan to cut initially from stiff card and transfer from this to the actual material, this applies equally to the valances in this instance.
Starting at the front end, first silver solder a $1\frac{1}{2}$ in. x 1 in. piece of 1.6mm brass sheet to the valance edge, together with another piece $1\frac{1}{4}$ in. x $\frac{3}{8}$ in. as the front flange. Mark off and profile the end as shown, then bend up the $1\frac{1}{8}$ in. radius on the valance. In the annealed condition, this should work O.K., but if you have problems, cut away part of the top flange where there is any buckling. The rear end is much simpler, though I will have to assume for the moment that the steps have been made and attached to the drag beam. Screw the rear portion to the steps and the front portion to the front buffer beam, then fashion the centre portion of valance to fit between the two ends, noting the $\frac{3}{8}$ in. set towards the rear. Use odd ends of 1.6mm material to join the three sections securing with a few $\frac{1}{16}$ in. copper rivets, then silver solder to complete.
For ease of bending and to be closer to scale, I have shown the running boards from 1.2mm brass sheet. Cut a piece $6\frac{1}{2}$ in. x 4 in. for the front running board and pull round a length of 2 in. o.d. tube, or bar, checking against the valance. When satisfied, trim off the excess so that the side running boards can project, and at the front end to extend about $\frac{1}{16}$ in. beyond the edge of the buffer beam. Cut $1\frac{1}{2}$ in. strips from 11/32 in. wide material for the steps, bend them up and then fashion the ends to drawing and to suit the running board. Make backs to suit from $\frac{1}{4}$ in. wide strip and silver solder the complete assemblies for strength before rivetting to the running board. Erect to the beam and valances, drilling No. 44 and countersinking for 8BA raised countersunk head screws at about $\frac{1}{2}$ in. pitch, tapping the mating parts to suit.
The side running boards are approximately $22\frac{1}{8}$ in. long, $1\frac{13}{16}$ in. wide and again from 1.2mm brass. Transfer from your card template to the actual material and trim to size. Pass a length of $\frac{1}{4}$ in. x $\frac{1}{4}$ in. x $\frac{1}{16}$ in. brass angle right across at the joint with the front running board, screwing or rivetting to place, then complete back to the saddle with a $3\frac{1}{8}$ in. x $\frac{9}{16}$ in. piece of the 1.2mm brass. Complete this part of the proceedings by screwing the running boards to the valances.

Midland Railway Compound No. 1000 was a magnificent sight indeed at Bold Colliery



# Saint Christopher

by: DON YOUNG

## Part 5 – Locomotive Conclusion

A glance at Sheet 5 will show how close we are to completing SAINT CHRISTOPHER, indeed if the fittings are purchased from DYD then it is only a matter of days before steam can be raised, so let me hurry on with the necessary description.

### Grate and Ashpan

If any failing can be levelled at L.B.S.C. it was for his universal adoption of a combined grate/ashpan which could be dropped simply by pulling out a dumping pin. Oh, the facility to be able to drop the fire quickly in an emergency was both practical and laudible, but for a design like SAINT CHRISTOPHER it meant the ashpan profile was less than ideal behind the trailing coupled axle to provide the necessary clearance, leading to limitation on boiler steaming over a period. Also, to allow the ashpan to drop clear, brake gear sometimes required quite drastic revision, with a complete absence of a brake beam at the trailing coupled axle, though I must not throw too many stones as surely one will rebound! It was about 20 years ago that I first thought in terms of fixed ashpans, as full size, but with some trepidation, as for one thing I was going against the teachings of the late maestro. I worked out several schemes for pivotting grates, this to speed the dropping of the fire, each becoming more and more involved, with less chance of successful operation, for simplicity is the key. In the end, for my K1/1, I adopted a grate in three separate sections each of which would pass through the firehole, the centre section with ease and the wing sections with some difficulty, as the latter had to be lifted and moved sideways before they would come through the door. In practice, lifting out the centre section deposited 90% of the fire immediately into the ashpan, and with hopper doors open it dropped clear. One only had to rake the fire off the side sections and all was achieved, in very few seconds more than pulling out a dumping pin, less if the ashpan did not fall clear of its own accord and had to be wrestled free. This proved to me that fixed ashpans were entirely feasible and could incorporate the correct design features, the rearward extension for SAINT CHRISTOPHER being a notable example. It will also be seen that immediately the centre section of the grate is removed, and to do this you simply bend up a length of 10 s.w.g. wire so that it hooks under the rear spacer, at least 30% of the fire drops clear through the rear air entry; the rest can be quickly raked out through the air entry slot for the front part of the ashpan; quick and effective.

First mark out the sides of the ashpan on a sheet of $\frac{1}{16}$ in. (1.6mm) steel, cut and file to line, drill the grate support holes then clamp to the firebox extension. Cut the remaining pieces to fit, either bending up integral fixing flanges or using odd ends of $\frac{1}{4}$ in. x $\frac{1}{4}$ in. x $\frac{1}{16}$ in. brass angle for the same purpose; drill through and assemble with $\frac{1}{16}$ in. soft iron rivets. Ashpans come in for abuse, so silver solder the joints for additional strength. Offer up to the firebox once more, drill four or five No. 44 holes along each side of the ashpan, continue at No. 50 through the firebox extensions and tap 8BA for round head screws.

Take a 6 in. length of $\frac{1}{4}$ in. x $\frac{1}{8}$ in. section mild or stainless steel, the latter only becomes essential when burning anthracite, grip in the bench vice and hammer over to get the $1\frac{1}{4}$ in. set, checking inside the firebox and trimming away if necessary, Drill the $\frac{1}{8}$ in. holes as shown, then produce another four identical bars, though the outer ones do not require to be drilled. Chuck a length of $\frac{1}{4}$ in. steel rod, face, centre and drill No. 30 before parting off four 7/32 in. slices. Assemble the centre section either with a couple of 1 in. long snap head iron rivets, or use lengths of $\frac{1}{8}$ in. steel rod, and hammer over. The grate supports can either be bent up from $1\frac{1}{2}$ in. x $\frac{1}{8}$ in. black steel flat, or fabricated from three pieces. Profile to drawing, then cut the slots to accept the grate sections; the centre section must be nice and free for ease of removal, but I doubt if the outer bars will ever need to be taken out, except for occasional renewal. Assemble the grate supports inside the ashpan, erect with the outer grate bars in place, assess that the top of the bars is at least flush with the top of the foundation ring, then drill the grate supports from the ashpan and secure with 6BA bolts.

### Rear Running Board and Splashers

The rear running board is merely a much simpler edition of that at the front of SAINT CHRISTOPHER, but the splashers require a detailed description. I admit to having found a lot of difficulty in making them look neat initially when I marked out the sides and cut them from plate for my O2, so remade them as follows.

Scribe out two circles at about $5\frac{11}{16}$ in. diameter on 1.6mm brass sheet, cut them out and drill a $\frac{1}{2}$ in. hole through the centre of each. Chuck a $\frac{1}{2}$ in. nut in the 3 jaw and bolt the two discs to same, to turn down to $5\frac{5}{8}$ in. diameter; you need a sharp tool and good nerves for this! Now you can mark off into chords to drawing, saw them out, clamp together in pairs and file to line. The curves are now perfect, so all you have to do is take 6 in. lengths of 27/32 in. x 1.2mm section brass strip, 1 3/32 in. wide for the drivers, and bend them to suit the side pieces, in fact if you clamp the ends of the strip down on to a substantial section steel flat, say $1\frac{1}{4}$ in. x $\frac{1}{4}$ in, you can trap the side pieces in place and soft solder the joints without having to worry about tiny pieces of angle to hold them together. Trim off the excess at each end, mark off, drill, offer up to the running boards and drill through at No. 44 for 8BA screws.

### Cab Front and Sides

The cab front I suggest be made in two halves, with a doubler at the joint about $\frac{1}{4}$ in. wide and attached with six 10BA countersunk screws, nuts inside. But first we need the actual cab front, for which I suggest you cut card templates and then transfer to the metal. Mark out also for the spectacle, drill a couple of $\frac{3}{8}$ in. holes to remove most of the metal, then saw and file to line.

The cab sides too are relatively easy, the main point to be watched is that they match both the cab front and running boards, so there are no unsightly gaps. I would favour silver soldering the joint between cab side and front for the additional strength it provides, especially in way of the spectacle, but pieces of $\frac{1}{4}$ in. brass angle can be used in lieu. Fix both cab sides down to the rear running boards with short lengths of angle. For the comfort of both driver and fireman, we need some beading around the 'look-out', so take lengths of brass beading and bend to place, including an outward projecting piece at the bottom to accept the top of the handrail stanchion; you may have to anneal the beading locally to prevent it cracking. Sweat in place and we can move on to the job which I assumed was made a couple of sessions back, namely the reverser box.

### Reverser Box

The reverser of course controls the way the valve gear operates, and to do so successfully it must be positively anchored; it certainly is on SAINT CHRISTOPHER! As both the R.H. cab side and frame is now erected, I recommend you first drill the cab side as shown for the ten 8BA countersunk screws, attach the brass angles, bend up the inside plate to suit and secure to the frame, then cut the remaining plates to complete, attaching with short pieces of $\frac{1}{4}$ in. brass angle before silver soldering all the joints. Bolt again to the frame, set the reverser on top of its box, spot through, drill and tap the three 6BA holes and secure; now you can fit the R.H. cab side in place again.

### Cab Roof, Steps, Stanchions and Hand Rails

Anyone possessing bending rolls should simply cut a piece from 1.6mm brass size 8 in. x $3\frac{3}{16}$ in., roll to suit the cab front, trim off the excess length and sweat on the $\frac{1}{8}$ in. beading to the rear edge. Looking round for an alternative, I found my central heating boiler has an 8 in. flue and by reducing the thickness of material to 1.2mm, I found it easy to wrap a roof around the flue, using a 1 foot length of $3\frac{3}{16}$ in. wide material, to achieve the desired result; again trim off the ends and sweat on the beading. It will be sufficient to attach to the tabs on the cab sides, three or four 8BA countersunk screws each side, filling the slots in the screw heads with plastic metal or similar before painting. If Churchward did not provide very good cab protection for crews in full size, he made an excellent job for access in $3\frac{1}{2}$ in. gauge!

Measure from the underside of the beading to the running board for the cab stanchions, cut and square off two pieces of $\frac{3}{16}$ in. steel or nickel silver rod to length. Chuck in the 3 jaw and reduce for $\frac{1}{8}$ in. length to $\frac{1}{8}$ in. diameter, then centre, drill No. 54 to $\frac{1}{8}$ in. depth and tap 10BA; reverse and tap the bottom end, turning the collar to drawing. Reverse again and complete the upper collar, then with about $\frac{3}{4}$ in. projecting, take a file and with lathe running at top speed, start dealing with the tapered portion. Advance about $\frac{3}{4}$ in. at a time, then reverse to complete, judging the result by eye; attach with a couple of 10BA countersunk screws.

Bend up the cab handrails from $\frac{1}{16}$ in. nickel silver or stainless steel rod as shown, to suit the holes in the cab sides, then turn up $\frac{1}{8}$ in. collars which are 3/64 in. thick. Sweat these latter in place, building up a nice fillet of soft solder which you can then tidy up to drawing. Run a 10BA die down each spigot and secure to the cab sides.

The backs for the cab steps are cut from 1.6mm brass sheet and are quite straightforward, with no cut-outs as there were on COUNTY CARLOW. Bend up the steps themselves from 1.2mm brass and silver solder the corner joints for additional strength, then attach each to the backs with about four 3/64 in. countersink copper rivets. One of the rivets for the top step can also be used to attach that length of $\frac{1}{4}$ in. brass angle, then add a couple more and offer the whole up to the engine; spot through, drill and tap 8BA for countersunk screws and the cab structure is complete.

### Safety Valve Casing/Top Feed

We already have the banjo fittings, plus bushes in the boiler for top feed, so only have to make the banjo bolts to complete this part. Chuck a length of $\frac{3}{8}$ in. phosphor bronze rod in the 3 jaw, face and turn down for 39/64 in. length to 9/32 in. diameter, screwing the outer $\frac{5}{16}$ in. at 40T. With a round nose tool, further reduce to 7/32 in. diameter over a $\frac{3}{16}$ in. length as shown, so the feed water has free access around the banjo bolt. Centre and drill No. 30 to 35/64 in. depth, following up at No. 21 to about an $\frac{1}{8}$ in. depth. Part off at a full 25/32 in. overall, then reverse and clean up before reducing for 3/32 in. length to 9/32 in. diameter and completing the little flange. Mill or file the $\frac{3}{16}$ in. square to suit your spanner, then complete with the four No. 47 cross drilled holes, which should be fairly equally spaced to leave metal between same for strength. Silver solder in a $\frac{3}{4}$ in. length of 5/32 in. o.d. thin wall copper tube, assemble with the banjo to the boiler and tighten up, then mark the orientation on the banjo bolt so that you can remove it and bend the copper tube towards the boiler shell, clear of the escaping steam through the safety valve.

The safety valve casing, or bonnet, is quite difficult to hold for machining, but if you file the top face flat it can then just be held by the top flange in the 3 jaw, With a boring tool and taking very light cuts, bore out to drawing, trying to get the $\frac{3}{4}$ in. diameter a tight fit over a short length of bar. Any slack take up with paper, in fact the rice paper used for rolling one's own cigarettes was put to many other such uses by the old time craftsmen, then grip the stub of bar in the 3 jaw and turn down the outside as far as you are able, completing by gripping the bar in the bench vice and using files and emery cloth. Tap out the stub of bar, turn it down to a tight fit in the $\frac{11}{16}$ in. hole at the top, then grip again in the bench vice to scallop the underside to fit the boiler cleading. You will of course have to cut away at the sides to clear the banjos, give about 1/32 in. clearance, when we must attend to the top feed casings.

Remove the banjo fittings and take either a lump of hardwood or metal and fashion it to what a top feed casing should look like, your eye will be the best judge of this. Use this block as a former to flange up the actual casings from 0.7mm copper sheet. Although the casings should have wee tabs for fixing to the cleading with screws, I recommend you silver solder them directly to the safety valve casing, when the whole can be lifted clear at any time.

### Coupling Hooks

Just the coupling hooks before we climb back into the cab for the last time, and for these we require good quality steel to prevent any accidents, say $\frac{5}{8}$ in. x $\frac{3}{16}$ in. section. Mill down to obtain two pieces each $1\frac{1}{2}$ in. x 17/32 in. x 5/32 in., then mark off to drawing and drill a $\frac{1}{8}$ in. hole to form the eye of the hook; another $\frac{1}{4}$ in. further back at No. 44 which is then bell-mouthed. Saw metal away at the other end, then chuck in the 4 jaw, turn down for $\frac{1}{4}$ in. length to $\frac{1}{8}$ in. diameter and screw 5BA. The rest is sawing and filing, the specification being that they be pleasing to your eye in conclusion, and that they will accept the coupling on your driving trolley; the latter is what really matters.

### Boiler Fittings

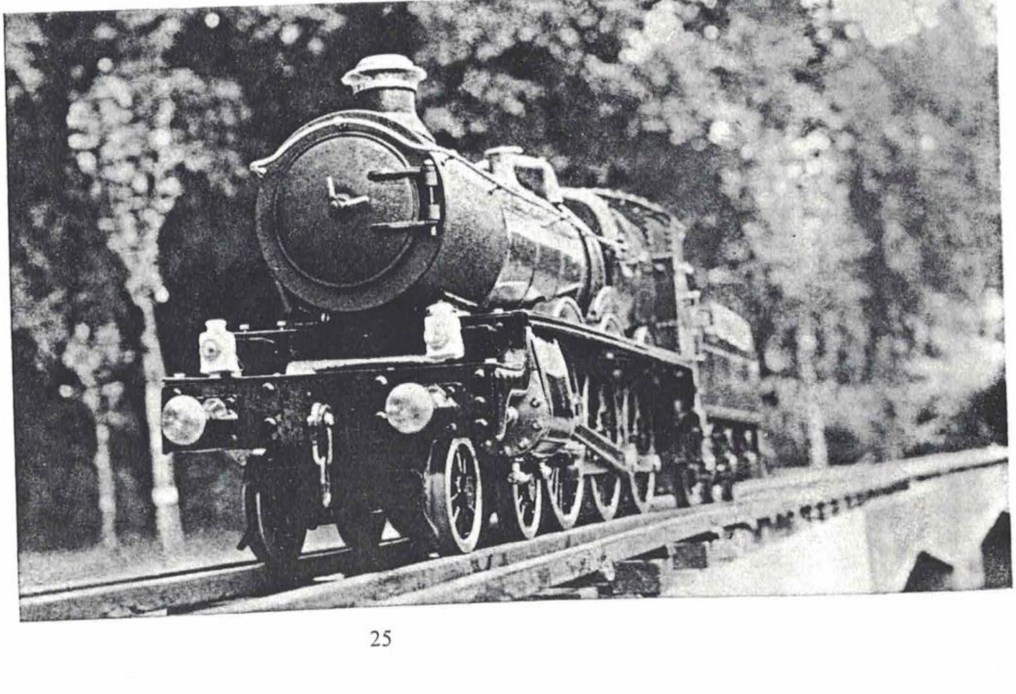
I have tended to dispense with description of boiler fittings in LLAS thus far, so for SAINT CHRISTOPHER there is ideal opportunity to redress the balance, cover some of your queries regarding injectors, and make a few points of my own.

### Injectors

All L.B.S.C. injectors that I can recall had a fabricated body from two or three pieces of brass. Stuck on top was a quite massive air valve chamber, an L.B.S.C. trademark, which had to be silver soldered to a square body and I soon identified this joint from bitter experience as being a source of trouble. For it required complete penetration of the spelter, particularly around the two passages, for the injector to be successful; the rest was hard enough without starting off with a failure. Thus did I develop a body which at the worse only had a

silver soldered water connection, but could also be machined from $\frac{3}{4}$ in. square bar completely from the solid; immediately this would more than double the success rate for the amateur.
I think all readers will agree that it would be wrong to disclose injector features which contribute to the success of the commercial product, to do so would put our livelihood at risk, but that depicted on Sheet 5 is still a considerable advance on anything published to my knowledge thus far, plus even I can make one from the details which works!; the difference lies in an injector that performs and one which can be guaranteed to do so. Let me describe manufacture of the injector as depicted as the next step.
Take a length of $\frac{3}{4}$ in. x $\frac{3}{8}$ in. brass bar and square off to $1\frac{1}{8}$ in. overall; this is an important dimension, so arrive at it with micrometer or vernier caliper. Next mark off to relieve the block for $\frac{3}{8}$ in. to $\frac{1}{8}$ in. depth at the top, $\frac{3}{8}$ in. depth at the bottom, then grip in the machine vice, on the vertical slide, and mill away this surplus metal. Turn up the water connection from $\frac{1}{4}$ in. brass rod, screwing the outside at 40T and preferably only for 5/32 in. length as against the full length shown, drilling centrally at No. 40 and then parting off to $\frac{3}{16}$ in. overall. Position to drawing, and remember for a pair of injectors that the water connection will be handed, clamp lightly in place and silver solder together; pickle, clean and inspect. Now chuck the embryo body carefully in the 4 jaw and turn away at the top to leave a $\frac{1}{4}$ in. diameter spigot to 5/32 in. depth; screw this at 40T.
Next chuck an odd end of $\frac{1}{2}$ in. brass rod in the 3 jaw, face, centre, drill through at 7/32 in. diameter and tap $\frac{1}{4}$ x 40T; screw the body into same. Turn the bottom end down to $\frac{1}{4}$ in. diameter for 5/32 in. length and screw 40T, then centre and drill through at No. 23, completing with a 5/32 in. reamer. Back to the machine vice and vertical slide to first deal with the ball chamber. Centre and drill No. 31 to a full $\frac{1}{2}$ in. depth, following up at 7/32 in. diameter to 7/32 in. depth and 'D' bitting to 9/32 in. depth. Tap the outer 5/32 in. at $\frac{1}{4}$ x 40T then use an $\frac{1}{8}$ in. reamer to tidy up the seat. Turn the body through 90 deg. and cross drill No. 30 at the two positions shown, right across into the ball chamber, tapping the first portion 5/32 x 40T. Continue at No. 40 from the water connection into the bore, poke the 5/32 in. reamer through again, then make up the little plug and 5/32 in. o.d. copper overflow pipe, fit these and run the reamer through yet again to check that all is clear.

Seat a 5/32 in. ball in the air chamber and measure down with vernier depth gauge to the top of said ball, then turn up the cap with screwed length 1/32 in. less than this, adding the extra specified 1/64 in. by an indentation with a centre drill. That virtually completes the body and we can move on to the cones.
Unlike our commercial pattern vertical injectors, steam enters at the bottom, with delivery of course out at the top, so the outlet portion of the combining cone is next to the delivery cone; the former has to be tackled first. Chuck a length of $\frac{3}{16}$ in. brass rod in the 3 jaw and turn down for $\frac{5}{16}$ in. length to .1565 in. diameter by micrometer. Face and with a round nose tool, scallop the end $\frac{1}{16}$ in. down to around 3/32 in. diameter. Now, lightly centre and then drill No. 72 to $\frac{1}{4}$ in. depth before starting to part off a $\frac{3}{16}$ in. slice. Before parting right off though, revert to the round nose tool and scallop this end for 3/64 in. length to around 3/32 in. diameter; part off. Choose a piece of 5/32 in. steel rod that is an easy fit in the reamed hole and square it off to .531 in. length, press this portion of the combining cone into the steam end of the body, bring up the rod and press home until said rod is flush with the end of the reamed hole. For the second portion of the combining cone, take the $\frac{3}{16}$ in. rod again and first turn down for 7/32 in. length to .1570 in. diameter, face and scallop the end for 3/64 in. length, then centre and drill No. 68 to $\frac{3}{16}$ in. depth; part off at $\frac{1}{8}$ in. overall. Take another piece of the 5/32 in. steel rod, square it off to .375 in. length and press in this portion of combining cone, when we need the cone reamers, yet to be made.
Chuck a $2\frac{1}{2}$ in. length of 5/32 in. silver steel rod in the 3 jaw, set the top slide over 4 deg. and turn on the $1\frac{1}{8}$ in. taper for the delivery cone. Next grip in the bench vice and carefully file half of the cone away, checking this with your micrometer as it is critical in making the difference between a reamer that cuts and one that just rubs. Place on a sheet of steel, heat the latter, wait until the cutting face of the reamer turns straw colour and quench, then lightly rub on a whetstone to hone the cutting edge. Take a second $2\frac{1}{2}$ in. length of the 5/32 in. silver steel rod, set the top slide over 6 deg. and produce the combining reamer, then reverse in the chuck and with a round nose tool, make this end the belling reamer; file away and temper.
Insert the combining reamer from the steam end, fit a tap wrench and gradually ream out until a No. 70 drill just enters



I have been saving this photograph by Cliff Howarth of his SAINT ANTHONY as being particularly impressive

at the far end of the second cone, then reverse to bring the belling reamer into play and open out the inlet end as shown.
For the steam cone, chuck a length of 6mm or ¼ in. brass rod in the 3 jaw and reduce to .210 in. diameter over a ½ in. length. Face and turn down for .406 in. length to .156 in. diameter, then gently scallop the end 7/32 in. down to .070 in. diameter right at the nose, checking with your micrometer again. Centre and drill No. 65 to 5/16 in. depth, following up at No. 64, then take the combining cone reamer and open out the end until the nose is virtually a knife edge, one that will cut your finger if you are careless! Part off to leave a 3/32 in. shoulder at .210 in. diameter, then reverse in the chuck, face lightly, centre and drill No. 36 to ¼ in. depth, then poke the No. 64 drill through again to remove any burrs. Push the steam cone into the body and blow into the water connection, when you should feel a very definite resistance, this due to the restricted annulus between steam and draft cones.
For the delivery cone, chuck the ¼ in. rod again and turn down to .210 in. diameter for ½ in. length; face and reduce for .375 in. length to .156 in. diameter, then scallop the last ⅛ in. down to .090 in. diameter at the nose. Centre and drill No. 77 to 7/16 in. depth, then use the belling tool to bell-mouth the end virtually out to the .090 in. diameter. Part off to leave a 3/32 in. flange, reverse in the chuck, face and then feed in the delivery reamer until a No. 75 drill will just pass at the throat; bell the outlet end to complete and push into the body. If all the holes through the cones are now perfectly concentric, and you can very easily check this by holding up to the light, then your injector will deliver.
For the steam elbow, turn up the body from ⅜ in. brass rod, screw hard on to the injector body with the cone in place, mark off for the correct orientation of inlet connection, turn this up, assemble and silver solder to the body.
For our commercial injectors, delivery check valves on the outlet are very definitely not recommended, as the only reason they were ever necessary was as additional insurance that hot water escaping from the boiler check valve would never get back to the injector itself and cause it to fail; our injectors will start perfectly when hot. Chuck the ⅜ in. brass rod again and turn down for ¾ in. length to 11/32 in. diameter, then face and drill No. 31 to ¾ in. depth. Follow up at 7/32 in. diameter to 5/32 in. depth, 'D' bit to 7/32 in. depth and tap ¼ x 40T before parting off at a full 11/16 in. overall. Screw hard on to the injector outlet to orientate the delivery connection, turn this up, drill the body to suit and silver solder together; pickle, clean and inspect. Rechuck in the 3 jaw, face, drill down to 9/32 in. depth at 7/32 in. diameter and 'D' bit to 11/32 in. depth. Tap the outer 5/32 in. or so at ¼ x 40T then poke an ⅛ in. reamer through the remains of the No. 31 hole. Seat a 5/32 in. ball, measure the depth to the top of same, then chuck a length of 5/16 in. A/F brass bar and turn down to ¼ in. diameter for a dimension 3/64 in. less than this. Finish the end as shown, then screw 40T before parting off to leave an ⅛ in. head.

### Boiler Check Valves and Snifter

For the in-line check valves, chuck a length of ⅜ in. bronze rod, for we must be more careful in our choice of material here, it being the first line of defence for the boiler itself, and turn down to 11/32 in. diameter over a 1 in. length. Further reduce to ¼ in. diameter for 7/32 in. length after facing across and screw 40T, then centre deeply to form the seat for the pipe nipple and drill No. 30 for 1 in. depth; part off at a full ⅞ in. overall. Reverse in the chuck, face off to length, drill 7/32 in. diameter to ½ in. depth and tap the outer 3/16 in. at ¼ x 40T. Cross drill 13/32 in. from this end at No. 53 and press in a 1/16 in. stainless steel pin to prevent the ball from lifting too far and blocking the outlet; silver solder the ends of the pin if you wish.
For the valve seat, chuck a length of 5/16 in. A/F bronze bar, face and turn down for 7/32 in. length to ¼ in. diameter before screwing 40T. Centre deeply and then part off to around ½ in. overall. Chuck an odd end of ⅜ in. rod, face, centre, drill 7/32 in. diameter and tap ¼ x 40T; screw in the valve seat. Face off to length, turn down for 5/32 in. length to ¼ in. diameter and screw 40T, then centre, drill through at No. 31 and ream at ⅛ in. diameter to complete.
The snifter is so similar to the in-line check valve that no additional description is required on my part.

### Injector Steam Valve

Only the steam valve is required to complete our injector system, so chuck a length of ⅜ in. bronze rod in the 3 jaw, face and turn down over a ¼ in. length to ¼ in. diameter, screwing 40T. Centre and drill No. 30 to 3/16 in. depth, then part off at a full ¾ in. overall. Screw the body hard into the backhead and mark on the position of the steam outlet position. Chuck a length of 6mm or ¼ in. brass rod and reduce to 7/32 in. diameter over a ¼ in. length, screwing the first 5/32 in. at 40T. Centre deeply and drill No. 30 to 5/16 in. depth, then begin parting off a 3/16 in. slice, but stop at about 11/64 in. diameter, move on another 1/16 in. or so and part right off. Measure the diameter of the spigot by micrometer, choose a number drill to be a press fit, then drill the body, press in the outlet connection, fit a 1 in. length of ⅛ in. o.d. thin wall copper tube at the inlet, silver solder, pickle, clean and inspect.
We already have a ¼ x 40T chucking adaptor from making the injector; use this to hold the injector steam valve body. Face and lightly radius the end as shown, this for appearance, then centre and drill through at No. 43. Follow up at 7/32 in. diameter to ¼ in. depth and 'D' bit to 5/16 in. depth, then tap the outer 3/16 in. or so at ¼ x 40T. If you have a 3/32 in. reamer, use this to clean up the remains of the No. 43 hole. otherwise use a No. 41 drill for the same purpose. Drill No. 30 from the outlet connection into the bore of the valve body and make up a union nut and nipple to suit, then set the inlet pipe 180 deg. away from the outlet connection, as much as you can without fouling anything inside the boiler.
For the valve stem, chuck a length of 9/32 in. A/F bronze bar in the 3 jaw, face and turn down for 3/16 in. length to ¼ in. diameter before screwing 40T; part off a full ½ in. length and fit to the screwed adaptor we used for the body. Face off to length, then turn down to 7/32 in. diameter with a round nose tool to leave a 3/32 in. length of hexagon; screw 40T. Centre and drill through at No. 30, following up first at No. 22 for 5/16 in. depth and then with a 5/32 x 32T tap to complete. The gland nut is identical to the union nuts we shall be using in some profusion, so on to the valve spindle.
Chuck a length of 5/32 in. stainless steel rod, face and turn down to .120 in. diameter over an ⅛ in. length. Set the tool over at 45 deg. and turn the actual valve as shown, pulling round by hand if there is any evidence of tool chatter. With a tailstock dieholder, screw the next ⅜ in. length at 32T, then part off at around 1 3/16 in. overall. For the handwheel, chuck a length of ½ in. brass rod, face and turn down to 7/16 in. diameter over a ¼ in. length and start parting off a 3/32 in. slice. Radius the outside with files, dish the intermediate portion if you wish with a round nose tool to leave a rim and centre boss, then centre and drill No. 32 to ¼ in. depth; part off. Use a Swiss file to produce a square in the centre of the handwheel then deal with the spindle to suit; push the handwheel on and peen over the end of the spindle. For the little bar projection from the handwheel, either drill into the rim at No. 55 and tap 10BA, or simply drill No. 53 and press in the 1/16 in. pin. Actually in full size the injector 'handwheel' was identical in form to that shown for the blower, which is simply a ¼ in. brass collar cross drilled with the spindle at No. 53 and the

pin pressed through, in fact this is the only description I propose for the blower valve, as it is just a simplified edition of the injector steam valve, indeed can be of identical construction if you so wish.

### Injector Installation

That completes all the components required for injector installation on the engine, so apply a little liquid jointing compound to the threads on the injector steam valve and screw into the backhead. I recommend the injectors be sited hard against the inside faces of the frames, with the $\frac{1}{8}$ in. o.d. thin wall copper tube for the steam pipes dropping vertically and then sweeping aft in a gentle curve to pick up the injector steam elbows; with our commercial pattern injectors with steam entry at the top the pipes are virtually straight. The water connection is a plain length of pipe, which must be 5/32 in. o.d. thin wall for the injector described, though sized to suit the nipples provided on our commercial injectors. The delivery pipes go forward between the frames, clear of the ashpan, and turn upwards just ahead of the driving axle, again in a gentle curve, where the in-line check valves are fitted, continuing upwards to the banjo fittings on the boiler top.

One item not described for SAINT CHRISTOPHER, to complete the injector installation on the tender, is the water cocks; builders wishing to make their own should refer to GLEN; now for the important part. All the components described are also suitable for use with our commercial pattern injectors, so provided you achieve air-tightness in the suction line, particularly at the water cocks and flexible connections between engine and tender, then the chances of success are 99.999%. Experience has shown though that there are commercial fittings available which (a) have inadequate bore at the injector steam valve (b) have glands on injector screw-down pattern water valves through which air can be drawn, and (c) balls in boiler check valves which partially block the outlet passage when they lift, faults for which our injectors get the blame. Therefore and only for the above reasons, we can now only guarantee our Injectors if, 1. you have made the ancillary fittings to my drawing details, or 2. have purchased same from DYD; I trust this is understood. Of course this statement does not imply blanket disapproval of all other commercial fittings than those of our manufacture, for it is realised that readers will have received good service over the years from other suppliers, and will continue to do so; I have no wish to interfere in this.

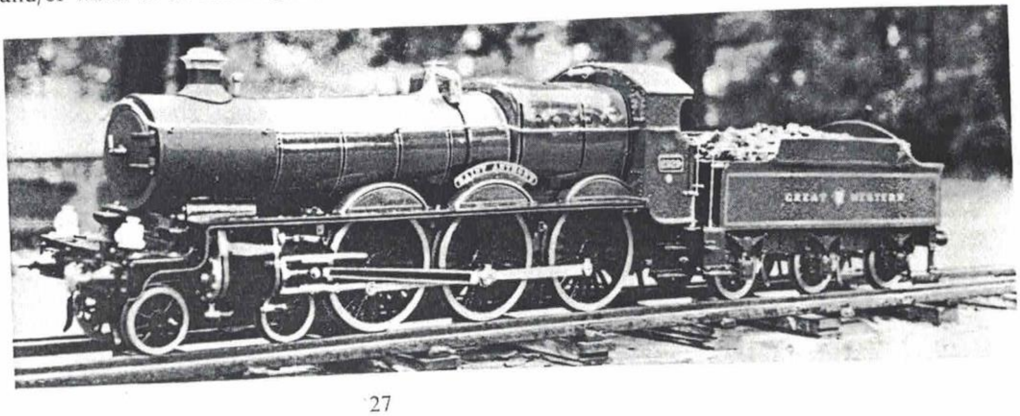
Let us now look at the way faults manifest themselves at the injector, stressing first though that in most cases they are utterly reliable and work perfectly at every time of asking. With a restricted steam supply it is usual for the injector to perform satisfactorily at the top end of the range, but with falling steam pressure the injector will 'knock-off' rather than respond to control of the water supply by the cock/valve. Air ingress in the water suction line is by far the most common fault and will cause steam and/or water to be discharged at the overflow. The check is the one recommended by Reg Booth of squirting water over all the joints, this to provide a temporary seal, when the injector will 'pick-up' whilst the seal holds. A faulty check valve usually manifests itself in that at low pressure the injector will feed fairly 'dry', but as steam pressure increases then the overflow becomes increasingly 'wet', exactly the opposite to the normal characteristic.

In normal service, as scale forms on the cones, the injector will lose the top end of its range, when it should be cleaned by immersion in a weak acid solution such as vinegar, though feed water can contain a variety of impurities depending on locality, ones that will react differently to acid cleaning fluids, so experience teaches which is best for the purpose. Injectors will also react to some forms of feed water treatment, with large build-up of sludge at the cones; again experience teaches. I will conclude with one example where feed water was taken from a water-softening plant last summer, this for a commercial operation. Early in the season no problems were experienced, but as traffic built up and boiler steam production increased to match, so in the afternoons did the injector begin to knock-off. Now the water-softening plant produces unharmful salts as far as scale deposits on boiler plates are concerned, but what is not often realised is that although said salts pass into the boiler with the feed water, they do not boil off with the steam, but simply stay in the boiler and increase in concentration. Soft water does have a tendency to prime and the concentration of salts can increase said tendency, water then being carried over with the steam into the injector steam pipe, causing the injector to fail. My recommendation was for a partial blow-down of the boiler each afternoon, to reduce the concentration of salts, which had an immediate and satisfactory effect, a perfect example of 'cause and effect' where so easily the injector itself could have been blamed.

### Tender Hand Pump and Check Valve

One item that should get very little usage on SAINT CHRISTOPHER is the tender hand pump, though at least it will come in handy for the boiler hydraulic test.

Take the body casting and clean up the edge of the end flange with files, rubbing over the face, then mark on the centre of the bore. Chuck truly in the 4 jaw, face across, centre, drill through and ream to $\frac{1}{2}$ in. diameter; reverse in the chuck and face off to $1\frac{9}{16}$ in. overall. Fit an angle plate to the vertical slide and use a $\frac{5}{16}$ in. bolt down through the bore of the body to secure to said angle plate; turn the bottom of the casting towards the chuck. Grip a $\frac{3}{8}$ in. end mill in the 3 jaw and mill the foot to drawing, then deal with the inlet valve facing in like manner. Centre and drill No. 30 into the bore, following up at 7/32 in. diameter to $\frac{5}{16}$ in. depth and 'D' bitting to $\frac{3}{8}$ in. depth; tap $\frac{1}{4}$ x 40T. So that the inlet, ball, valve does not restrict flow when it lifts, use a 3/32 in. square file to elongate the $\frac{1}{8}$ in. hole towards the end of the bore, as shown. Turn the body through 180 deg., mill the facing for the outlet connection, then centre and drill No. 31 into the bore. Again follow



At this point I must thank Cliff Howarth for giving us so much pleasure with his fine photographs. He is by no means the only builder of my SAINT CHRISTOPHER design, but thus far all other photographs received have proved unsuitable for publication.

up at 7/32 in. and 'D' bit to $\frac{3}{8}$ in. depth, tapping $\frac{1}{4}$ x 40T, but this time be careful not to destroy the outlet, ball, valve seat; complete by putting an $\frac{1}{8}$ in. reamer through the remains of the No. 31 hole. To gain the full stroke of the pump, file an $\frac{1}{8}$ in. slot from the end of the bore to the outlet hole, again as shown. To complete the body, mill the two side flanks of the outlet boss and drill a No. 42 hole through for the link pin.

For the inlet valve seat, chuck a length of $\frac{5}{16}$ in. A/F brass or bronze hexagon bar, face and turn down for $\frac{3}{16}$ in. length to $\frac{1}{4}$ in. diameter; screw 40T. Centre and drill No. 31 to $\frac{3}{8}$ in. depth and ream at $\frac{1}{8}$ in. diameter before parting off at a full 9/32 in. overall; fit to the screwed adaptor and face off to complete. Chuck the bar again for the delivery connection, face, turn down for $\frac{1}{8}$ in. length to $\frac{1}{4}$ in. diameter and screw 40T; part off at a full $\frac{1}{2}$ in. overall. Fit to the screwed adaptor, face and turn down for $\frac{1}{4}$ in. length to $\frac{1}{4}$ in. diameter and screw 40T, then centre deeply and drill through at No. 30. Again we have to make provision so that the ball does not restrict flow when it lifts, so either file a cross at the bottom, or use a square file to make 'nicks' around the entrance to the No. 30 hole; assemble the pieces made thus far.

The end cover is cut from 13 s.w.g. (2.5mm) brass sheet to suit the casting; mark off and drill No. 34 in six positions, offer up to the body, spot through drill and tap 6BA, fitting a 1/32 in. thick gasket and securing with brass screws.

Select a piece of $\frac{1}{2}$ in. stainless steel rod for the ram and square off to $1\frac{13}{16}$ in. overall, then cross drill No. 43 for the lever pin. The lever itself is from $\frac{1}{4}$ in. x $\frac{1}{8}$ in. brass flat, so mill a slot to $\frac{7}{16}$ in. depth in the end of the ram to accept this, or use saw and files; press in a 3/32 in. stainless steel pin to secure same. Only the links to complete, from $\frac{3}{16}$ in. x 3/32 in. brass flat and drilled No. 41 at $1\frac{3}{4}$ in. centres; radius the ends of said links. You can either use 3/32 in. stainless steel rod or snap head brass rivets to complete the assembly, rivetting over to trap the links in place.

Eleven years on I can now confess that of all the parts I ever describe, that for the tender hand pump will remain most indelibly inscribed in my mind. During 1972 I became totally disenchanted with electronics, it was not my scene, and had gained such satisfaction in watching Arthur Grimmett making his range of fittings that an ambition grew in my mind to join him. It became clear that I would have to concentrate on particular fittings which I could handle mainly in my own workshop, and that at the outset I would also require some other part time employment to guarantee a portion of my income. For fittings, I chose first my design of tender hand pump and proved to myself it was a viable product; the die was cast, or so I thought. That week an advertisement appeared in the local press for a part time draughtsman in the marine industry, just up my street, so of course I applied. I went to the interview as a budding part time draughtsman and came away with the full time plus post of engineering manager; end of fittings dream!

For the delivery check valve on the boiler, chuck a length of $\frac{5}{16}$ in. bronze rod, face, centre deeply then turn down for 7/32 in. length to 7/32 in. (or $\frac{1}{4}$ in.) diameter and screw 40T; part off at a full $\frac{11}{16}$ in. overall. Screw into an adaptor, face off to length, centre and drill through at No. 31. Follow up at 7/32 in. diameter and 'D' bit to $\frac{3}{8}$ in. depth, then poke an $\frac{1}{8}$ in. reamer through the remains of the No. 31 hole before tapping $\frac{1}{4}$ x 40T to $\frac{3}{16}$ in. depth.

For the outlet stem, chuck a length of $\frac{3}{8}$ in. bronze rod, face and turn down to $\frac{1}{4}$ in. diameter for $\frac{3}{16}$ in. length before screwing 40T. Centre and drill No. 30 to $\frac{5}{8}$ in. depth, following up at No. 21 to 3/32 in. depth; this latter is optional being a standard feature when a length of 5/32 in. o.d. pipe is then fitted internally. Part off at $\frac{1}{2}$ in. overall, chuck in a screwed adaptor and then turn down to $\frac{1}{4}$ in. diameter with a round nose tool to leave a 5/64 in. thick flange at $\frac{3}{8}$ in. diameter. Face off to 15/32 in. overall and then reduce the end 3/64 in. to around $\frac{3}{16}$ in. diameter. Check the actual size by micrometer and drill the body to suit, press in the outlet stem, silver solder together; pickle, clean and inspect.

Chuck the $\frac{5}{16}$ in. rod again, face, turn down to $\frac{1}{4}$ in. diameter for $\frac{3}{16}$ in. length, screw 40T then turn on the wee pip as ball lift restrictor. Part off at $\frac{3}{8}$ in. overall, chuck in the adaptor, face and turn down to $\frac{1}{4}$ in. diameter to leave a 3/64 in. flange; file on a $\frac{3}{16}$ in. square to complete. Poke the $\frac{1}{8}$ in. reamer through again and tap out if the silver solder has run into the threads, then seat a 5/32 in. rustless steel ball with a short length of brass rod, fit the cap and erect to the boiler.

### Water Gauge

This is argueably the most important component on the whole Locomotive and care should be taken to preserve the $\frac{1}{8}$ in. diameter 'clearway' right through same, in fact this is mandatory in Australia.

For the top fitting, chuck the $\frac{5}{16}$ in. bronze rod, centre and drill No. 10 to $\frac{11}{16}$ in. depth, then tap the outer $\frac{3}{16}$ in. at 7/32 x 40T. Part off at a full $\frac{9}{16}$ in., reverse and face before screwing 40T, though if you have 9/32 x 40T screwing tackle, reduce for $\frac{3}{16}$ in. length first, as this way you can use a much neater gauge glass nut from .324 in A/F hexagon.

The boiler stem is so similar to that we have just made for the check valve that I can dispense with description, plus the wee boss so we can check the steam passage is clear is also straightforward; drill the top fitting to accept same and silver solder together. The top again mirrors that plug for the check valve and the other simply a smaller edition, so we can move down to the bottom fitting.

Chuck the $\frac{3}{8}$ in. rod, face and turn down to $\frac{1}{4}$ in. diameter over a $\frac{1}{4}$ in. length and screw 40T; part off at a full $1\frac{1}{4}$ in. Chuck in the screwed adaptor, it is earning its keep!, face off to length then turn down to $\frac{5}{16}$ in. diameter with a round nose tool to leave a 3/32 in. flange. Centre and drill through at No. 31, then follow up at $\frac{3}{16}$ in. diameter and 'D' bit to $\frac{7}{16}$ in. depth before tapping the outer $\frac{3}{16}$ in. or so at 7/32 x 40T. We know how to make the little screwed connections by now, so screw the bottom fitting hard into the backhead, mark off and drill so that the gauge glass gland and drain connection are both press fits therein. Silver solder together, pickle, clean and inspect, then back to the screwed adaptor to clean up the drain valve seat with the 'D' bit and then run an $\frac{1}{8}$ in. reamer through.

The drain valve itself was my first attempt at what I call 'captive spindle', so that the valve can never be completely unscrewed from the fitting, which would be a disaster. Although some of my valves are somewhat more sophisicated now, like those which will appear for E. S. COX, the original idea is still sound, so let us manufacture same. Chuck a length of 5/32 in. stainless steel rod and reduce in about $\frac{1}{4}$ in. increments for a total length of $\frac{11}{16}$ in. to $\frac{1}{8}$ in. diameter; use the tailstock die-holder to screw 5BA. Leave 5/64 in. of the 5/32 in. rod, then try to form the actual valve at about 45 deg. as you part off; the finish will probably be rough, but if you chuck lightly over the 5BA threads then you will be able to tidy up the valve to complete.

For the stem, chuck a length of $\frac{1}{4}$ in. A/F hexagon bronze rod, face and turn down for $\frac{3}{16}$ in. length to 7/32 in. diameter and screw 40T. Centre and drill No. 40 to $\frac{7}{16}$ in. depth and tap 5BA, then part off at $\frac{5}{16}$ in. overall, reverse in the chuck and tidy up the end, running the 5BA tap through again. Assemble to the valve, turn up the little brass collar from $\frac{1}{4}$ in. rod, screwing 5BA to suit the spindle, then cross drill right through at No. 53 and press in a length of $\frac{1}{16}$ in. rod.

To cut gauge glass, take a small 3-corner file and lightly scratch around the periphery, when you will be able to snap off a piece fairly cleanly, though if there are any rough edges, grind them off, always remembering to wear goggles. For the seals, wet a piece of 5/32 in. bore rubber tube and push over a length of $\frac{3}{16}$ in. steel rod. Grip the latter in the 3 jaw, run at top speed, dip an old razor blade in soapy water and cut into $\frac{1}{16}$ in. rings. When fitting gauge glasses, only tighten the nuts with your fingers, never with a spanner, and if you get a fountain at the first light-up, most likely it will self-heal as boiler pressure increases and never give another moment's bother.

### Turret

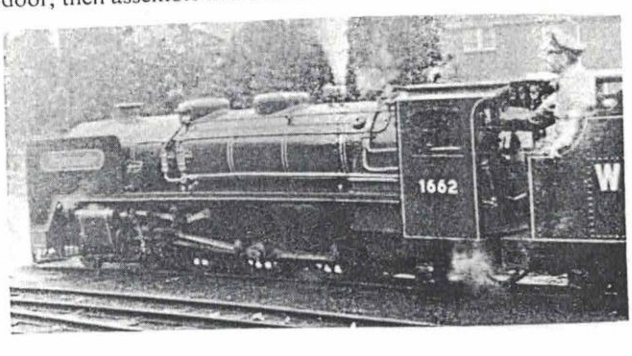
Making the stem and union connections is a repetition of what has gone before, so let me concentrate on the body. Chuck a length of $\frac{5}{16}$ in. bronze rod, face, centre and drill No. 41 to 1$\frac{5}{16}$ in. depth. Follow up at $\frac{3}{16}$ in. diameter and 'D' bit to $\frac{3}{4}$ in. depth, tap the outer $\frac{3}{16}$ in. at 7/32 x 40T and part off at a full 1 7/32 in. Reverse and clean up to length then drill No. 11 to $\frac{3}{8}$ in. depth and again tap the outer $\frac{3}{16}$ in. at 7/32 x 40T. Now it is a question of fitting the stem and union connectors, the orientation of that for the whistle being as Sheet 1, when you can silver solder together. Seat the rustless ball, fit a 22 s.w.g. bronze spring to hold it in position, then turn up the retaining cap from $\frac{5}{16}$ in. A/F hexagon bar.
The end fitting for the whistle lever is from $\frac{3}{8}$ in. square bar, which can be brass as it only occasionally comes into contact with steam. Chuck truly in the 4 jaw and turn down for $\frac{3}{16}$ in. length to 7/32 in. diameter, screwing 40T. Centre and drill No. 50 for $\frac{1}{2}$ in. depth, then part off at $\frac{7}{16}$ in. overall. Screw hard into the body and select the orientation for the whistle lever, then saw and file a 3/32 in. slot to accept same, but do cross drill at No. 52 for the lever fulcrum first. Now it is simply a question of filing or milling away the excess metal to arrive at the dimensions shown. The lever itself is best filed to the shape shown, held in place and drilled No. 52 from the block. Cut a push rod from $\frac{1}{16}$ in. stainless steel rod to lift the ball, but in the 'off' position there should be .005/100 in. clearance from the lever; too little and you could get an embarrassing leakage of steam to the whistle. Complete with a $\frac{1}{16}$ in. pin to keep the lever in place, which can be a snap head brass rivet, then erect.

### Whistle

The whistle is next and our commercial ones have gained such a reputation that I doubt if many builders will follow these notes!
I suggest you start with a finished 4 in. length of $\frac{1}{2}$ in. brass tube, as the kicking-off point for your testing and tuning, though this lies a little way ahead yet. Mark off the opening, saw it out roughly and file to line, then chuck a length of $\frac{1}{2}$ in. brass rod in the 3 jaw and turn down for $\frac{3}{16}$ in. length to a push fit in the tube; part off an $\frac{1}{8}$ in. slice. Now file almost half way round the periphery, to match the opening, to remove 1/64 – 1/32 in. of metal. Turn up the blanking end cap from the $\frac{1}{2}$ in. rod to the same push fit, or use another $\frac{1}{8}$ in. disc, then push the proper disc to be flush with the opening and blow through the open end; this will give you a clear note, though what it will be I cannot say! Now it is simply a case of adjusting the length of tube until you arrive at a note which pleases you. The inlet fitting is again straightforward, when you can soft solder all the pieces together, using Bakers fluid as flux, but remember to apply a very minimum of spelter to the disc, via the opening, otherwise it will flash round and fill up the wee gap.

### Steam Brake Valve

So we come to the last fitting, the steam brake valve, for which first make three union connectors with $\frac{1}{16}$ in. long spigots between 5/32 in. and 11/64 in. diameter, this to avoid a break in proceedings as we tackle the body.
For the latter, chuck a length of $\frac{7}{8}$ in. diameter bronze bar, face off to get a decent surface for the valve to sit on, then centre, drill No. 31 to $\frac{1}{2}$ in. depth and ream at $\frac{1}{8}$ in. diameter. At a full $\frac{1}{4}$ in. from the outer end, start parting off, reducing to about $\frac{3}{8}$ in. diameter over a $\frac{3}{16}$ in. length for the spring housing, then part right off at a full 13/32 in. Reverse in the chuck and clean up to drawing, then drill back at $\frac{3}{16}$ in. diameter and 'D' bit to 5/32 in. depth. Actually this depth is to suit a home made bronze compression spring, but a better solution is to use a double coil bronze spring washer, only I haven't run into one for years. So if any reader can provide information as to current availability, I for one would be very grateful. Lightly scribe on the bolting circle, mark off for the five holes and drill these No. 51; from these holes mark off for the three connectors to be clear of same. Back to the machine vice and vertical slide to drill in from the periphery in the three positions at No. 42 to $\frac{5}{16}$ in. depth, following up at the appropriate size to accept the spigots on the connectors; silver solder in place. Mark off for the three No. 42 ports, the dimension leader somehow stops at a No. 51 hole on the way!, and drill these into the passages already dealt with. Deal also with the 7BA tapped hole on the same pitch circle, then polish the face with fine grade wet-and-dry paper.
Chuck the $\frac{7}{8}$ in. bar again, face and bore out to $\frac{5}{8}$ in. diameter to $\frac{3}{16}$ in. depth, then part off at a full 9/32 in., reverse and face. Offer up to the body and drill through the five No. 51 holes, securing with 10BA bolts, only we have to deal with the valve ahead of this.
Chuck a length of $\frac{5}{8}$ in. diameter brass bar, face and turn down for $\frac{1}{4}$ in. length to 19/32 in. diameter. Centre and drill No. 40 to $\frac{1}{4}$ in. depth and tap 5BA before parting off a 5/32 in. slice, Mark out the slots and drill three No. 42 holes in each of the 'through' ones, completing with a round file. For the blind slot, drill another three holes but this time only to 3/32 in. point depth, then grip in the machine vice and complete the slot with an end mill; it dos not have to be a perfect arc, but keep clear of the centre hole and periphery, so there will be no steam leakage.
For the spindle, chuck a length of $\frac{1}{8}$ in. stainless steel rod, face and screw 5BA for 5/32 in. length using the tailstock die-holder, then part off at $\frac{7}{8}$ in. overall. Reverse in the chuck and turn down for $\frac{1}{8}$ in. length to .086 in. diameter and screw 8BA; now for the brake handle.
Chuck a length of $\frac{1}{4}$ in. brass rod, face, centre and drill No. 42 to $\frac{3}{16}$ in. depth before parting off an $\frac{1}{8}$ in. slice. For the handle itself, chuck a length of $\frac{1}{8}$ in. brass rod and first reduce to about 5/64 in. diameter over a $\frac{1}{16}$ in. length; this is the spigot for which we shall drill the periphery of the collar and silver solder together. Before doing this though, with about $\frac{1}{2}$ in. protruding from the chuck jaws, take a file and produce the taper as shown; the handle can be as long or as short as you like. Saw off when satisfied, rechuck carefully by the taper and round off the end with a file. Now all you have to do is file a square in the collar, deal with the spindle to suit, after first screwing the spindle into the valve to arrive at the correct orientation of said handle to be clear of the firehole door, then assemble and next session we can tackle the tender.



# Saint Christopher

by: DON YOUNG

**Part 6 – Tender**

Although over the years there has been similarity in my description of various designs, for there is little point in changing winning ways, never before could I turn the clock back 14 years and with just a few dimensional changes, lift an entire article from the COUNTY CARLOW series in 'Model Engineer' and transplant them into LLAS. It was a tempting thought, though more attractive still was to get recent builder Ted Benn to do the job for me, but in the end I decided to start again from scratch and without reference to my earlier notes, but making full use of Ted's helpful suggestions, so off we go into the final session.

**Chassis**

For the frames, take a 17 in. length of $2\frac{1}{2}$ in. x 3/32 in. section steel flat, mark on the profile and holes, clamp to a second identical piece, drill through No. 41 in about four places and secure together with copper or aluminium rivets. Drill the remaining holes, save at the rear beam tapping those for the brake hanger pins, then saw out and file the profile, taking care both with the slots to accept the axleboxes and the lugs to aceept the hornstays.

Cut and square off to 6 in. length, two pieces of 1 in. x 1 in. x $\frac{1}{8}$ in. bright steel angle. The slot to accept the frames is best cut with a slitting saw, one about 1/32 in. thick for preference. Fit the saw to your mandrel, grip the angles as a pair in the machine vice, having carefully marked one off, then saw along each line, breaking out the surplus metal with a small chisel and then completing with a key cutting file into the frames as gauge. Mark off and drill the rest of the specified holes, filing the slots to drawing, then cut four bare $\frac{7}{8}$ in. lengths from the same angle and square off in the lathe. The section also needs reducing to suit the beams but before doing this, mill away the top edge of each beam end to drawing. With an odd end of frame material in the slot, fit the angle after trimming off and clamp firmly in place; drill through and secure with $\frac{1}{8}$ in. snap head iron rivets, hammering the shanks down into the countersinks. The rear beam is complete save for fitting the buffers we have already made, but the front one still requires a little attention. Cut and shape the anchor lug for the drawbar pin roughly as shown, clamp hard under the top face and drill the $\frac{1}{4}$ in. hole right through. Turn up the drawbar pins and use the tender one to align the lug immediately below the slot; spot through, drill No. 43 and tap 6BA for countersunk screws. At the ends of the top face, cut and fit $\frac{7}{8}$ in. lengths of $\frac{1}{4}$ in. brass angle with about three $\frac{1}{16}$ in. copper rivets. Clamp the beams in place on the frame ends, lay upside down on a flat surface and check also with a square, then drill and tap the 5BA holes, securing with hexagon head screws.

For the frame stretchers, take 5 in. lengths of 1 in. x $\frac{1}{8}$ in. black steel flat, bright will crack, and at about $\frac{5}{16}$ in. from one end, bend at 90 deg. Move on $4\frac{3}{16}$ in. and repeat, when with any luck the dimension over flanges will be a little over $4\frac{7}{16}$ in. Even if this is not so, grip in the machine vice and mill the flanges flat, machining to obtain the $\frac{3}{8}$ in. flange dimension at the same time. If the overall length is slightly less than $4\frac{7}{16}$ in. at conclusion, simply fit brass shims to correct the error, clamp in place, spot through, drill and tap the flanges at 6BA for hexagon head screws.

Wheel turning we know about and as SAINT CHRISTOPHER builder John Woodward tells me the description for dealing with the bogie wheels proved ideal in practice, this as a 'first time' effort, then use said technique for those on the tender. For the axles, square off two 5 9/32 in. lengths of $\frac{3}{8}$ in. diameter bright steel bar, then with one end projecting about $1\frac{1}{8}$ in. from the 3 jaw chuck, check that it is running true, changing to the 4 jaw if not so. Reduce the first $\frac{1}{2}$ in. to $\frac{1}{4}$ in. diameter and the next to $\frac{5}{16}$ in., the latter to either be a press fit for the wheels, or a sliding fit for application of Loctite 601. Reverse and repeat, then fit the wheels.

The horns require very little attention, so grip in the machine vice, they are cast in pairs, and lightly mill the working face. Turn through 90 deg. and mill the frame fixing face, after which they are all but completed, so separate into individual horns, stamp as a pair and tidy up with files.

Take the axlebox stick and first mill the back face across to arrive at the correct overall thickness of just under $\frac{7}{8}$ in. Sit this machined face on the bottom, fixed, jaw of the machine vice and carefully pack at the top to avoid spoiling the cast-on covers. Mill the face, then change to a $\frac{3}{8}$ in. cutter and rough out the slot to accept the horns to $\frac{1}{16}$ in. depth, gradually widening to the $\frac{1}{2}$ in. specified and taking note of the final cut settings on the vertical slide micrometer collar; turn through 180 deg., mill to $\frac{11}{16}$ in. wide and deal with the second slot. Saw into individual boxes and face off to $\frac{13}{16}$ in. depth, keeping the cover as shown, then find the centre of the journal by the 'X' method, centre pop and chuck to run true, drilling $\frac{1}{4}$ in. diameter to $\frac{3}{4}$ in. point depth to complete.

Fit a pair of axleboxes to a wheel set, erect to the frames, bring up the horns and clamp over the axleboxes. Check the wheels turn sweetly, easing the axle end a few thous if necessary to achieve this, then drill from the frames through the horn at No. 41 and secure with 3/32 in. snap head iron rivets, heads outside. For additional security you can use another two $\frac{1}{16}$ in. rivets for each horn, in fact four $\frac{1}{16}$ in. rivets might be the ideal on reflection. To complete this part of the assembly we need the hornstays, so take a length of $\frac{3}{16}$ in. square steel bar and mill a $\frac{3}{16}$ in. x 3/32 in. slot about $\frac{1}{16}$ in. from one end to be a tight fit over a frame lug. Move on $\frac{11}{16}$ in. and repeat, checking as you mill to get a good fit over the pair of lugs in conclusion. Saw off and square to $1\frac{3}{16}$ in. overall, then offer up to the frames, drill through at No. 41 and secure with 7BA bolts.

**Springing**

Reference back to Sheet No. 1 as published in LLAS No. 10 and showing the complete Tender will be useful throughout this session; even more so to see how the various spring details are employed.

Spring hangers are $\frac{3}{8}$ in. finished lengths from $\frac{1}{2}$ in. x $\frac{1}{2}$ in. x $\frac{1}{8}$ in. BMS angle; drill the two No. 30 holes and then fashion to drawing. The short arm is attached to the tender frames with an $\frac{1}{8}$ in. soft iron rivet, the plain turned brass 'shock absorber' fits underneath and the next item required is the spring pin. Chuck a length of $\frac{3}{16}$ in. steel rod in the 3 jaw, face, centre and drill No. 41, then part off six $\frac{5}{16}$ in. lengths. The pin itself is from $\frac{1}{8}$ in. steel rod, screwed 5BA for $\frac{5}{16}$ in. at one end and scalloped to accept the collar at the other; silver solder together and clean up. For the spring links, spend time making a 'master' to the best of your ability, caseharden it and use both as a drill and filing jig for another 12 pieces. As the No. 41 holes have to be countersunk, this time the 'master' will have to be scrapped after use, but it will have served its purpose well.

Take the cast springs and clean them up with files, tidying up the end lugs and drilling through at No. 41; final assembly to links and pins is with 3/32 in. countersunk rivets. First though we have to deal with the spring pocket, so grip in the machine vice, mill across the bottom of the strap, then centre and drill $\frac{5}{16}$ in. diameter to $\frac{7}{16}$ in. point depth, following up with a 'D' bit. Turn the spring plunger to an easy sliding fit in the spring and complete with 20 s.w.g. springs of about $\frac{3}{4}$ in. free length.

**Brake Gear**

Strangely, until one realises there is nothing else available to support the brake shaft, the brake gear starts with the front steps, and whilst we are at it, the rear pair and valances can also be dealt with. Mark out the step supports on $\frac{1}{16}$ in. (1.6mm) brass, saw out and file to line. The steps themselves are folded up from 1/1.6mm material as you wish, and secured to the backs with a few 3/64 in. copper rivets. Mark off and drill the fixing holes to the beams, offer up to the latter, spot through, drill and tap as specified; secure. The rear steps are well supported, the front pair which are loaded by the brake gear not particularly so. However, I think you will see that the addition of a further piece of $\frac{1}{4}$ in. brass angle, or $\frac{1}{4}$ in. square bar, in the vertical plane will add the necessary strength, so fit this to place.

After the initial problems with the valance on COUNTY CARLOW's tender, in providing clearance for the spring links, this time my notes are copious on the detail such as very little description is now required. Use a straight edge to project from the beam ends to check for said spring link clearance, bend the valance to suit and only then trim off to $16\frac{7}{8}$ in. overall to a good fit between the beams. Remove the top face to the dimensions shown, mark off the fixing holes clear of those for the steps, drill through, offer up, spot through, drill and tap for 8BA screws. Now for the brake gear proper. Let us start with some simple turning, like brake shaft trunnions and brake nut, which call for no comment on my part. For the brake shaft, chuck a $5\frac{1}{2}$ in. length of $\frac{1}{4}$ in. steel rod, face and turn down to $\frac{3}{16}$ in. diameter, an easy fit in the trunnion, for $\frac{1}{4}$ in. at one end. Reverse and face off to a bare $5\frac{7}{16}$ in. overall, an easy fit between the steps, then deal with the second journal. Now you can file off the excess flange on the trunnion as shown, clamping the whole assembly in place and checking with a square before drilling through at No. 44 and securing the trunnions with 8BA bolts, only the latter will have to be removed immediately to complete the shaft. For the shorter pair of arms, take a length of $\frac{3}{8}$ in. x $\frac{1}{8}$ in. BMS flat and at 13/64 in. from one end, drill through at $\frac{1}{4}$ in. diameter, or 6.3mm to be a better fit. Grip a length of $\frac{1}{4}$ in. rod in the machine vice, eased slightly if the latter drill was used, chuck an end mill in the 3 jaw and radius the ends. Saw into individual arms, clamp together as a pair, drill the No. 30 hole and complete profiling with files.

The hand brake arm is from $\frac{3}{8}$ in. x 3/32 in. BMS strip, the large end being dealt with as previous. Drill a plain No. 30. hole at the other end to start with, then complete profiling Take another piece of strip and bend up to give the required $\frac{1}{4}$ in. set to accept the brake nut, clamp to the arm, drill through at No. 30 and profile this portion. Next position correctly with an $\frac{1}{8}$ in. rod for alignment, profile the rest to match the arm, then trim off and drill right through at No. 44 for an 8BA bolt. To complete this part, elongate the No. 30 holes to form a slot, using the brake nut as your gauge.

Assemble the arms to the brake shaft, spacing as per detail and orientating as shown on the tender frames, squashing very slightly if necessary so that the arms are a tight fit over the shaft, then no additional support is necessary for brazing. Wash off, wirebrush clean and apply matt black paint as anti-rust protection.

There is only one problem with the brake gear as detailed and that is one frame has to be removed for its assembly, but as this was almost standard L.B.S.C. practice and I did not hear many complaints about it, hopefully yours truly will also be spared criticism. Brake hanger pins and beam spacers are simple turning, the brake beams themselves straightforward, so on to the brake hangers. As we have been using $\frac{3}{8}$ in. x $\frac{1}{8}$ in. BMS quite liberally, this can be the standard section for the hangers, so scribe a centre line on one piece about $2\frac{1}{4}$ in. long, mark out and drill the holes. Radius the ends over a mandrel and complete profiling; and you have guessed it, caseharden and use both as a drill and filing jig for the remaining five pieces.

The shoes will just come out of $\frac{1}{2}$ in. x $\frac{1}{4}$ in. BMS bar, so saw and square off six $1\frac{1}{4}$ in. lengths. With so little metal to be removed, I recommend you take a coarse half round file and simply match each piece to a tender wheel, simple as that. Mark off and drill the No. 42 hole then grip in the machine vice, on the vertical slide, to mill the slot to accept the hanger. It is very important here that when the brakes are fully released that the shoes do not 'trip' and jam the wheels, so control the depth of slot to be just sufficient for the shoes to follow the wheels as they move up and down relative to each other. To complete the shoes, mark out the back profile, saw and file to line. Assemble beams, hangers and shoes to the hanger pins and clamp said shoes hard to the wheels, this to measure the intermediate and trailing pull rod lengths; make the leading pair to drawing. The section for the pull rods is $\frac{1}{4}$ in. x $\frac{1}{8}$ in. or 3/32 in., remembering to use additional spacer washers if the latter is your choice. Drill at the arrived at centres, radius the ends over a mandrel, then reduce the section between said ends. For this sort of filing job you can ues the hardened jaws of the bench vice as a 'stop', though don't be too enthusiastic or you will greatly reduce the working life of the file; they are much more expensive now than when I did this as a matter of course! Assemble all the pieces made thus far, drilling for and fitting 3/64 in. split pins where called for, and we need just the hand brake.

For the column, take a 3 in. length of $\frac{3}{8}$ in. A/F hexagon brass bar, face and centre at one end. Reverse, face off, centre and drill No. 30 for about $\frac{3}{4}$ in. depth, then turn down to $\frac{5}{16}$ in. diameter over an $\frac{1}{8}$ in. length and screw 32T. Chuck an odd end of $\frac{1}{2}$ in. rod, face, centre and drill through at 9/32 in. diameter before tapping $\frac{5}{16}$ x 32T; screw in the column and bring the tailstock into play. The taper on the column is approximately $1\frac{1}{2}$ deg., so set the topslide over somewhere near this and using a round nose tool, take a first cut; assess the result with your micrometer and adjust until the final cut gives the required dimensions. Change to the tailstock chuck and drill right through at No. 30 then carefully face off to length.

The spindle is a $6\frac{1}{2}$ in. finished length of $\frac{1}{8}$ in. stainless steel rod, screwed 5BA for 1 in. at one end to suit the brake nut. Chuck a length of $\frac{1}{4}$ in. brass rod, face, centre and drill No. 31 to $\frac{3}{16}$ in. depth. Start parting off a 3/32 in. slice, but before completing the cut, round the corners as shown; press onto the spindle at the position shown. For the handle boss, chuck a length of $\frac{3}{16}$ in. stainless steel rod, face, centre and drill No. 31 to $\frac{3}{8}$ in. depth then part off a $\frac{1}{4}$ in. slice; press this on top of the spindle. Cross drill No. 55, take a length of 18 s.w.g. stainless steel wire and bend up as shown, then braze this and the collar to the spindle. Only the collar at the base of the column to complete, so chuck the $\frac{1}{4}$ in. brass rod again, face, centre and drill No. 30 to $\frac{1}{4}$ in. depth before parting off a 5/32 in. slice. Erect to drawing, cross drill No. 60 and fit a 1mm spring dowel pin. This most versatile item was originally 'invented' as hinge pins for furniture, but has since found many uses in engineering. Screw the hand brake into the front beam, connect to the brake nut and check brake operation.

## Drawbar and Pins

Only one small job before we move upstairs to the tender body, the means of connecting engine and tender, one which has caused me a red face on occasion by its omission from the drawings, though infinitely less embarrassing than turning up at the track minus said 'missing link'! Perhaps surprisingly, it is about as easy to separate an engine and tender full size as in miniature, though many an apprentice has found that feed bags contain water; lots of it!

As for the actual details, the drawbar itself is but a variation of lots of pieces like brake hangers and pull rods made recently, and we know how to make pins from plain rod with separately brazed on heads. Make sure though there is plenty of taper on the end of the pin, particularly the engine one, then you will be able to couple up with ease.

## Tender Body

The soleplate for the 3,500 gallon tender is plain rectangular, size 17¼ in. x 6⅜ in. and 1.6mm thick for preference; in 3½ in. gauge brass is recommended universally, especially as this body is a little on the complex side. The pads are cut from 2.5mm sheet, turned to size and fitted in place with a couple of copper rivets, after which the holes in the soleplate can be dealt with to suit, not forgetting that to clear the hand brake column.

The sides come next and this is where I would rather be doing the job in 3D than describing it in 2D! I do, however, have those helpful notes from Ted Benn who has completed his body just ahead of my notes, but for some reason Ted declined to write the description for me; it seems no way can I delegate! Cut two pieces 20 in. long x 3⅛ in. wide from 1.6mm brass sheet. Grip at the top in the bench vice, together with a length of ⅞ in. diameter bar and a little at a time, pull round to produce the flare to be roughly as shown, using a wooden or soft faced mallet to assist in producing the bend only as a last resort. The main thing to aim at is that the flare be regular throughout the whole length rather than be exact to drawing; when satisfied, file the top edge so that the, upward, plate extensions and beading will sit squarely. Although a skilled light plater or coppersmith would be able to produce the back corner radius complete with flared portion, for us amateurs it is best to cut the flare away, produce the bend, and make up an insert as shown on the drawing detail. At 2⅝ in. from the end of each side sheet, and remember they will be handed by the flare, scribe a line right down to indicate the start of the rear corner, then move on $\frac{7}{16}$ in. and scribe another line; cut away to ⅜ in. depth then pull the corner round a length of ½ in. diameter bar. Take a hardwood block and fashion it to represent the flare at the corner, then take a piece of 1.6mm thick material, copper for preference, and hammer over the hardwood former, trimming to a good fit to place.

Coal rails are an absolute menace on a tender, they are the sort of fragile object that always manages to catch a sleeve, with disastrous result for both, so the plated upward extensions on the GWR tenders have much to commend them, though life would be even better without that flare. I suggest you cut a cardboard template in the first instance and transfer this to metal when you are happy with the appearance; blending the end radii out to a point needs care. Ted Benn sent me a sample piece for joining the upward extension to the tender sides, being a length of $\frac{3}{16}$ in. x $\frac{1}{16}$ in. brass strip nicely rounded at each end and drilled for two $\frac{1}{16}$ in. copper rivets. Make up about eight of these ¾ – ⅞ in. long and bend to suit the flare, then clamp firmly in place, drill through and rivet. It is preferable if this joint, and the corner inserts, be silver soldered for the additional strength it provides, but do use a minimum of heat to reduce distortion, and correct any that does occur before going any further.

This tender will consume a vast quantity of ¼ in. x ¼ in. x $\frac{1}{16}$ in. brass angle for its size, in the order of 10-12 feet, so take two pieces and rivet to the bottom of the side sheets as a starter: use $\frac{1}{16}$ in. snap head copper rivets, heads inside and at about 1½ in. spacing, again taking care to avoid distortion. A second length of angle is positioned $\frac{7}{16}$ in. down from the top of the side sheets, to support the wing and tank tops. Bring the two halves together and cut a full 2 in. long doubler from ⅜ in. x $\frac{1}{16}$ in. brass strip. Position to suit the pieces of angle, as shown, then drill $\frac{1}{16}$ in. holes and rivet all three pieces firmly in place. Erect to the soleplate, position carefully and clamp down firmly. Because the assembly is far from being a permanent one at this stage, use 8BA countersunk brass screws to attach the angles to the soleplate, drilling said soleplate No. 44 and countersinking the bottom face to suit the screws, then continuing at No. 50 through the angle and tapping 8BA. We now have a fair idea as to how our completed tender will look and must move inside the body to provide the water space, starting with the wing tanks.

Cut two pieces each 12 in. x 4¼ in. from the 1.6mm brass sheet, though 1.2mm material would suffice here. It is also convenient to mention here that it is usually better to work brass sheet in its bright 'as supplied' condition rather than annealing same before use, that way you can employ its natural springiness to avoid nasty dents and the like. At 2$\frac{5}{16}$ in. from one of the longer edges, scribe right along as the start of the top corner radius, grip in the bench vice together with a length of ½ in. diameter bar and gradually pull round, giving a final tighten to said bend radius by hand pressure only. Rivet a length of ¼ in. brass angle to the foot of each wing tank, erect, then use 8BA screws to attach to soleplate and side sheet.

We now have to fill in the central portion between the wing tanks, sloping up to the coal partition plate, where the shape is quite nasty over a short length, a good case for a cardboard template. Transfer to 1.6mm sheet and cut out, making sure there is sufficient metal at the front end to project to form the shovel plate; up to ⅛ in. more than I have shown if you like. Bend to place, scribe onto the wing tanks, then fit ¼ in. brass angle to said wing tanks with either screws or rivets to choice, this for the tank top to sit on; fasten the latter down with screws. Next comes the closing plate at the front end, not very difficult in itself, though it will take a mite of patience to fit lengths of the ¼ in. brass angle to the tender sides, wing tanks, soleplate and tank top so that you can then add yet more 8BA screws to hold the closing plate firmly in place.

Only one more permanent piece, the coal partition plate, cut again from 1.6mm brass and if made a close fit then it will require no further support, as we are about to sweat all the joints/seams. Fit wooden bungs to all the holes in the soleplate, pour in some Bakers fluid and begin to gently warm the whole tender body, trying to maintain a fairly even temperature to minimise distortion. Feed in some soft solder, get it nice and liquid, then swill about so that it seals all the joints, adding more Bakers fluid as necessary. There is a simple tool you can use to 'paint' the soft solder onto the seams; pull a tuft out of a wirebrush, poke in the end of a length of ¼ in. copper tube and squeeze it tight. At the other end add a file handle. to make things comfortable, then you dip the brush in Bakers fluid, melt on a little soft solder and simply paint it on. Before removing the bungs, fill with water and check for leaks, minor ones can be sealed with paint, but reheat if any are more serious, especially at the joint where the coal plate passes through the front, closing, plate. Use warm soapy water to really clean out the tank, give it a good scrub, then dry and paint the interior gloss white; again you can simply pour in the paint and swill it about; drawing off any excess.

It may be a wise move to sweat on the ⅛ in. beading before applying paint, although the heat required is minimal, and applied with an electric soldering iron. Brush some Bakers fluid along the top edges of the tender sides, coal partition plate too, then take up solder on the electric iron bitt and tin the edges; do the same to the flat face of the beading. Bend the beading to shape, clean the soldering iron and apply the bitt to the top of the beading, drawing it along to fuse the two tinned faces together – quite a swift operation as too much heat transference leads to problems.

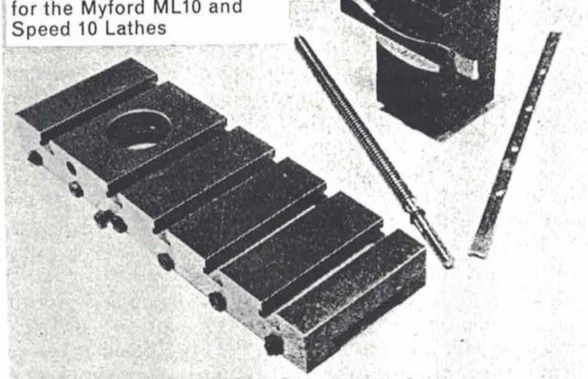
The removeable section of the tank top is $5\frac{3}{4}$ in. x $3\frac{13}{16}$ in. from 1.6mm material and can simply sit on the $\frac{1}{4}$ in. brass angle, though you may attach it with about six 8BA counter-sunk brass screws if you wish. Before that though we have to provide the filler, so square off a $\frac{13}{16}$ in. length of $1\frac{1}{4}$ in. o.d. copper tube, clamp to the tank top in the position shown and silver solder in place. Now you can drill out the centre and file to suit the tube bore, when we can deal with the filler lid.

Scribe a $1\frac{5}{8}$ in. circle on 1.6mm material, cut and carefully file to line, then saw into the two pieces as dimensioned. Chuck a $1\frac{1}{4}$ in. length of $\frac{1}{8}$ in. brass rod in the 3 jaw, face, centre and drill through at No. 56; repeat for a second piece and silver solder to the edges of the filler lid. Mark off into individual hinges, saw and file away until they match, sweat a wire handle to the lid and the smaller portion to the filler tube, completing with a 3/64 in. diameter hinge pin.

The tender body is fixed to the chassis with six 6BA cheese head screws, clear holes in the soleplate and tapped ones in the top of the beams. At the front end these can be positioned clear of the tank space, but at the back they have to come inside the tank, so use large washers and paint everything before assembly to form a seal; we can now fit out the tank.

### Tank Fittings

We already have the tender hand pump and this must be positioned under the filler tube to give maximum stroke; you will soon discover this position, when it is a matter of four No. 34 holes in the soleplate and 6BA tapped ones to match in the pump foot. For the hand pump fitting, chuck a length of $\frac{7}{8}$ in. diameter brass bar in the 3 jaw, face and turn down to $\frac{3}{8}$ in. diameter over a $\frac{5}{8}$ in. length, then part off at a full $1\frac{1}{16}$ in. overall. Reverse in the chuck, face and turn down to 9/32 in. diameter over a 11/32 in. length, then centre and drill No. 22 to 1 in. point depth. Turn up the union connector, something we are familiar with now, mike its spigot and drill the fitting to suit; press home. Silver solder the connection and fit an approximate 10 in. length of 5/32 in. o.d. thin wall copper tube into the No. 22 hole. Bend the tube roughly as shown, insert into the tank, bend again to suit the hand pump delivery, trim off to length and braze on the nipple. To complete, drill the four No. 41 holes in the fitting flange, offer up to the soleplate, spot through, drill No. 47 and tap 7BA for cheese head screws, applying a little liquid jointing compound on assembly.



The long cross-slide and rear toolpost recently introduced for the Myford ML10 and Speed 10 Lathes

The pump bye-pass fitting is very similar, its internal pipe outlet being positioned to be seen through the tank filler; injector suction fittings have 5/32 in. o.d. thin wall tube brazed into their outlets. For the filters themselves, wrap a piece of 100 mesh bronze gauze around $\frac{1}{4}$ in. rod, sweat the seam, pinch over the top and sweat this also, using a minimum of solder otherwise you will restrict the water flow; slip over the fittings and bolt them in turn to the soleplate.

Use plastic or rubber hose to connect from the injector water fittings to the engine, renewing each year as they do deteriorate, causing air ingress and 'injector failure' – we get many an SOS at the start of a season – but 'it worked alright last year'. Run copper pipe forward from the bye-pass connection to around those for the injector water and complete with flexible hose. The hand pump fitting is positioned 'a la L.B.S.C.' to use a cycle pump connector as providing the hand pump supply to the engine, but you can make up your own flexible pipe if you wish, using thick wall rubber tubing. All we have to do now is add the final trimmings.

### Tool and Oil Boxes

In my building days, nothing gave me greater pleasure than small fabrication work, using odd scraps of material and some home made clamps; axlebox keeps for instance were a real speciality. When I became 'commercial', in some respects I had to play down fabrications, especially where the alternative was a casting, but perhaps more important still was the fact that many builders run into trouble with things like those axlebox keeps and actually prefer a casting.

Items like the oil and tool boxes, I would make up a wooden former to represent the inside of the box, cut out a piece from sheet and knock it over the former, trimming off the joints as I went, or fitting separate end plates as in the case of the tool box. A few rough spacers and a clamp, then silver solder the joints, and I had a lovely little tool box, which only required the lid to close it off, completed with a couple of miniature hinges and a clasp. The alternative of course with such small items is to make them solid, when very little is involved and they can simply be positioned and screwed into place as indicated on Sheet No. 1.

The tender tank steps are also positioned to Sheet 1, being folded up from 1 or 1.2mm brass and sweated to place; lamp irons again require no comment on my part. Handrail stanchions are however a bit special and if any builder gets into trouble with them then we shall be pleased to help out; the handrails themselves are quite straightforward from $\frac{1}{16}$ in. stainless steel rod.

### Painting – a naughty word!

Whilst it is relatively easy to paint your SAINT CHRISTOPHER in GWR green, actual liveries are a specialised subject and beyond me, indeed we need an authority on this subject to contribute to LLAS, especially the ornate painting scheme used at Swindon around the time that the 29xx began to appear. I do have a colour print of 'The Great Bear' as it appeared in the March 1908 issue of THE LOCOMOTIVE, all the evidence points to it being a very good oil painting, but I could not even begin to describe the livery, never mind the colours, for I do know there is a fault in my eyesight in the blue/green spectrum and I don't think 'The Great Bear' was ever blue!; that really sums up my problem.

### The End

So the SAINT CHRISTOPHER tale draws to a close; I have greatly enjoyed it from my end and I hope that, despite the interruptions, she has found favour with readers. I have learnt much of GWR practice over the years and though by no means a Swindon stalwart, there will be few more successful Locomotives that I will ever commit to print, or with more historical significance as far as British Locomotive development is concerned.