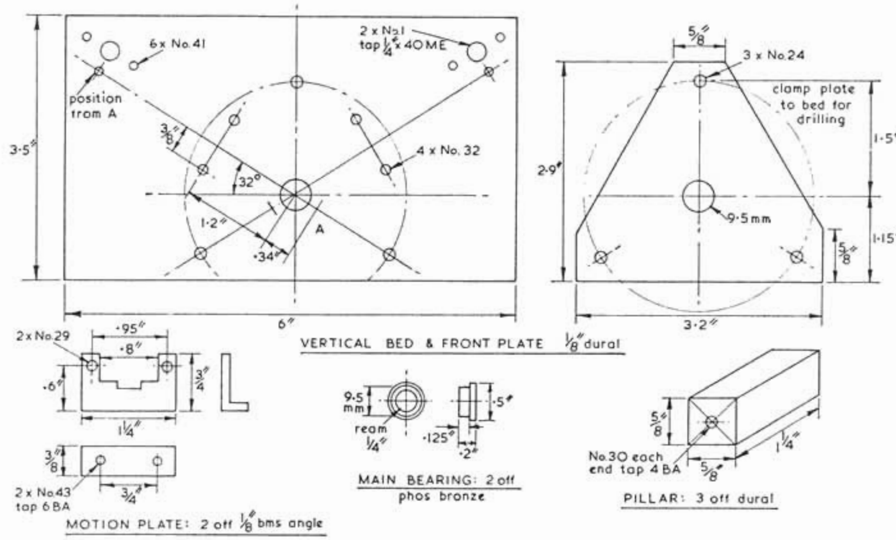


The big end brasses are turned down from 5/8 in. phosphor-bronze. Cut a piece about 1 1/2 in. long, saw down into the end 1/2 in, then cut one half out. File the cuts flat to perfection and Comsol solder the half back into place, which will be a little displaced, before turning the two brasses on the lathe, drilling the hole 6mm. Ream out to 1/4 in. only after the brasses are in the big ends, and before melting the Comsol. Run the fitted brasses together on the crankshaft, using plenty of Brasso, to run them in.

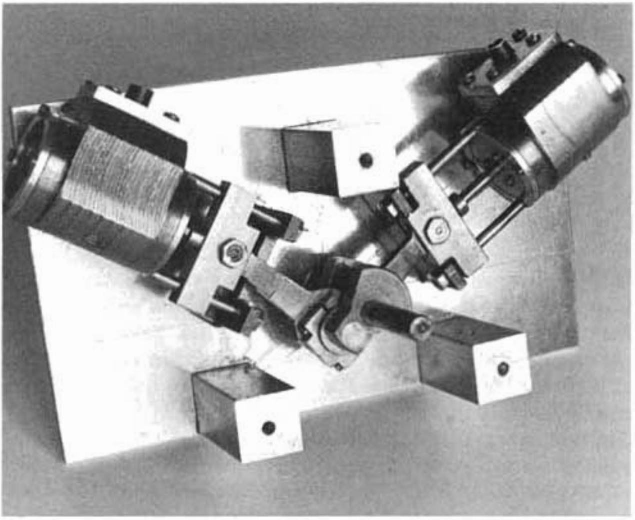
Make all the other bits and piece and assemble (including the displacement lubricator, which works a treat). Everything should feel very tight, so run in a little with "3-in-1" everywhere, on the Unimat; listen for squeals and groans while running in quite slowly, and ease any tight motion fittings.

RUNNING IN

Fit a nice heavy flywheel and give a pneumatic run on an air compressor at about 50 psi, fill the lubricator with "3-in-1", and, after a few minutes of assisted tick over, if all is well, it will begin to show signs of life and run quite fast, throwing oil and air from the exhaust left open at the back of the bed. The pressure can be gradually reduced until the engine will run well at about 35 psi. Refill the lubricator and let the engine tick over for an hour or so to run it well in before applying steam. When the engine feels to have an easy cycle fit a collar each side of the shaft, and the correct flywheel.

Before running with steam refill the lubricator with Valvata, and oil all moving parts with a thicker oil than the "3-in-1". The lubricator, when full, has space enough above its feed hole to lubricate by gravity the two engine units

A view of the engine with the front plate removed



plus a little back to the regulator, which is warming up at the smokebox end of the boiler.

Under steam the engine runs well from about 30 psi at all speeds with good regulation, up to about 50 p.s.i., which is the maximum steam pressure so far obtained on this boiler.

The lubricator is made from a 3/4 in. dia. piece of aluminium alloy bored 10mm., 20mm., deep, with a hole drilled in the side, No. 1, just touching into the bore and tapped 1/4 in. x 40 M.E. to be suspended from the fourth end of an "X" – piece taking the steam to the units. The lid is made from similar material and fitted with a hallite gasket; the lid is coarse threaded into the body. After a good run it will be full of water with a skim of oil on top, just as it should be.

IN CONCLUSION

The engine will self start from any position on opening the regulator, providing the steam pressure is sufficient. To change the direction of rotation the flywheel needs to be given a half turn in the required direction. Remember that if the engine and a boiler are fitted below decks in a boat a supply of air is required for the fire, and for prolonged running, a supply of water will be needed for the boiler via a feed pump.

Chapter Eight

Vertigo - Valveless Column Engine

This engine was built simply because it had been suggested that my valveless engine design would not work properly in a vertical mode in a large size, that the moving cylinder would fall by gravity, and so on. I made Vertigo about as big as possible with the Unimat SL, and this version of the engine unit has a 1 in. bore by 1½ in. stroke. The name may be considered as either quite sensible or as a terrible pun.

In designing this version an attempt was made to adapt the old-type vertical column engine to a modern and utilitarian style, with simplicity of construction. In the construction economy is the keynote, with a deal of thought given to variations in positioning, so that each unit can be made to fit the next with the least bother, even when minor discrepancies occur, the idea being that a beginner could easily make the model.

Holes which have to be parallel are bored out on the lathe, at the centre height of the Unimat. Silver steel is used for the three columns, and two of these double as cross-head guides. Bearings are either ball-races or simple fittings of phosphor- bronze. The connecting rod is over three times the length of the stroke to minimise angularity effects. The design is such that the height of the engine can be altered by simply increasing or decreasing the length of the columns, and then making a connecting rod to suit.

The engine is mainly of aluminium alloy for ease of machining, but drilling and tapping need a little care in this material. The only part fabricated in mild steel is the connecting rod and most of the work on this can be carried out on the grinding wheel.

The engine unit is the same valveless design, but with a power stroke of 1.1 in. plus a cylinder movement of 0.4 in. in the block. The cylinder block is a sleeve of thick brass tube, with a steam block saddled to fit. The steam block is made to incorporate a displacement lubricator. Lubrication for parts of the motion is by means of wells, or just a squirt from the can.

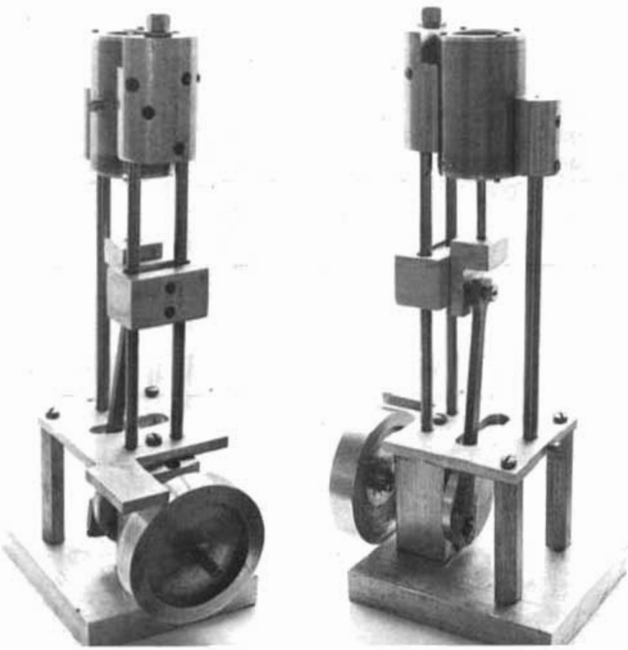
It should be noted that the overall diameter of the cylinder unit is only 1 11/16 in., so that with the larger piston of 1 in. diameter the additional concentric thickness of the moving cylinder is barely noticeable. Two units of this size as outside cylinders of a small 3½ in. gauge locomotive would look in scale.

THE ENGINE UNIT

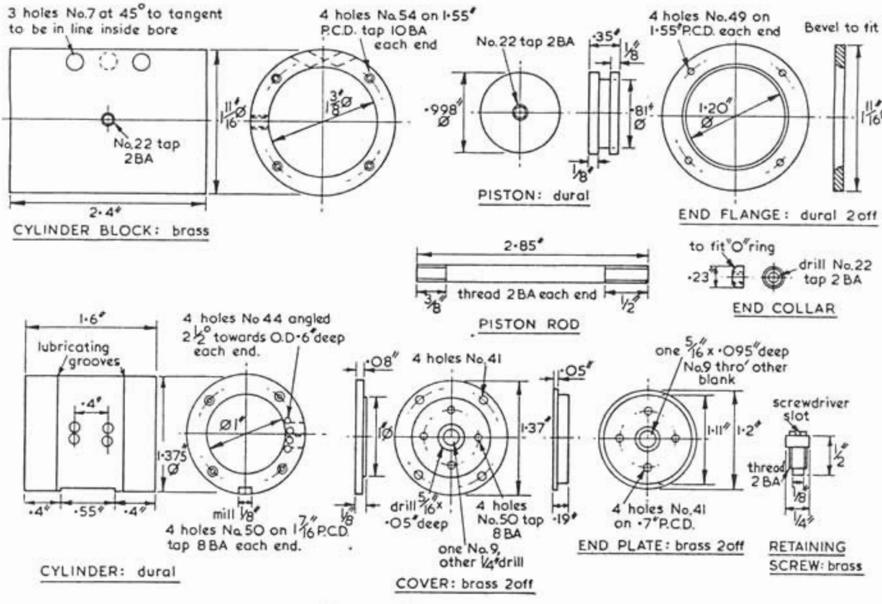
Being a larger unit the engine requires slightly different methods of machining than the little version. Turn the cylinder from 1½ in. diameter aluminium alloy,

boring the hole for the piston by first drilling through, up to about 12mm., with the metal held in the three-jaw, and at the other end by the three-point steady, with greased points. Then using a boring tool held in the tool-post on the cross-slide, bore out the first inch to about 0.95 in. so that you can see to bore out the deeper part. When the cut is level all through, reduce the cut to a thou a pass (remember this takes off 2 thou from a bore). Have the vernier calliper set to a couple of thou under the inch, and when the inside jaws can just enter the bore take another cut at around half a thou and pass the boring tool through with a slow feed, bringing it back and passing it through three or four times at this setting, and leave it at that. If you have an inch reamer you may wish to try reaming by hand, but I always manage to score soft alloys with the larger hand reamers, also ending up with a rifled pattern right through. Turn the two ends to the correct length to a finish.

Turn a piece of light alloy, between centres, to just fit the bore, with a little protruding each end. Put the piece carefully into the bore and add two spots of Loctite 641 or 242, diametrically at one end to hold the parts together while turning the outside of the cylinder to fit the inside of the brass tube of the cylinder block. Make the two oiling grooves and rub down any burrs produced. Drop a few drops of 3-in-1 between the cylinder and core, place over a suitable hole and give the core a swift tap with a hammer, to displace it from the Loctite.



Two views of the finished 'Vertigo'.



VALVELESS ENGINE UNIT

Thread the piston rod in the lathe, 2 BA both ends, starting with the die right open and using lots of RTD tapping compound on the stainless steel. Turn the piston as a blank with one finished end and part off. Put the blank in the three-jaw chuck to drill No. 22 and to tap 2 BA. Clean the threads and secure the blank on to the piston rod with Loctite 601. Turn the rod in the drill chuck and turn the outside to size, make the groove to fit the Viton "0" ring with a flat ended parting-off tool. Make sure the bottom of the groove matches the final sizes of whatever the cylinder turned out to be less the ring, and its tolerance should be minimised. Make the end collar.

Turn a piece of 1⅜ in. diameter hard brass in the three-jaw chuck and turn out the covers and end-plates, one after another. For the cylinder block, which is just a sleeve in this case. I used a piece of 1 11/16 in. O.D. by 1⅜ in. I.D. brass tube (this is difficult to obtain these days) and simply polished it internally after turning off the ends square and relieving the corners. Make the end flanges from dural.

When all the pieces for the engine unit are made, stake out the holes with a centre drill using the indexing attachment, Unimat head in the vertical position, 40-tooth plate in place. Drill for the 8 BA screws in the cylinder and 10 BA in the block. Tap the holes taking great care with the small blind holes, particularly when withdrawing a tap in duralumin after bottoming.

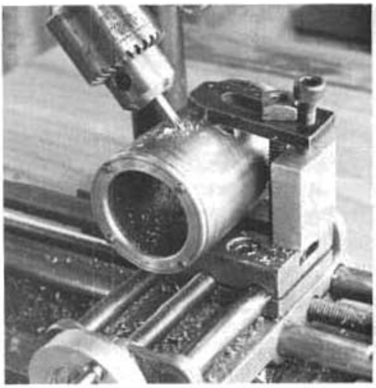
The steam ports have to be drilled to match in block and cylinder. So that enough steam is available, each half of the double action has four small steam holes from each end arriving at two holes in the side. Drill the four small holes first, staking with a No. 1 centre drill tip, on the set-up as before but angled at approximately 2½ degrees from the vertical. The four holes are one tooth of the 40 plate apart. Drill the holes No. 44, withdrawing the drill often in this soft material. The holes should not run together or the drill will break, and can be left this way. The two holes meeting the four are staked in the side with a No. 3 centre drill, and drilled No. 25 to run slightly together; the sharp bits between are removed with a needle file.

The brass tube of the block is drilled No. 7 at 45 degrees to the tangent, so that the steam and exhaust holes in the bore are three ellipses in line, but are quite separate outside. Drill the hole for the retaining screw No. 22 and tap 2 BA, fit the cylinder with the holes lined up, and mark through the position for the slot to be milled. Make two sets of calico discs and polish the bores using Brasso. It will make this easier if a piece of dural rod is pushed into the bore of the block to remove any burrs before polishing. File a flat for the four steam holes, each end, and file the covers to match.

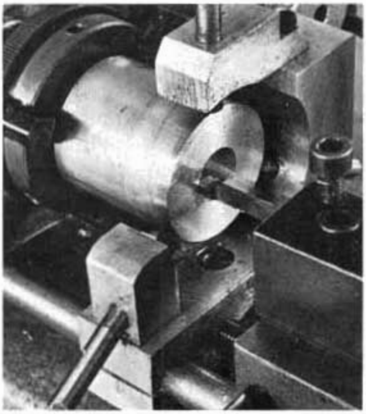
Fit the parts together, giving the piston in the bore its "against the light" check, and if all is well, the covers and end plates can be secured in place with Loctite 601 and screws. When cured the cylinder unit can be checked by oiling through the holes until the piston moves freely and, covering them with two fingers, ensuring thus that the piston movement does not expel air from any leaks.

Make the retaining screw from ¼ in. diameter brass and fit the cylinder to its block, exposing each end to fit the "O" ring so as not to push them past sharp ports. Fit the end flanges and check, by measuring that the piston travels the full 1½ inches. Adjust the milled slot length, or the bevel of the flanges, whichever is the cause of the short stroke.

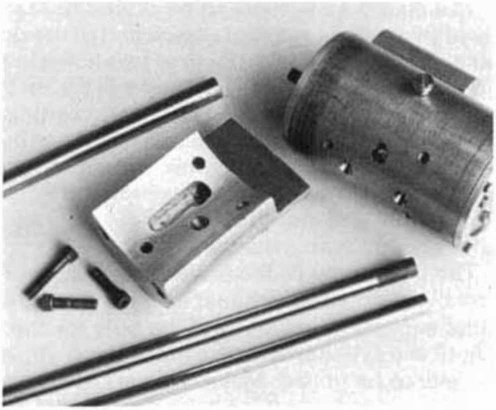
Drilling the steam ports in the cylinder block.



Components. Compare size of original unit placed between block and cylinder



Boring the cylinder.



The engine unit and saddled block.

MOUNTING THE ENGINE UNIT

The unit is mounted on three columns of silver steel, two of which serve as a crosshead guide so they must be precisely fitted in their saddled block, which is also the steam block, and contains the lubricator.

This saddle is cut from 1½ in. diameter aluminium alloy, with a flat sawn out from a longer piece than finally required and a further cutaway made down to the limit, and at the end of, the required size of block. This is mounted on the cross-slide and the saddle fly-cut or bored right up to the extra cutaway part. This is working the Unimat to the limit of its flexibility and the result may not fit perfectly, but a certain amount of finishing will be required anyway, with emery cloth wrapped around the circumference. Be careful not to make the curved saddle end up awry. Further corrections can be made for gaps up to about 0.02 in. by the fitting of a paper gasket, epoxy resined into the saddle, the paper wrapped tightly around the cylinder block whilst setting; to finish being Loctited on to the block just the same as a finely machined saddle. This must be carried out after the spare piece has been sawn off and the top, isolated a little for the lubricator section to provide condensation, filed away.

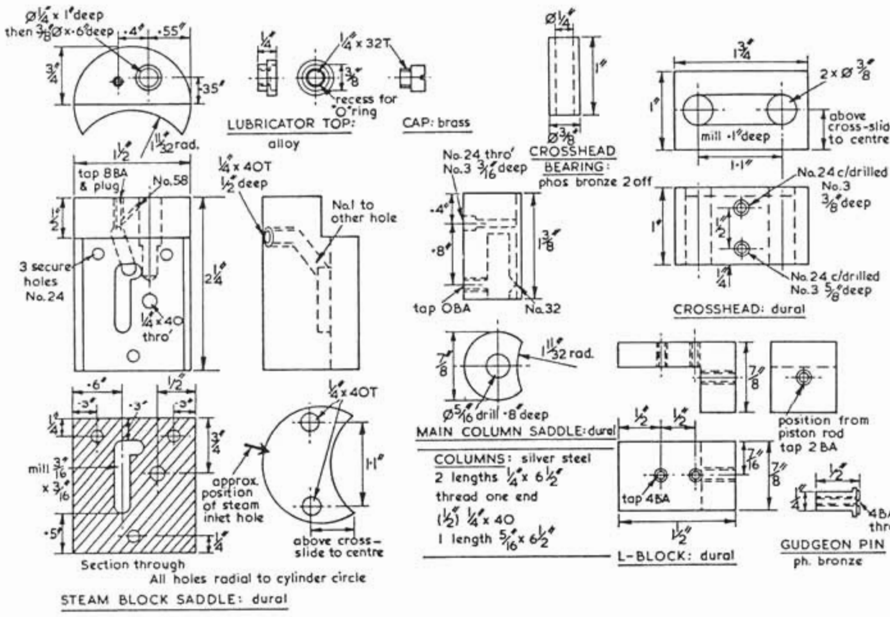
Rub off the two sharp edges of the saddle with emery cloth on a flat surface. Cut a piece of ⅛ in. mild steel and bolt the saddle, on the mild steel, on to the cross-slide of the Unimat; it will half overhang at the back, two flats down. Bore the two holes for the columns, at centre height, starting with a No. 2 centre drill up to its flutes and finishing, to depth, with a No. 1 drill. Tap the holes in the lathe ¼ in. x 40 ME. Cut the silver steel for these columns by cutting a length of ¼ in. diameter right in half and thread one end of each.

Drill the other holes and mill the slots to miss the support holes. The chamber for the lubricator can be drilled at centre height. Drill the holes for the three securing screws in the saddle radial to the cut surface (radial to the

cylinder block) and counterdrill the other surface for the hex. cap heads. Fit against the cylinder block and mark the position of the holes through, drill the block No. 31 not quite through, after removing the works, and tap 4 BA for the three screws.

Tap the outer steam and exhaust ports ¼ in. x 40, make the lid for the lubricator from aluminium alloy, to take the "O" ring and plug, tapped ¼ in. x 32 in this case. Fit the top in with Loctite 601, making sure that the little hole is neither filled in nor covered over. This can be checked after fitting the saddle by pouring oil into the steam hole with the cap off the lubricator, and moving the piston whilst covering the steam hole, when oil will spit and bubble in the lubricator.

The main column saddle is made from ⅞ in. diameter aluminium alloy, longer than finally required, turned in the lathe and bored for the $^{5}/_{16}$ in. silver steel column, after which the saddle is fly-cut or bored, clamped to the cross-slide of the lathe. The holes for the securing screws are drilled, the top hole is counterdrilled for the hex. cap head. The lower hole is first drilled No. 32, and then drilled No. 7 to countersink the 6 BA hole, and to be tapped O BA for the column securing screw. Drill the cylinder block to match, not quite through and tap the top hole 4 BA and the lower 6 BA. The two saddles can now be secured to the block with their screws, cut to fit, and using Loctite 275, in both cases. Fit the columns and measure to ensure that parallelism is inherent.

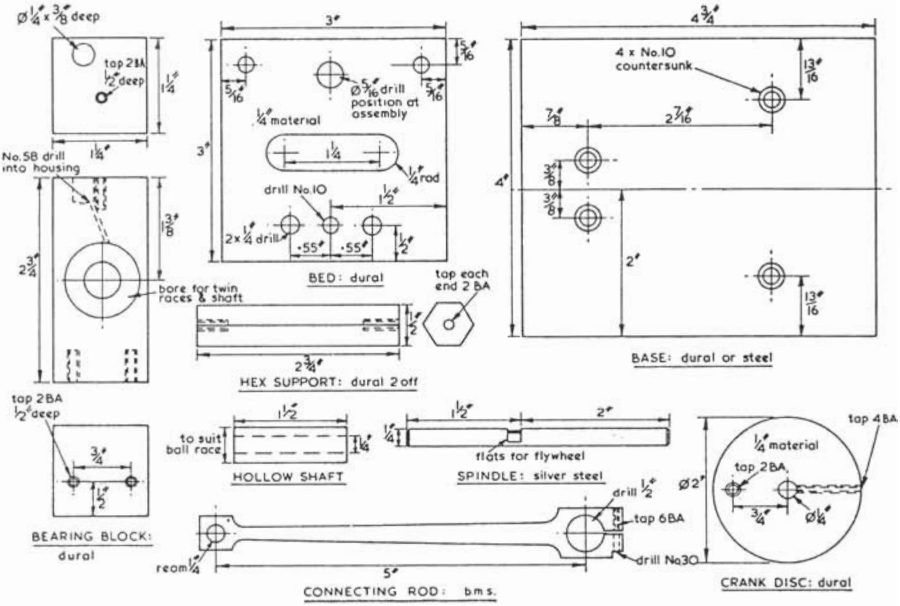


THE CROSSHEAD

The crosshead consists of a block of aluminium alloy fitted with two turned cylinders of phosphor-bronze to travel up and down the two 1/4 in. diameter columns. The block is fitted with an L-shaped piece of alloy to accept the piston rod at the top of the gudgeon pin, of phosphor-bronze, below. The gudgeon pin is screwed to the lower screw securing the L to the block. A well is milled in the top of the crosshead to oil the two columns and bearings.

The bearings are turned 3/8 in. diameter stock in the lathe and reamed. The holes in the block to fit are bored in the lathe at centre height to correspond with the holes in the saddle block. Mark with a scribe and an engineer's square two lines on the block the precise distance of the centres apart. Clamp the work on the cross-slide allowing for sufficient movement so that both holes may be drilled without unclamping. Find the lines with the tip of a centre drill before drilling through.

Fit the bearings on to the columns and slide up the block when all should fit together beautifully, and slide with a taste of oil. If they do not it is no good looking for a hammer. Check that the bearings are concentric; if they are not the block will have to be remade, clamping down really tightly this time. I have mentioned before that better clamping bolts can be made from coach bolts with their heads filed to fit the T-slot. If all is well mill the slots for the well, drill and counterdrill the holes for the 4 BA hex. cap head bolts; the bottom hole is



counterdrilled deep so that the threaded shaft is available for the gudgeon pin. Secure the bearings into the block with Loctite 601.

Cut the L-shaped block and drill for the securing screws and tap. Secure the piece to the block and slide up to the piston rod to mark the position for the No. 22 hole. Slide the motion down together to note that the position remains the same. If it doesn't you've done something wrong.

THE BED.

The bed is a piece of ¼ in. thick duralumin. Mark for the position of the two ¼ in. holes and lightly centre-pop. Measure the centres at the saddles for the distance of the support column away from each of the cross-head columns, and with the spring dividers mark each distance on the bed to obtain a cross for the position of the supporting column to be centre-popped. Drill the holes for the three-columns, and also through the edge of the bed for the securing screw of the support column; the other columns are eventually secured with Loctite. For the slot, drill the extremes with a ½ in. drill to saw and file out the rest.

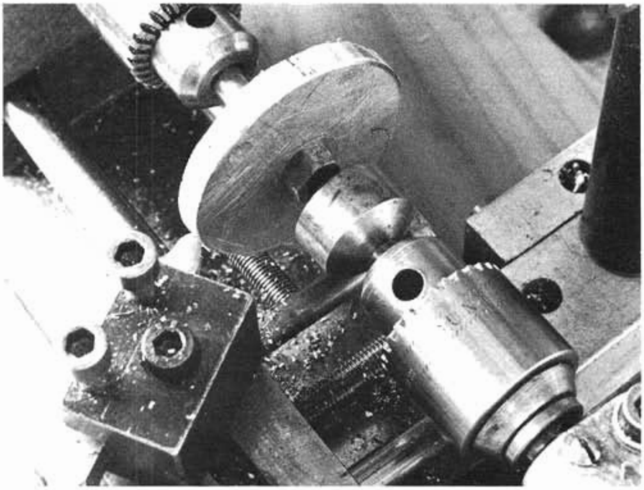
THE BEARING BLOCK

First obtain the ball-races. The ones 1 used were 1⅛ in. O.D. x ½ in. I.D. x ⅝ in. and for the big end race, ½ in. O.D. x 3/16 in. I.D. x 5/32 in. Try to get the right small size, but the bigger ones can vary without any bother, so get the cheapest.

Swing the block in the four-jaw chuck, jaws reversed with the extension piece under the headstock and toolpost, boring tool in place. First drill through with the largest drill the chuck can accommodate – 7mm. Then bore out to take two ball-races, plus just a little deeper to give a little space between for oiling.

Check the ball-races for fit before flycutting each end of the block square, and to size. Drill and tap for the securing screws, drill the oil well and a No. 58 hole from this to where between the ball-races will come. The bearings should be of the single shield type, and secured with Loctite 601. shields outside, unshielded sides together, with a small gap between. The ¼ in. silver steel spindle fits into a hollow shaft of dural to run in the races. The shaft is made in the lathe, and one end drilled and tapped for a 4 BA grub screw to hold the spindle. The hollow shaft is secured in the ball-races with Loctite 601.

The crank is a 2 in. disc of duralumin, made from ¼ in. thick stock, sawn out and drilled at 90 degrees in the three-jaw chuck, jaws reversed, to be secured on to a mandrel and the edges turned nicely. The small ball-race is secured by means of a 2 BA screw with about 3/16 in. unthreaded, and a brass washer holding the race away from the disc. The No. 22 hole for this big-end bearing is exactly ¾ in. from the centre of the disc, centre to centre, to give the throw of 1½ in. Drill a hole diametrically opposite the big end, from the circumference to the middle, No. 30, to be tapped 4 BA for a long hex. cap head screw. Loctite the disc to the spindle, and some hours later insert the screw and tighten right down. Check for wobble. Fit into the hollow shaft, add the 500 g flywheel, and try for ease of spin, apply oil to the well and make sure it leaks right through.



The crank disc is machined on a mandrel.

FINISHING THE MOUNTING

When flycutting the main bearing block it would have been useful to have fly cut the two hexagon blocks at the same time to the same length. Drill the bed No. 10 for the 2 BA securing screws and fit the three blocks. Make the base from some heavier material. I used a piece of 3/4 in. thick duralumin, but 3/8 in. mild steel would add more weight and give sufficient clearance for the flywheel. Set the engine on the base and mark out the positions of the screw holes, drill and countersink. Secure the columns to the bed using the locking screw on the supporting column and securing the others with Loctite 601.

CONNECTING ROD

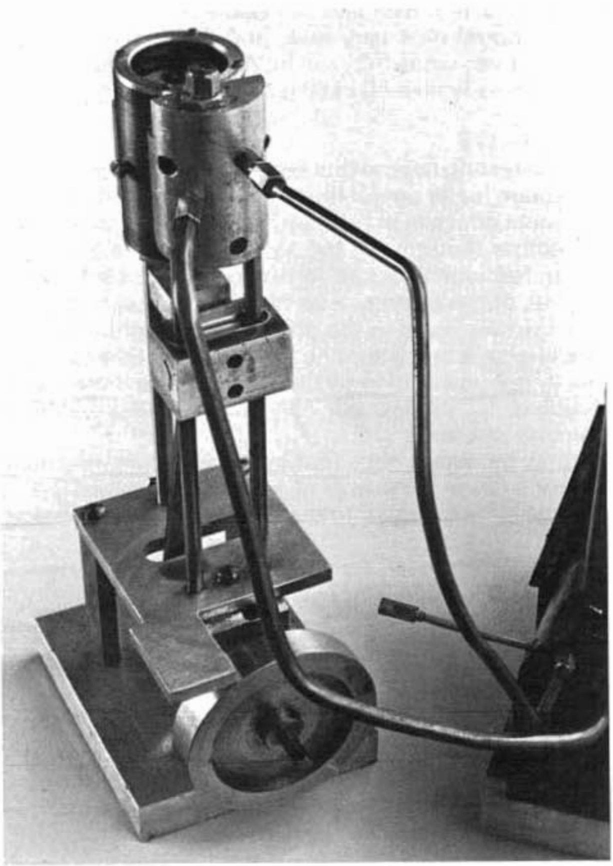
Screw the piston rod into the L-piece, leaving a couple of turns for any necessary adjustment later. Turn the crank to the lowest position and pull down the cross-head; measure the centres with a 6 in. rule. Turn the crank to top dead centre, push up the cross-head and measure again. The second figure must be the same as or fractionally greater than the first. Make the connecting rod centres the first distance measured apart, centre popping before drilling. The big end is drilled with a 1/2 in. drill and the small end with a No. 3 centre drill; the connecting rod is made from 3/16 in. m.s.

Mark out the shape using the holes as guides to get a good shape. Grind out to the guide lines, with goggles fitted to the eyes, and finish by filing. Drill through the extreme of the big end No. 43 for a 6 BA tap, and drill out the first half No. 30. Saw through at the half and file out a space for the hex. cap head of the securing screw, tap 6 BA. Check on the big-end bearing for sufficient tightening room, file out some of the sawcut if needed.

Make a gudgeon pin from phosphor-bronze turned in the lathe and drilled and tapped for 4 BA, with a sawcut at the blunt end for a screw-driver blade. Fit the connecting rod and give the complete engine a turn over to ensure that the piston throws the moving cylinder evenly at each end, adjust the piston rod in the cross-head if necessary, and wick in some Loctite to secure.

As the main bearings are ball-races there is little point in a preliminary running in with air, using a compressor. Go straight for steam. Make fittings for the engine to boiler, both for steam and exhaust. If the exhaust is not to be taken back at least fit a length of tube to the orifice or the condensate will fall into the motion oilwell, floating out the oil.

Fill the lubricator, motion oil well and main bearing well with Valvata and put a drop on the top of the cylinder, the big-end and the small-end. Steam up on



Connected up ready for running on steam

the boiler to an initial 20 p.s.i., and with the piston at the start of a stroke open up the regulator and the engine will either rotate at around 100 r.p.m., or oscillate at a similar rate. If it only oscillates it is a little tight, so close the regulator and get up a little more pressure before trying again. Run up to about 120 r.p.m.; there will be a little knocking upon the cylinder changeover, as this will be the tightest part until run in. Run the engine for about ten minutes at this stage.

Empty the lubricator with an eyedropper and refill with oil. Raise a steam pressure of around 50 p.s.i. in the boiler and gradually open up the regulator as the engine runs. The engine will need clamping down at faster speeds, but all the knocking will disappear. If knocking starts again with the simultaneous slowing down of the engine this will be caused by the flywheel, or some other part, working loose, so stop immediately and check. The engine develops quite a deal of power and can easily break something.

The model runs very well, and there is no sign of the cylinder falling by gravity, even when fully run in. When run in the engine will tick over at 15 p.s.i., and will really take off at 60 p.s.i.

THOUGHTS

It is interesting to note that since the engine does not employ any expansion of the steam for its power the regulator could be placed in the exhaust side, with the same effect as in the inlet, but without the heat loss and condensation.

Another thought, by the same precept, is that as the steam has not been expanded when passed to the exhaust it could be first supplied to another engine, of the same size as the one the steam is expelled from, and give the same power again to the other engine, without compounding, as long as the first engine is being supplied with steam at the high pressure and in phase. As I see it, the power then available will be as if the steam chamber volume was doubled, for power, but only using a single amount of steam, at a given working pressure.

I may be wrong but a four-cylinder engine, two feeding two, would provide towards twice the power of a two-cylinder version, but use no more steam. After all, this is similar to the way a compound engine works.

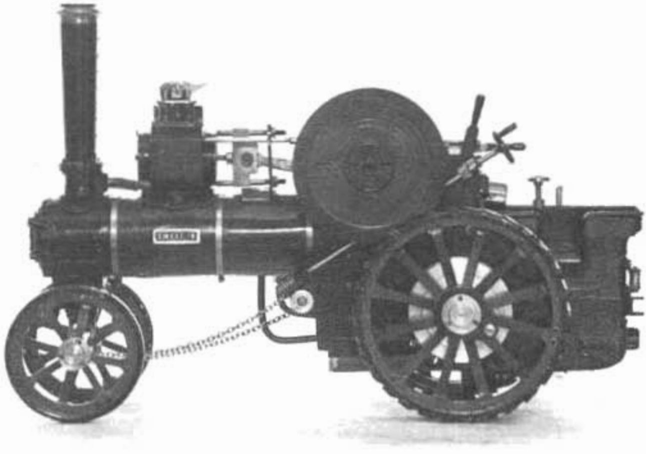
Chapter Nine

Sweet Sixteen

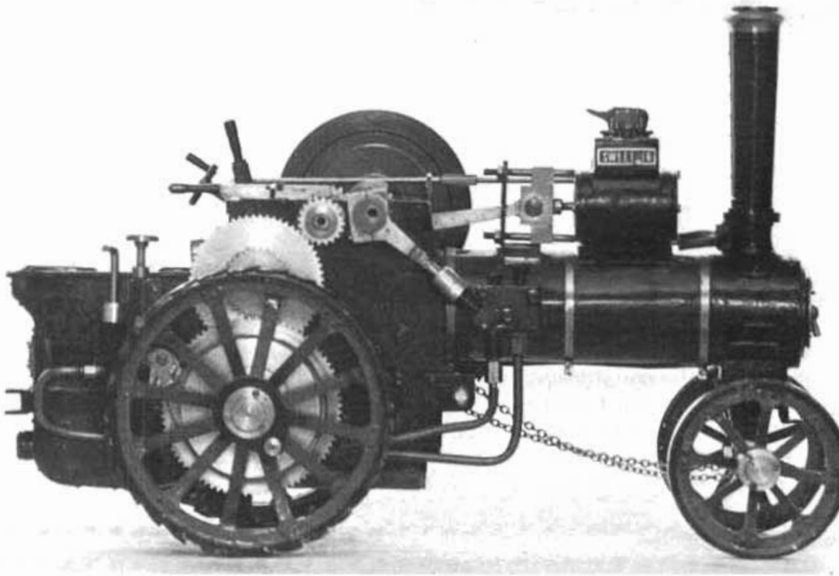
Section 1 – Introduction and the Boiler

I started the design of Sweet Sixteen in 1976, making it all on the Unimat SL. Every part presented something of a challenge and led towards most of the modifications and improvements which I have made to the Unimat. It was for this traction engine that the new type of valveless engine in Chapter 6 was designed with the consideration that the formal valve gear might be difficult in this small size. All this took time, time over and above the work of completing the engine itself, which was finished early in 1978. However, that design was spirit-fired and proved messy and perhaps a little dangerous as spilt spirit is not easily seen. The rear end has now been redesigned and firing is by butane gas, which has proved to be very reliable, clean and easy to handle, beside being safe.

All the parts of the engine are to be made, apart from the steering chain and the pressure gauge; the gear wheels are self- cut. The scale chosen is 16mm to the foot, hence the name Sweet Sixteen. In this scale a maximum rear wheel diameter of four inches is required, and this can be reasonably machined on either model Unimat using one of my modifications. Reeves can supply alloy castings for the rear wheels which will machine to just 4 in. with care (order



This attractive little traction engine is only just over one foot long



All the features of larger models are included in this miniature model.

Minnie front wheel castings), thus avoiding the long chore of turning wheels from solid – a long job on the Unimat.

Sweet Sixteen is a freelance design, and has most of the features of the full-size engine, but as stated it dispenses with valve-gear and eccentric, using a "valveless" engine with a self-acting shuttle valve system. The crankshaft is of the counterbalance type with webs, not at all like the old hammer- forged jobs really fitted; you may make one if you wish! The boiler is a simple stayless design a little slimmer than is usual, but with the pads for the motion and engine saddle on the outside, and after lagging and sheeting around the boiler is about scale size, with a slender teenage look. The "backhead" has water space, but the sides and front are solid copper, the double layer at the sides making the hornplate fitting very simple. This set-up is not suitable for coal firing, where it is necessary to have a water space all round, but with a tank-full of butane in the tender there is enough fuel for around 25 minutes running. I have had this engine running for 32 minutes at one time, which is rather longer than the small lubricator can provide oil for.

The engine is designed to be made cheaply and simply. A one foot length of copper tube and a square foot of 16 gauge copper will make two of these boilers with some to spare. Parts are generally made from block. For example, the feed pump is a brass block with inserted fittings: this means that the clacks

can be made and tested before inserting, Loctiting them into place. Bearings for the moving parts are nearly all phosphor-bronze, but just simple cylinders of the bearing metals inserted into metals easier to work, usually duralumin. The smokebox can be made from tube 1/8 in. larger that the boiler, or can be of the same diameter as the boiler, split and riveted to the brass rings before filling the gap and silver soldering. The chimney is taper-turned from duralumin, with a row of false rivets, but the inside is step-drilled, and the chimney top is turned from brass rod.

The front wheels are turned from solid dural stock, and the rear wheels from castings. The strakes and spokes are of mild steel, all riveted up with round hubs to be hard soldered. On the rear wheels oval hub plates are fitted either side to make them appear correct, and pretty little brass hub caps are fitted, turned from solid. The tender is riveted together from brass sheet, with a water tank Comsol-soldered in place, and the fuel tank sliding underneath presenting the fuelling valve at the rear end. The engine unit is the same as the one previously described, but modified with a saddle and steam dome, the exhaust being taken from the front directly into the chimney saddle. The motion work is mainly of mild steel, and the drive and change gears are cut from aluminium alloy. All of this is to be fully described in the course of construction.

The boiler, by the way, has only three fire tubes and, so that water can readily circulate from the rather isolated backhead space, two small diameter syphon tubes are fitted through the firebox, assisting the heating-up operation marvellously . Below the syphon tubes is a thick copper conduction block, to concentrate the heat in this area.

THE ORDER OF CONSTRUCTION

With my designs I try to determine the order of construction first by fabrication variations which may occur and alter positionings, secondly by the way interest must be kept alive, and finally by the sheer thought of the slogging necessary to get the thing constructed.

1. First make the boiler as everything has to fit around this, and pressure test, hydraulically.
2. Cut the gears so that the hornplates may be marked out to fit the bearings in the right places, make the hornplates.
3. Make the smokebox, chimney and boiler fittings.
4. Construct the engine unit, saddles, flywheel and crankshaft, fit them so that a test run can be carried out and the engine be seen to work.
5. Make the tender, boiler feed pump and by-pass valve, and with the gas burner make a further, self-contained run, and see the pump working.
6. Make and fit the wheels and axles, stand back and look at the lovely job. Lag, sheet, and paint the boiler and smokebox.
7. Fit all the spindles, change and running gears, plates, steering, winding and brake gear. Dismantle to finish everything and paint before final reassembly.

8. Complete a trial run on steam, taking care not to burn off all the paint.

Sweet Sixteen is fun to make and to run, is unique in design and quite simple in construction, giving many pleasant hours of soothing work on the Unimat machine, as well as the usual frustrations of fitting. It can be made on other small lathes as well, of course, as long as they can swing at least 4 in. So now to work.

SWEET SIXTEEN SPECIFICATIONS

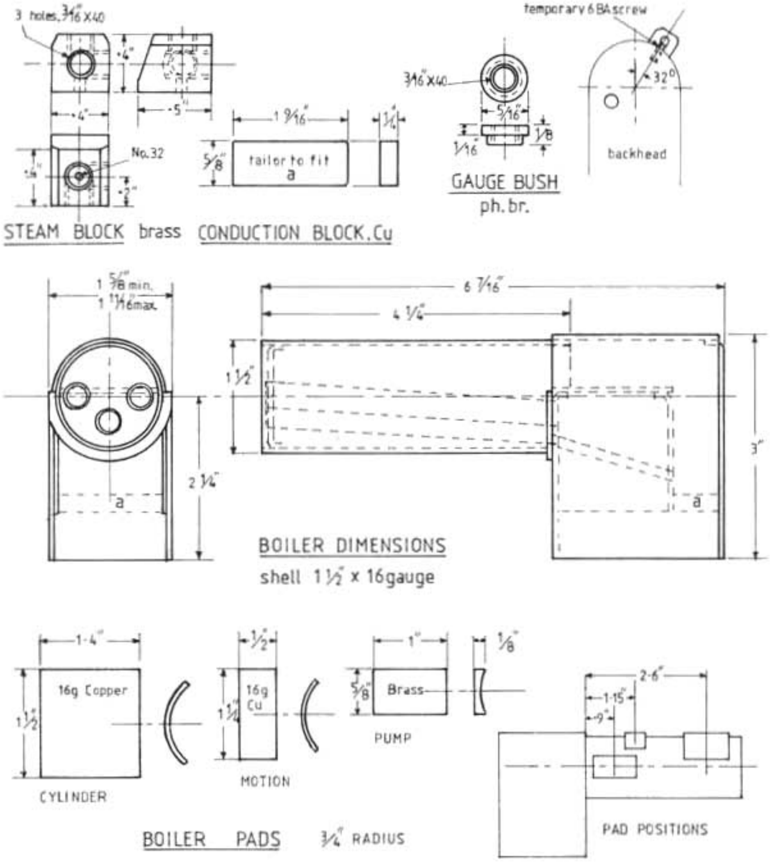
Length 12 in.
Width 6 in.
Height 7.9 in.
Rear wheels 4.1 diameter.
Front Wheels 2.6 in. diameter.
Wheel Base 7½ in.
Engine single cylinder, double-acting, ½ in. bore x .6 in. stroke
Flywheel 3in. diameter.
Boiler 1½ in. diameter. 3 x ⅜ in. firetubes and 2 x $^3/_{16}$ in. syphon tubes. Butane fired.
Working Pressure 40 psi
Gears Low ratio. 15.6 : 1 High ratio. 9.75 : 1

THE BOILER

Cut the length for the boiler shell, getting the ends nice and square, checking with an engineer's square. Use a 32 t.p.i. blade in the hacksaw frame for this job. Cut out the other pieces using 10 in. general purpose snips from a sheet of 16 gauge copper, following the economy cutting guide; do not worry about bends and buckles at this stage. Copper marks out very easily for this work with a sharp scriber, a 6 in. steel rule and small, spring dividers. Cut the firetubes from ⅜ in. O.D. copper tube, 20 S.W.G., and the syphon tubes from $^3/_{16}$ in O.D. x 22 S.W.G.. With all the pieces cut place them on the brazing hearth and, one by one, heat them up and then dunk them in a pickle bath, picking them up with a pair of old combination pliers. This both anneals and cleans the copper.

The pickle bath should be around 3% sulphuric acid (add the acid to the water when mixing from concentrated) and can be used in a plastic bucket for all the pickling work with small boilers: the sides of the bucket help to contain any splashing. Always rinse the hands, the pliers, and the work before proceeding. A pickle bath can be safely stored after use in a plastic jerrycan, and will continue to perform its function even when quite a deep blue colour.

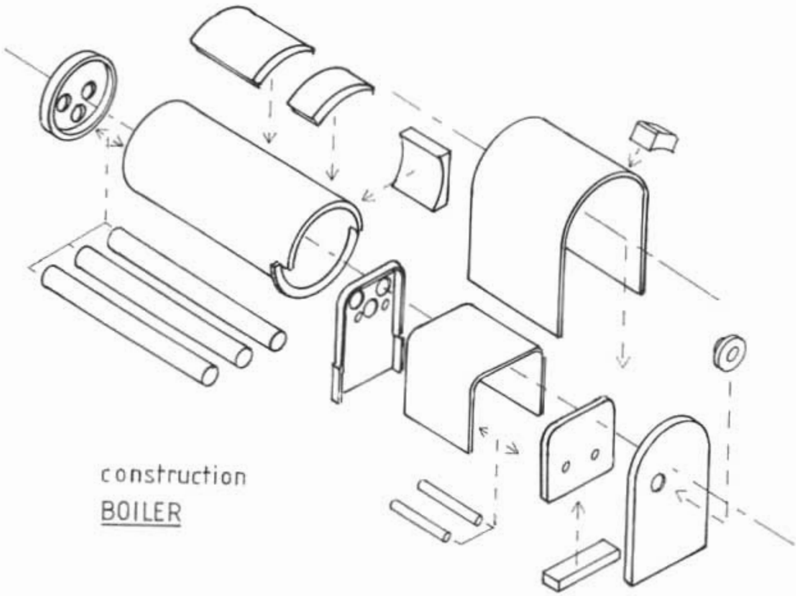
With the copper annealed, the parts requiring a flange will need working on before any holes are cut. For the smokebox tubeplate use a piece of 1¼ in. diameter aluminium alloy as a former, turning the end of the former square in the lathe. For small boilers all flanging can be carried out over formers held in the small vice using a medium weight ball-pein hammer. For rounded edges use softer alloy formers, and for hard straight edges use 90 degrees mild steel edges. 16 gauge copper can stand the filing off of small buckles etc.



BOILER

Flange the firebox back, using a piece of round mild steel at the corners. Fold the firebox wrapper around the firebox back and use the wrapper as a guide when flanging the firebox tubeplate; it has a step in its flange, either side, to come level with the firebox wrapper and provide a flat surface for the outer wrapper. If any flanging becomes difficult re-anneal the copper.

The backhead top can be flanged on the 1¼ in former, or a 1⅜ in. dia. more easily used here, bending the sides down to right angles when the round flange is halfway made, then finishing the round flange right down. The bottom of the box comes down a little too far at present, and will require cutting away, eventually, but this makes a good strong job with room for a little error. Do not flange the boiler barrel at this stage.



Drill out the plates for the firetubes and syphon tubes, remember that the tubes rise a little in the boiler, and make the holes for the syphon tubes a little undersize.

SAFETY FIRST

When brazing a boiler indoors have plenty of fresh air circulating, and avoid breathing fumes of flux. If the hearth is of asbestos use only pure white asbestos sheet, as used in fire doors, and not cement asbestos sheet as used in wall and roof sheeting as this will certainly explode when heated. Do not strip off to braze, and wear shoes, long trousers and a shirt with sleeves. Keep tools off the hearth where they can be heated up without noticing. Avoid working in bright sunlight where flame cannot be seen or red-heat readily observed. Wash off flux and pickle splashes from the skin immediately.

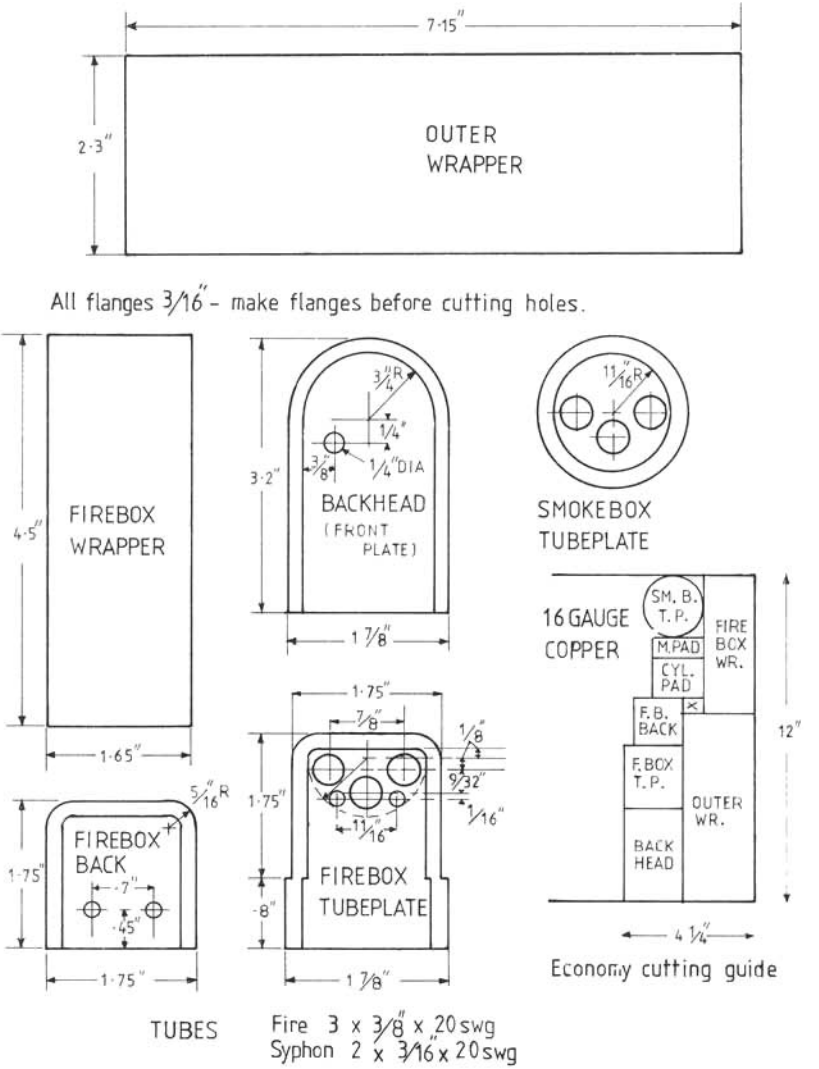
BRAZING

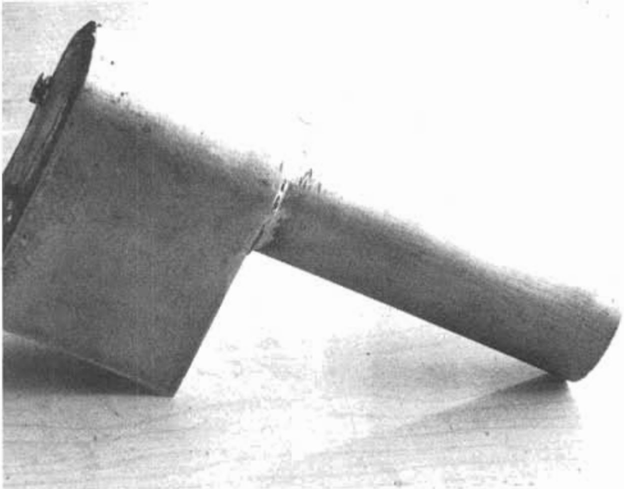
For small boilers a blowtorch using butane from a standard 10lb blue cylinder is sufficient. As the job gets bigger the increasing mass of copper makes the brazing need progressively more heat. To avoid the use of excessive heat a descending temperature range of brazing fillet is used.

Firebox and tubes C4 with Tenacity 4A flux.
Backhead and syphon tubes Phosphalloy. No Flux
Everything else Easy-flo No. 2 Easy-flo flux.

Closely fitting parts may move when heated, due to expansion, and so a certain amount of riveting is necessary. With this small boiler use 1/32 in. rivets; brass rivets will melt in with the C4, but if copper rivets are used they must be emplaced in flux.

Rivet the firebox backplate into its wrapper in three places, one on top and





The complete boiler before adding pads and fittings.

one each side. Before riveting the firebox tubeplate in place first fit the three tubes, bell their ends a little, slip a ring of C4 up to the bell and push the tubes right through, up into place. Using a small brush paint all the crevices inside and out with freshly made up Tenacity 4A flux, as a weak cream.

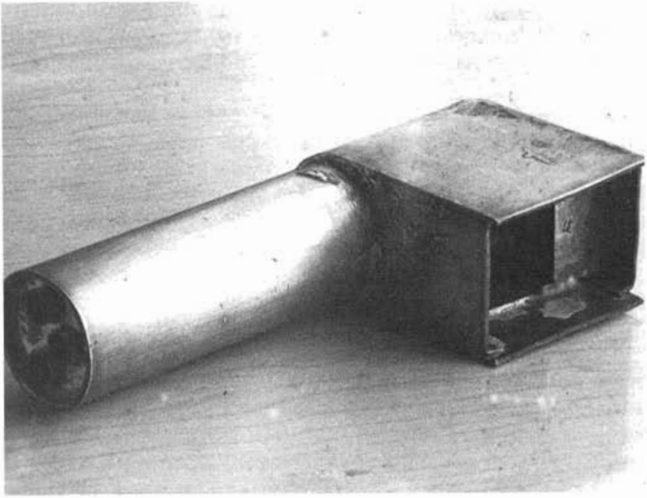
Slip the smokebox tubeplate on to the ends of the tubes to hold them in position; and place, one side down, on the hearth. Check that the pliers and a pointed steel prodder are on hand, not too near to get hot, and the C4 (also called Silver-Flo 24) is within reach with its flux.

Use a medium blowtorch, output nozzle aperture between ½ in. and ⅝ in, and on full blast put the tip of the blue cone of the flame up to the point where the tubes enter, from the outside, until the rings melt inside, with the flame moving a little all the time. Dip the C4 in the flux and run a fillet around the top of the firebox, and the sides which are down. Pick up more flux with the hot C4 and rebraze the tubes outside the box until a small bead hangs from each. Turn the work with the pointed stick, pick up flux with the hot stick and apply to the seams now down, followed by fluxed C4 with the flame to finish the box. Give a blow inside, up the tubes, until the beads, now uppermost, disappear.

Pick up the box with the pliers by the top side and drop it carefully into the bucket of pickle to leave it for a few minutes. Pick it out with the pliers and wash under the tap, with the pliers and the hands. The copper of the box and the tubes will be a bright pink with gold lines along all the seams, inside and out. File off any lumps from areas where flanges or wrappers will fit for the next braze. Enlarge the holes for the syphon tubes and fit these in place.

Rivet the backhead to the outer wrapper, one rivet on top and two either side. No flux is needed this time as the braze is Phosphalloy, and the annealed copper is clean enough to make a perfect job. Place the riveted work, backhead

The boiler on its side, with the syphon tubes just visible.



uppermost, on the hearth and cut a short length of Phosphalloy and place it at the start of one side. Heat up with the blowtorch and the braze will melt suddenly and flow to be followed around with more Phosphalloy and the flame, the braze going a bright silver as it flows. Pickle the open sided box, and bring over the firebox to braze in the syphon tubes from the inside, before pickling this again. Wash both parts.

EASY-FLO No. 2

The rest of the boiler is to be brazed with Easy-flo No. 2, which is a more expensive silver solder. However, it is not wise to be mean with the silver solder as it is false economy to make an expensive copper boiler which leaks due to shortage of silver solder fillet in the joints.

The wrapper is to be brazed, now, on to the sides of the firebox while being clamped tightly in place. Gauge the distance from the back by temporarily slipping the copper block in sideways; it has to be tailored to fit for its final positioning. Before clamping up one side apply a mean coat of Easy-flo paint to the inside of the wrapper and the outside of the firebox. Cut a length of the braze to fit along the inside top after clamping up the side to be uppermost, remove the block and slip another length of Easy-flo, this time down the back of the firebox on the unclamped side. Paint along the length of silver solder with Easy-flo flux.

With two $\frac{1}{8}$ in. mild steel blocks on the hearth place the unclamped side down and with the blowtorch heat from slightly below and into the box opening until the flux flows red and the Easy-flo runs neatly, by capillary action, between the copper surfaces. Turn off the torch, unclamp to turn upside down. With the pointed stick pick up the flux and run into the new gap,

cut the Easy-flo strips for this side, flux them well before manoeuvring into position for heating as before. The Easy-flo paint makes a good starter for an operation such as this, helping the additional silver solder to flow well. Pickle the work.

Take the strong, but well annealed, copper box and check that it is all square, and particularly that the sides of the outer wrapper are parallel, tapping carefully, using a flat wooden block as a protector, to gain perfect sides before fitting the barrel. If the sides are out of true it will make the fitting of the hornplates very difficult, and little correction can be made once the barrel is brazed into place.

Take a 1½ in. tube, and, against the brazed box, mark exactly for the half circle to enter the wrapper and carefully saw into the tube and across to leave the part for the flange standing. Flange over against a block of mild steel held in a vice. Check with the barrel in the box to ensure a flat fit with the top and sides parallel. The trick here, to ensure perfect alignment, is to braze the smokebox tubeplates and tubes first, pickle, and then realign with the barrel being held by the firetubes during brazing.

Use plenty of silver solder at the smokebox end, well fluxed, and have about ½ in. of the three tubes projecting, to be sawn off later. When brazing the flanged shell, after realignment, flux and then tap gently all around to tighten the copper together. Use slips of 16 gauge steel, on a flat hearth, to keep everything lined up when hot. Assist the flow of the silver solder at each end with the help of the pointed stick, assisting the formation of a good fillet.

After pickling and washing, drill the holes for the backhead bush and the steam block securing screw, and then tailor the copper block to a perfect fit, underneath. A slight angle filed on two sides, forming a fraction of a wedge, is helpful when carrying out this operation. Flux the inside and the block, before pressing and tapping home. Prop the boiler upside down and cut a length of Easy-flo No. 2 to fit along the back edge. Heat the block from one side, concentrating the flame on the block and when the flux, then the braze, flows, prick the Easy-flo right around, liberally adding more, well fluxed. Pickle the boiler allowing it to fill quickly (that's why the holes were made first). Make the water gauge bush and silver solder it into position. Tap the steamblock hole 6 BA, and the bush 3/16 in. x 40.

TESTING THE BOILER

The first test of the boiler can be a pneumatic test using an air pump. Make an adaptor into the water gauge bush and fit a 6 BA screw with a soft washer into the steamblock hole. Totally immerse the boiler in a bucket of water and pump up with air to observe lines of bubbles emerging from any leaks.

The hydraulic test can be made straight away and is essential for safety when using the boiler under steam pressure. Use a ram-pump together with a full-size pressure gauge; I use a 2 in. gauge, O to 200 psi. Open the top screw and pump water into the boiler (it will have to be connected up with copper tubes) until the water emerges from the screwhole, shake a little and pump

again to release air-bells. Screw up and pump up to 50 psi. Wipe up any water around the boiler and if no leaks are apparent take pressure up to 100 psi and leave it at this pressure for at least five minutes. If everywhere is still dry take the pressure up to 150 psi, when the back will bulge a little. This is about three times the pressure that the boiler will raise in practice, and gives an excellent safety factor: the boiler stands this pressure, and I actually went to 180 psi with no effect. If a weep of water does appear, mark the spot with a circle of dye marker to be rebrazed after picking out the hole with a sharp point and fluxing well. If a definite flow occurs anywhere, this will need to be drilled into, plugged with a fluxed copper rivet and rebrazed.

FINISHING THE BOILER

The motion and cylinder pads are made from copper sheet, annealed and tapped to the curvature around a 1½ in. diameter; finish with emery around the same former. The pump pad is of brass, one surface taken down on the emery cloth around the same former, the other side being finished on fine emery cloth held on flat glass. Make the steam block, which is fitted with a brass screw after painting with Easy-flo paint. Paint the copper pads and secure them both in place with a single copper rivet, just pushed through centrally, after drilling.

Place the boiler, nose down at a slight angle, on the hearth and locally heat each part in turn, applying a little stick Easy-flo down the angle. Pickle, wash and examine by scratching all around with a needle point to ensure that there is a fillet of braze all around each part. Turn the boiler on its side and braze on the pump pad, no rivet this time, and check as before.

Drill through the steam block, No 30, taking care to avoid the other threads. At this stage a blowdown valve can be fitted, if required, into the underneath of the copper block.

Criticism has been levelled against the use of brass fittings on copper boilers as electrolytic action may result, causing deterioration of the brass over the years. Providing only distilled or purified (de-ionized) water is used then brass fittings can be safely used, particularly since prolonged, high temperature use of this small boiler is out of the question.

Chapter Ten

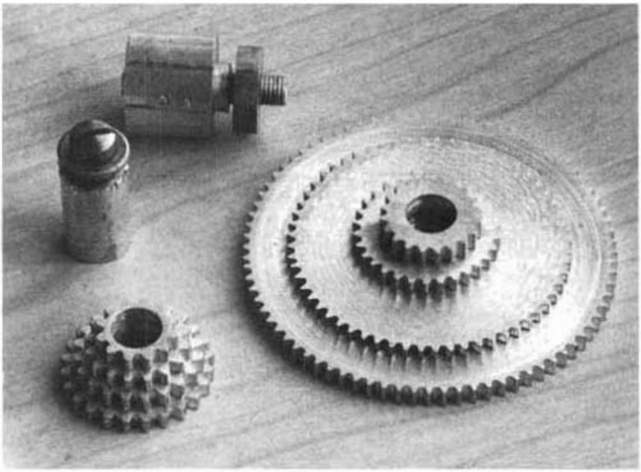
Sweet Sixteen

Section 2 – Gears, hornplates, smokebox, chimney, saddle, perch bracket, engine unit.

The gears are cut with home made cutters on aluminium alloy blanks, using the indexing attachment. The change gears are cut eight teeth to the inch and the drive gears ten to the inch. These differ from standard gears, as bought, which are cut to have a certain number of teeth related in size to the pitch diameter. My system cuts a number of peripheral teeth per inch and allows the diameter to find itself, But ratios are ratios, and it works out to be very similar in the end. Generally it should be said that gears cut with the same cutter will tend to run well together. The cutters employed here are straight hobs, made from silver steel then hardened and tempered. The hobs have five sets of cutting teeth, and make a gap, centrally, rather than a tooth, the other cutters each side modifying the tooth shape as the blank is indexing around, as detailed in chapter 3.

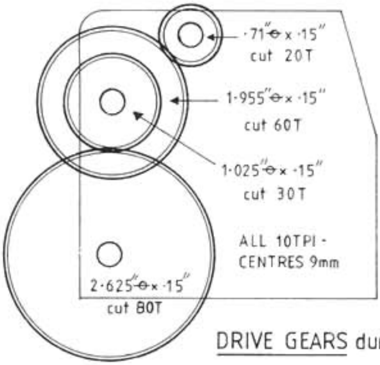
CUTTING GEARS

The gears are cut from aluminium alloy blanks either sawn from round stock or cut from sheet. If sawn from the round, make them overthick, drill the centres 1/4 in. the three-jaw chuck and turn as much as the jaws will allow, and

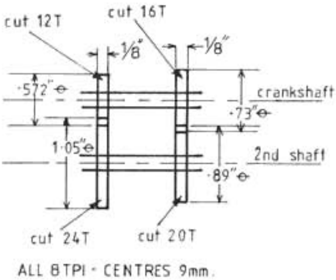


Drive and change gears, with the turning and gear-cutting mandrels.

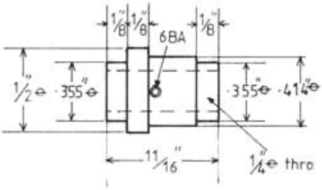
GEARS and CENTRES



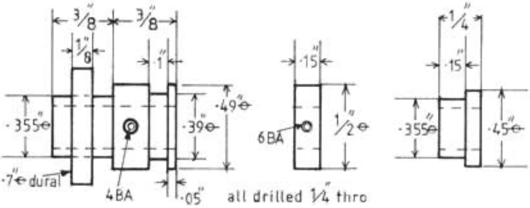
DRIVE GEARS dural



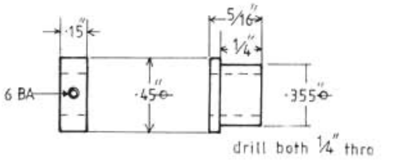
CHANGE GEARS dural



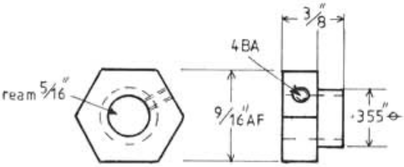
CRANKSHAFT GEAR CENTRE brass



2nd SHAFT GEAR CENTRES and COLLAR brass



3rd SHAFT CENTRE and COLLAR brass

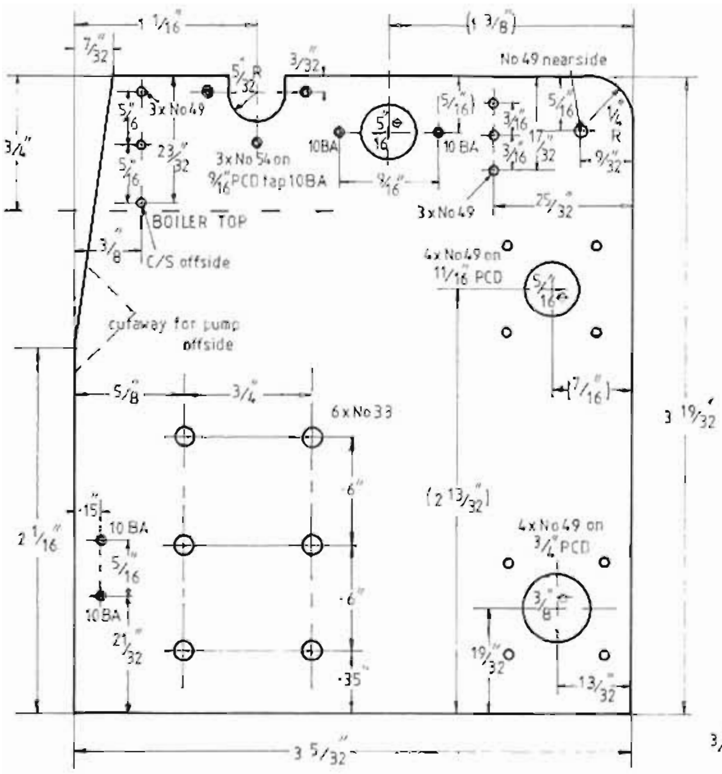


REAR AXLE GEAR CENTRE brass

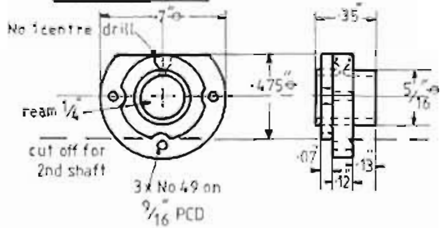
reverse on to a 1/4 in. mandrel for completion of the other surface and turning the periphery to size. This is made easier if each job is completed on all the blanks before going on to the next stage. If the blanks are made from sheet material, just mark out, drill the centre 1/4 in. for the mandrel and rough-cut the circle to be finished on the mandrel.

Finally with all the blanks made the centres are drilled out to 9mm and a 9mm mandrel made for cutting the teeth on each. The teeth are indexed on to

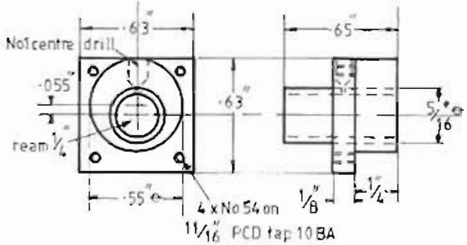
HORNPLATE 2 off 16 swg bms



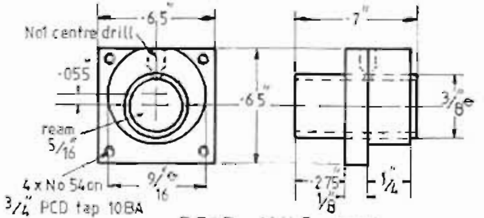
BEARINGS dural.ph br inserts



CRANKSHAFT & 2nd SHAFT 2off each



THIRD SHAFT 2off



REAR AXLE 2off

the blanks, the requirements being covered by the plates available for both Unimats. With the 60 tooth and the 80 tooth wheels the requirements are met by the 30 and 40 position plates and the cutters will have almost completed the intermediate tooth-gap the first time around, so that there is little difficulty in finding the correct positioning for the second cutting operation.

A tooth is cut so that the cutting hob just bottoms on the diameter of the blank, needing perhaps two passes on the soft alloy, noting each time the final handwheel position, which should be the same. Any minute turning variation of the circles will be equalized on the 9mm mandrel in the cutting, and the shape of each tooth modified as the next gap is indexed around. Take off any burrs on fine emery cloth, and, using number punches, lightly mark the number of teeth cut on each wheel for easy identification.

Make two 9 mm alloy centres, just stubs, with light centre pops made in the lathe using a No. 1 centre drill. These stubs are for pushing into the gear wheels to determine the combined radii of two wheels running together, so that the hornplates may be accurately marked out.

THE HORNPLATES

The hornplates are made from 16 gauge mild steel. Marking out will need to be accurate, and made more apparent on the hard steel by using marking-out blue, which can be made by adding aniline dye to french polish. Tool requirements are a sharp scriber, a 6 in. rule to 64th of an inch, spring dividers, a 4 in. engineer's square and two centre punches, one at 60 degrees and one at 90, both newly sharpened.

Cut the pieces of sheet steel $3^3/_{16}$ in. x $3^5/_8$ in. and finish one long side of each straight and true. Blue one side of each and mark out for the six holes, in the same place on both, using the engineer's square against the true side and measuring from this front side. With the 60 degree punch lightly centre pop the top left and bottom right of the six on both plates, feeling for the crossed lines with the sharp punch. With the dividers set to the two pops on one plate, check that the distance matches that on the other plate. Pop with the 90 degree punch and drill the two holes on each $^1/_{16}$ in. for eventual riveting together of the plates. Mark out one plate completely for the nearside, ringing around the top steering bracket hole with black marker to indicate that this is not to be drilled through both. Centre pop lightly with the 60 degree punch, check all measurements before re-punching with the 90 degree punch.

For the bearings a detailed routine is necessary. Mark out the centres, on the hornplate, for the crankshaft and the main axle and lightly pop them to give the dividers a hold. The crankshaft hole needs the surplus given on the long side above it for the easy drilling of a round hole before the top is brought down. Draw the vertical line for the second shaft bearing at the bracketed position shown. With the short alloy centres in one pair of change gears, flat on a surface, measure the distance between the centre points with the dividers, checking with the other pair of gears, which must be the same. Transfer the measurement as an arc through the vertical line using the crankshaft pop as a

centre. Repeat the operation with the main axle gear and its drive gear from the third shaft, just making an arc drawn with the rear axle centre as axis. Repeat for the second shaft drive gear and the third other gear, using the found second shaft centre on the vertical line as the axis for the dividers, and find the third shaft centre on the arc. Check the distances against the drawing and mark in any discrepancy to remember it when fitting the tender.

Clamp the plates together, marked out side uppermost, fronts in aligment and two rivets through the holes, and rivet together. With the clamp still in place drill the three backplate holes and rivet one of these before unclamping and drilling all the small holes. To drill the large holes the plates will need clamping to the milling table, preferably, and on a piece of 3/16 in. thick dural. Use a slower speed and lubricate with soluble oil, about 20:1

In the vice saw and file the plates to finished size. Pop the bottom rivet hard, with the 90 degree punch and drill out No. 33, centre pop the other rivet in the sixth hole but clamp the plates together before drilling this one No.33. The other rivet will just pull out of the oversize holes as the plates are pulled apart. Drill the extra hole in the nearside plate, and countersink the lower spectacle plate hole for pump clearance. Tap the holes, as required.

BEARINGS

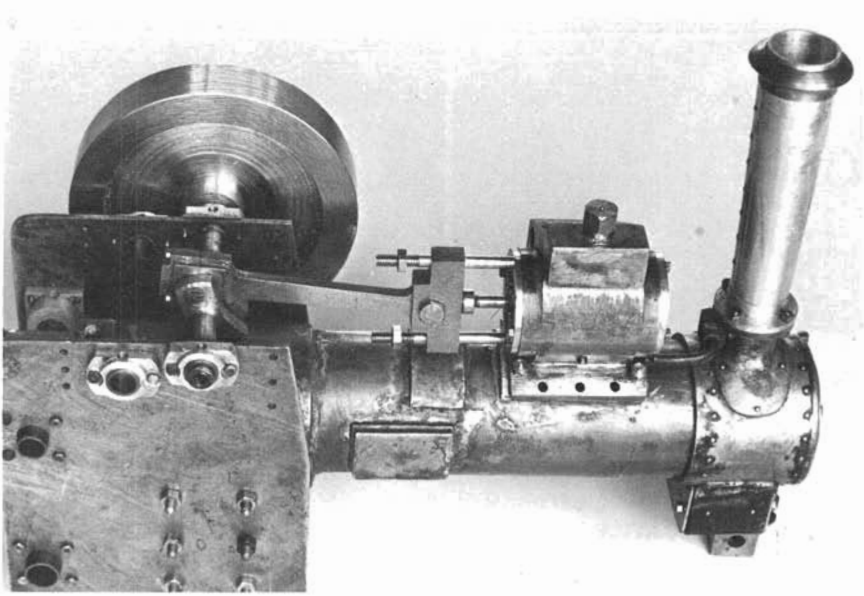
The actual bearings are made from phosphor-bronze round stock drilled in the lathe and reamed. They are then inserted into prepared alloy bearing blocks and secured in place with the bearing fit grade of Loctite. When cured, an oil hole is drilled through into the bore with a No. 1 centre drill, forming a small well leading to an oiling hole.

The cylindrical bearings are not easily drilled as phosphor-bronze will suddenly overheat and grip the drill, slowing the Unimat to a halt. Cooling with very dilute soluble oil helps a little, as does the frequent withdrawal of the drill. Start with a drill about 5/32 in. after centre drilling, and drill right through before redrilling to 1/64th undersize. Ream through with the work held in a clammed vice.

The blocks are made from dural stock; for the crankshaft and the second shaft from 3/4 in. dia., and for the third and rear wheel shaft from 3/4 in. square. The round four are all made using the three-jaw chuck, and the square four using the four-jaw chuck, with some filing and sawing by hand on all four sets.

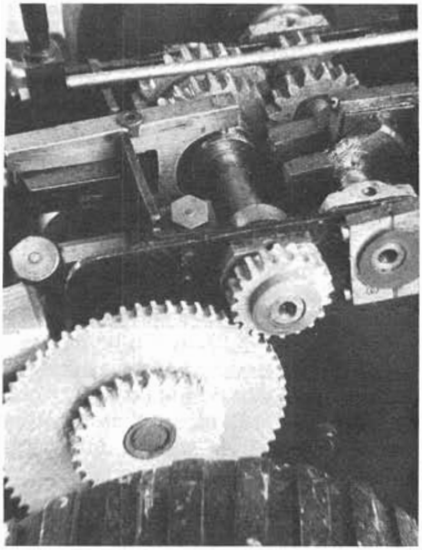
FITTING THE HORNPLATES

The fronts of the hornplates come level with the front of the wrapper, but the placing in the horizontal plane can be troublesome. However, here the problem is solved very simply. A piece of hardwood is milled on the milling table exactly 3/4 in. thick, and exactly the width of the boiler wrapper, one end is squared off and the block is cut to 1 7/8 in. long. Clamp the hornplates either side with the two lower bearings fitted to each plate and slide a length of 1/4 in. silver steel into the third shaft position and 5/16 in. dia. in the main axle bearings, using a little oil for ease. If all is lined up correctly the rods will fit and turn easily in the bearings, if not, then a loosening of the clamp and an

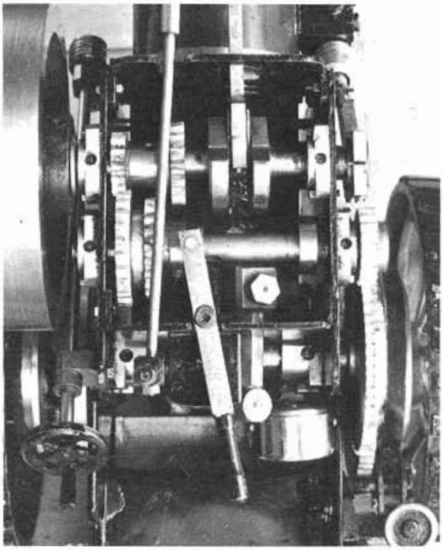


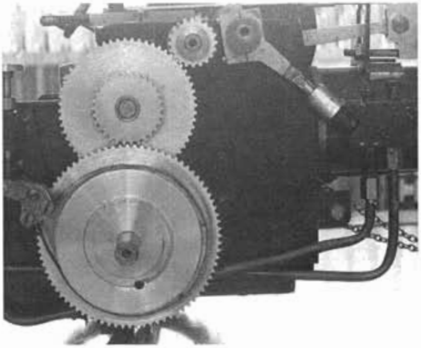
The boiler at a more complete stage.

The completed gear assembly.

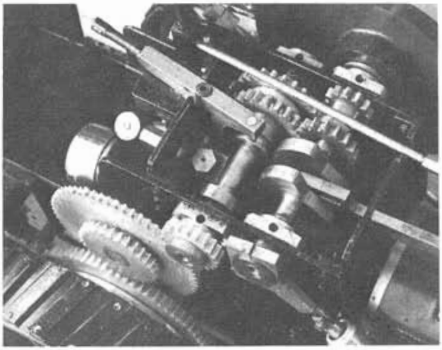


Looking down on the gears, in low.





The drive gears.



The gear change in high.

adjustment before retightening will do the trick. Insert a couple of small wood screws either side into the block from two of the plate holes.

This whole set up can now be slid over the boiler, lining up the hornplates with the front of the wrapper and with the wood block hard down on the top. Fit two small clamps to the lower edges, one either side and the temporary axle can be removed so that the six holes, either side, can be drilled in situ, or marked out to be drilled after removing the plates.

Make the twelve hornplate spacers and use ½ in. x 6 BA high tensile steel screws to secure through from the inside of the boiler firespace. Try the hornplates in place, securing them on the outside with steel 6 BA nuts; the screws can be cut down to size later. Measure all round to ensure parallelism.

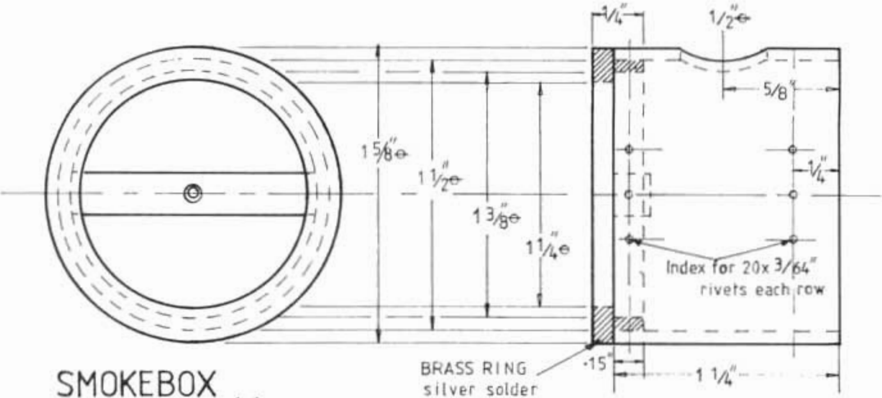
All the bearing blocks can now be secured to the hornplates and lengths of silver steel passed through all the bearings to check for line-up. The gear centres and collars are now required to be turned from round brass, the gears fitted tightly on the 9mm stubs. Put the gears, complete with centres, on the shafts to check them for good running. With the change gears there should be a neutral position centrally between a tight change-over from low to high ratio.

Second and third shaft details are drawn on page 154.

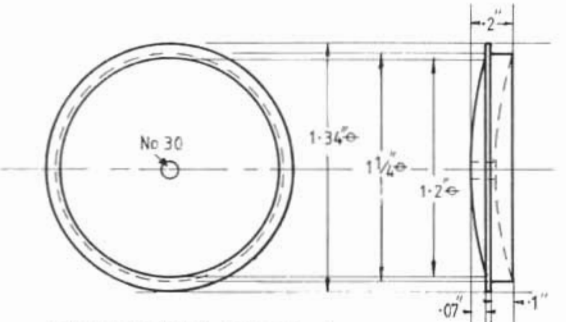
THE SMOKEBOX

The smokebox is made from 16 gauge copper tube with a brass annulus at the front. For the easiest constructed smokebox the tube to use is 1⅝ in. diameter, which will only need the ring brazing in to stay the correct shape. A more economical smokebox is made by splitting the 1½ in. diameter tube, as used for the boiler, annealing the split tube and using the brass ring and a slender circle of the tube just pushed in place temporarily, to obtain the correct circle. Afterwards a piece of the 16 gauge copper is tailored to fit the gap, and, with a short and overwide piece riveted to go inside, this is silver-soldered in at the same time as the ring, removing the thin circle beforehand.

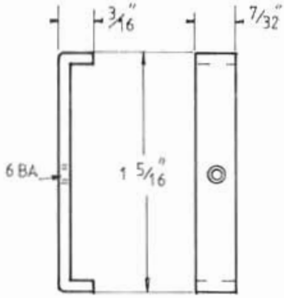
After brazing and pickling the round box is indexed around for the rings of rivets with the 20 position plate (40 tooth plate on the SL). The rivets are



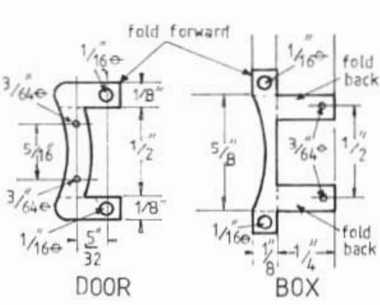
SMOKEBOX 16swg copper



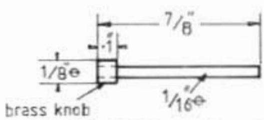
SMOKEBOX DOOR brass



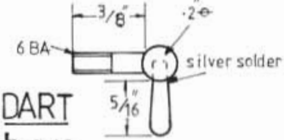
BAR 16swg brass



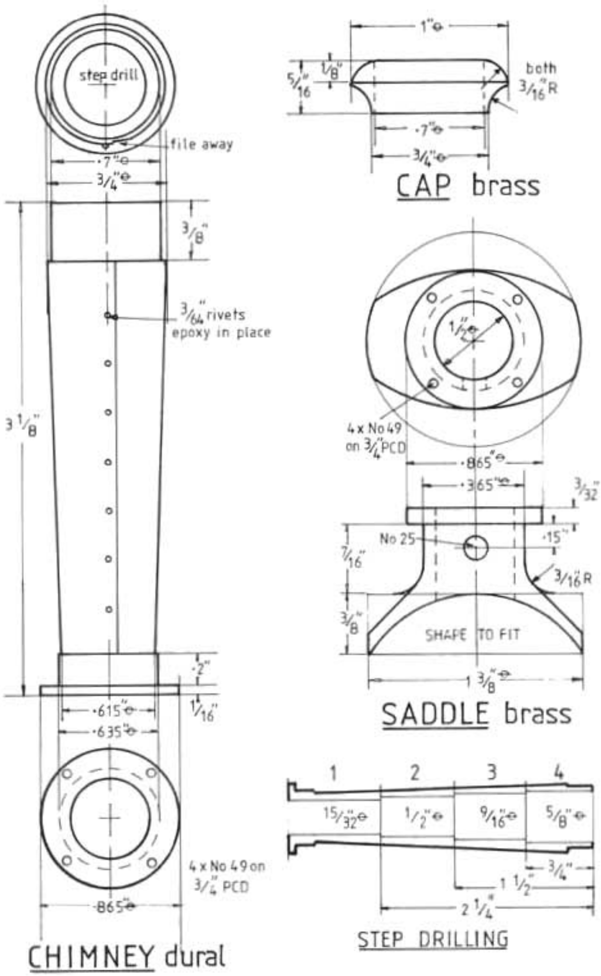
HINGE 16swg brass



HINGEPIN st st



DART brass



emplaced with Easy-flo paint, and do not need riveting over. The only rivets which are actually used merely keep the bar and hinge in position while they are brazed in, at the same time as brazing the other rivets. The back row of rivets correctly positions the smokebox on the boiler when it is eventually secured. Avoid any surplus fillet on the outside of the box or inside the ring, where the door will fit. Drill the top hole, opposite the copper insert.

Make the door from round brass, turning a 1 in. long piece in the three-jaw chuck and making the flange to be a perfect fit in the smokebox ring. Hollow

out the back, manipulating a good cut across with minute variations of feed. Centre drill No 1 and drill No 30 about $\frac{1}{4}$ in. deep to bring up the live centre and parting off at about $\frac{3}{4}$ in. Put a ring of thin dural around the flange and secure it in the chuck, bringing up the centre hard, before tightening up. Take the centre back, measure from the chuck jaws and turn the front of the door correctly, producing the domed front by manipulation, as before. Use a small round-nosed tool for this.

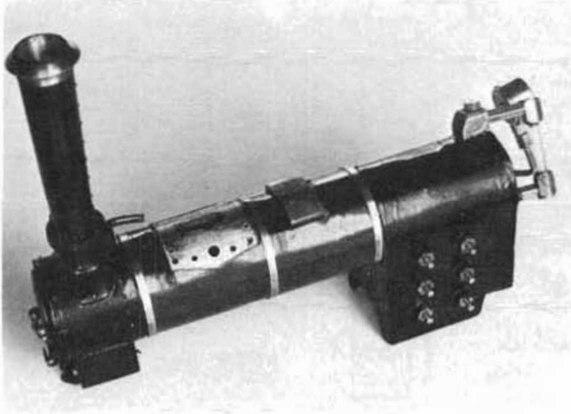
If difficulty is experienced with folding the hinge then make a cardboard model first and try this in place. The door half fits inside the smokebox half. With the door in the ring, drill lightly through into the bar, smokebox back on the cross-slide, and tap the bar 6 BA. Make the dart and try it in place.

THE CHIMNEY SADDLE

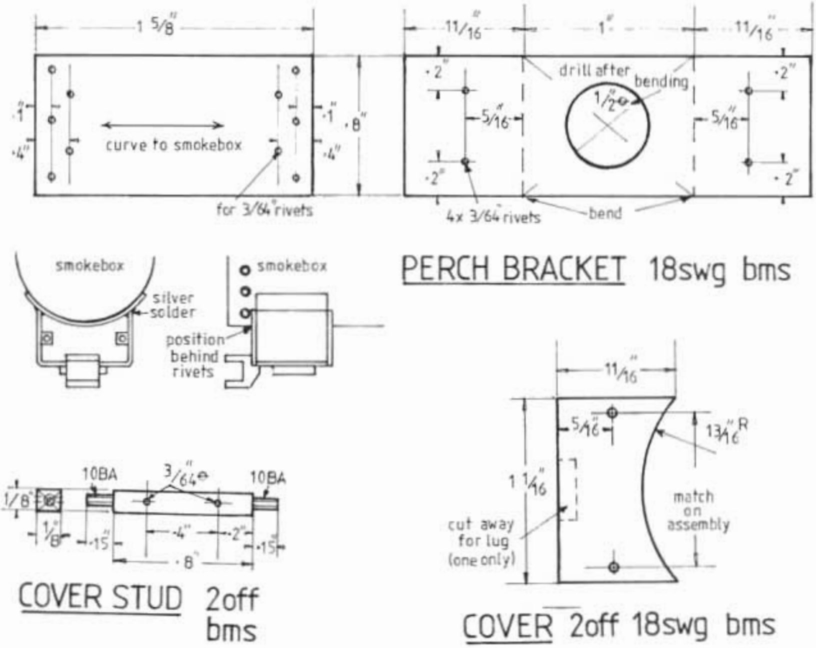
The chimney saddle is turned from $1\frac{3}{8}$ in. dia brass in the three-jaw chuck, jaws reversed, and held by the live centre in the tailstock. The top, flanged part is turned down and the $\frac{3}{16}$ in. radius made with a round-nosed tool before the $\frac{1}{2}$ in. bore is made through. The saddled part can then be either flycut to fit the diameter or filed by hand, in both cases further work by hand will be necessary.

The handwork on the brass will need new files if enough metal is to be removed, then a suitable diameter, covered with emery cloth, will give the correct finish to the saddle, but ensure that the saddle, in situ, keeps its top flange parallel to the smokebox line, or the chimney will tilt. When the saddle is right, file away the corners right down, to present a nice line. Clamp through the smokebox and saddle with a nut, bolt and washers, and drill for a pattern of rivets through both. Determine the back centre relationship of the saddle to smokebox and mark for the exhaust fitting; make the fitting and blast nozzle, drill the saddle.

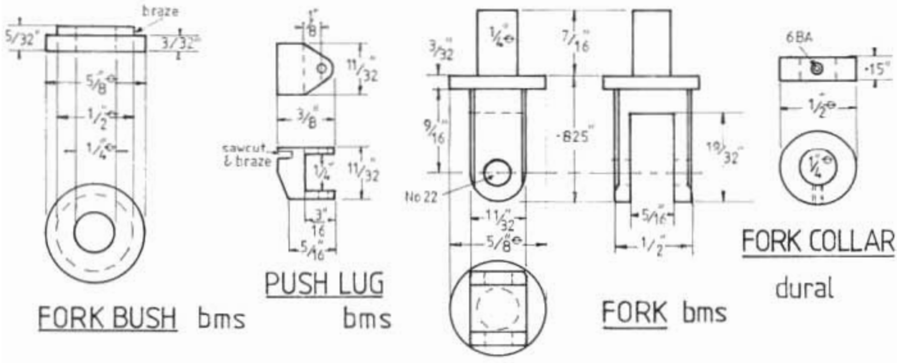
Boiler, smokebox, chimney etc. finish painted.

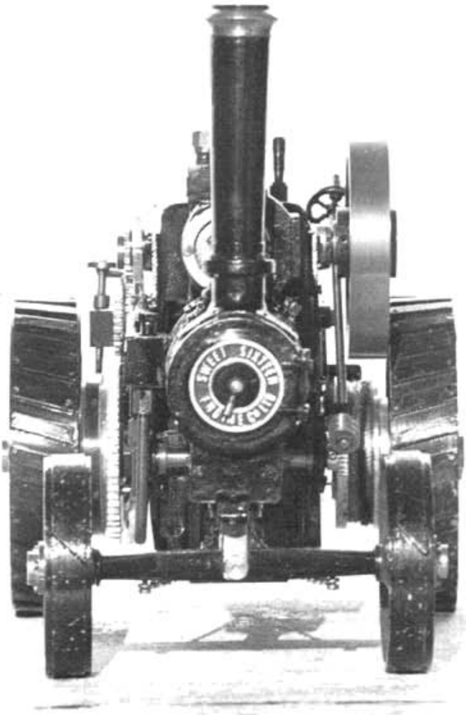


Smokebox and perch bracket.



Paint with Easy-flo paint and insert the fitting from the outside and the nozzle inside into the fitting, clamp with a small G clamp. Braze the nozzle and fitting securely in the saddle, ensuring that the nozzle will point straight up the chimney when fitted. Pickle, wash and place to one side until the perch bracket is made.





Although not a scale model of a particular prototype 'Sweet Sixteen' captures the proportions and charm of a typical traction engine. Height is not quite 8ins, width over hind wheels 6ins.

THE PERCH BRACKET.

The perch bracket is made from 18 gauge steel sheet, as shown in the drawings. Bend up and saddle the bracket and make the studs, push lug, and fork bush. Braze the bracket to its saddle with Easy-flo 24, using Tenacity 4A flux. Rivet on the cover studs, flux for the lug and bush and push these in place. Paint a touch of Easy-flo paint along the studs, and braze up the bracket fitting with Easy-flo No. 2, with only the paint for brazing the studs.

Position the perch bracket on the smokebox so that when the front cover is in position it will just be against the front rivet. Drill the holes through into the smokebox, and then paint the bracket and the saddle with Comsol paint and secure them to the smokebox with rivets, just pushed through, and bent over a little in the smokebox space. Heat the smokebox with a moving flame until the paint runs, applying a little stick to fill any obvious gaps. When the solder just sets plunge the box in a bowl of cold water to remove flux.

Make the back and front perch bracket covers to fit, and secure in place with 10 BA nuts. Remove one cover and wipe over all the steel parts with an oily rag.

THE CHIMNEY.

The chimney is made from 1 in. or 7/8 in. dural rod, sawing a length 1/8 in. oversize and centring both ends and centre drilling. With 1/4 in. of the rod in the three-jaw chuck and the other end with the running centre in the tailstock turn the length available down to 3/4 in. Remove the tailstock and fit the steady. Set the headstock just under 2 degrees back (Unimat SL) and with the steady holding off-centre, at about 1/8 in. from the end, turn the taper from the .375 in. down to the .2 in. shown on the drawing. With the Unimat 3 the taper turning attachment is used.

Using a length of rod through the tommy bar hole in the main spindle, secure the chuck against turning. With a pointed tool in the toolpost, angled forward, make a groove along the chimney, taking off about 2 thou. each pass (unplug the motor when doing this job). This groove represents the joint in a real chimney of overlapping iron sheet. The groove can be improved later by running a file along one side.

Return the headstock straight and the steady to hold concentric, and drill down 2 1/4 in with the 1/2 in. drill, following with the larger drills for the shorter distances. Bring up the tailstock and the larger diameter live centre and turn down the top of the chimney to .7 in. Reverse, wrap brass shim around the finished top, and hold in the three-jaw. With the steady holding near the end turn the chimney to length and drill through to the 1/2 in. bore 15/32 in. Remove the steady, bring up the large live centre and turn the part above the flange.

Carefully mark for the PCD holes, using a centre square and rule, and drill. Mark for the seven rivets, drill and push rivets in place, bending over the ends inside. Turn the brass cap from a short length of 1 in. dia. stock. Finish the end, centre drill, bring up the centre in the tailstock to turn the top radius with a round-nose tool by manipulation of the handwheels, then the lower radius. Drill 3/8 in. deep with a 1/2 in. drill and bore out to .7 in. before parting off. Secure the chimney top with epoxy resin.

THE ENGINE UNIT

I have previously described the engine unit as a self- contained engine rather than one saddled and domed, and fitted to a traction engine.

At this stage it is a sound idea to complete the engine in its original, complete form, with the bed and flywheel (which will be used on the engine anyway) to run it on compressed air, or with steam, to get the feel of the little beast before completing any modifications to adapt it for Sweet Sixteen. If this side- step is required then go right on to make the motion, fitting it all to the bed shown in the drawings, and running it, after which the further modifications can be carried out to the block, and the saddle made.

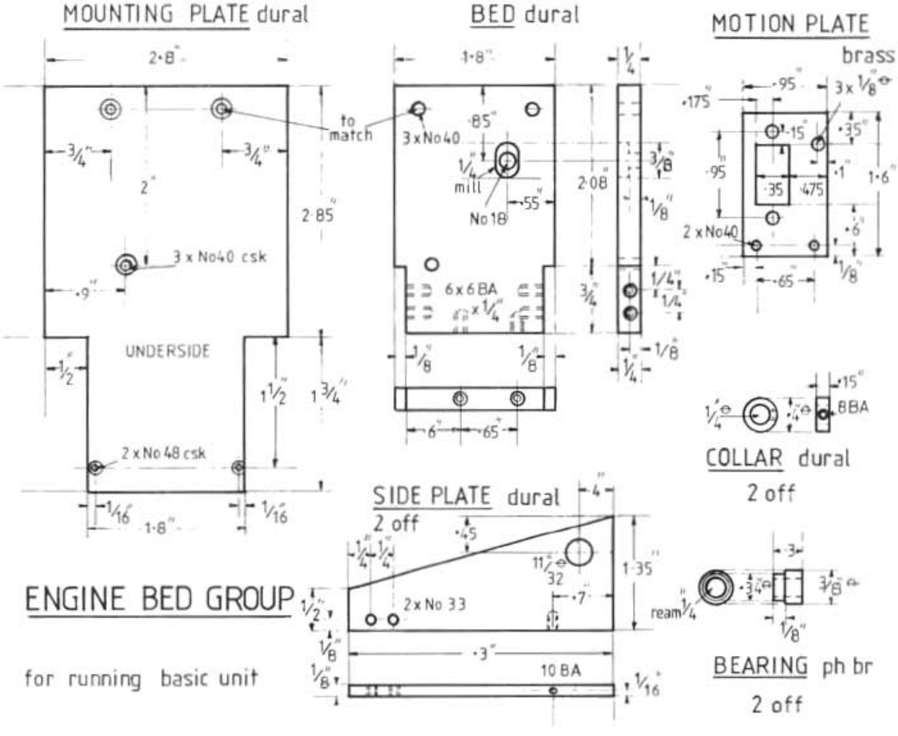
MODIFICATIONS TO THE CYLINDER BLOCK

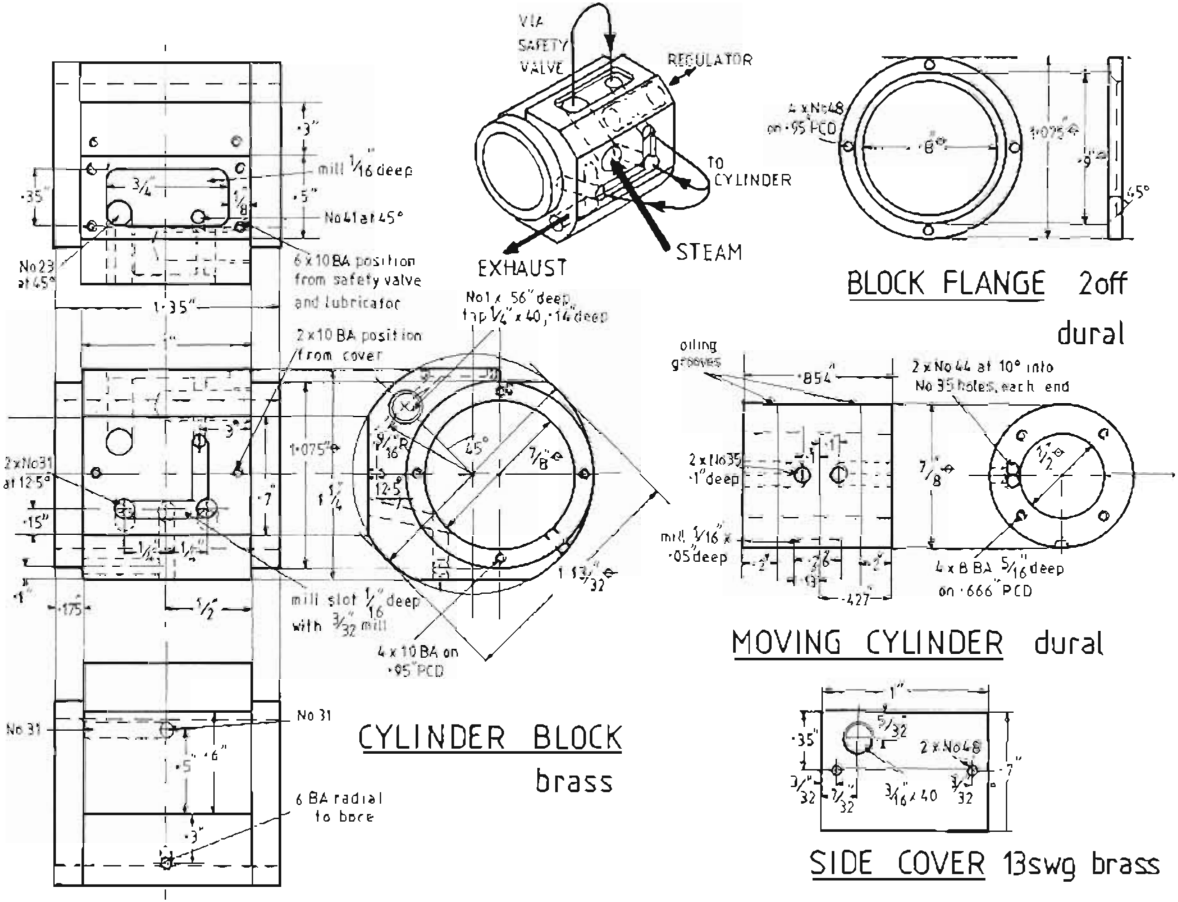
The basic engine unit now needs to be adapted to fit the boiler of the traction engine, and this work is all carried out on the cylinder block, including the addition of a saddle.

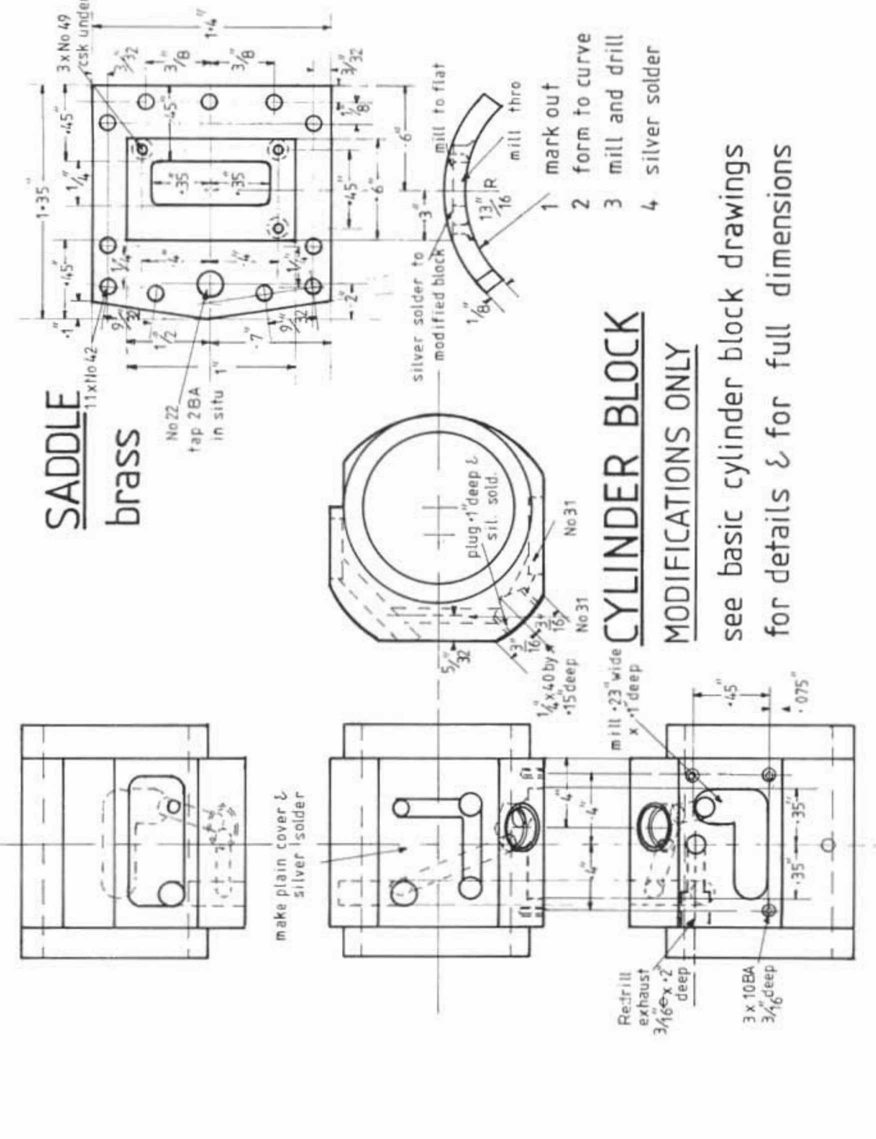
First mill the "dome" in the underside of the block, and drill the three holes. Support the block at an angle on the cross- slide and drill the hole, No. 1, to be tapped ¼ in. x 40 and eventually plugged. This is a convenient aperture to join up the extra steam channels with little risk of cutting into other passages. Drill the short hole from the milled dome into the No. 1 hole, which is straightforward, but take great care when drilling the next hole.

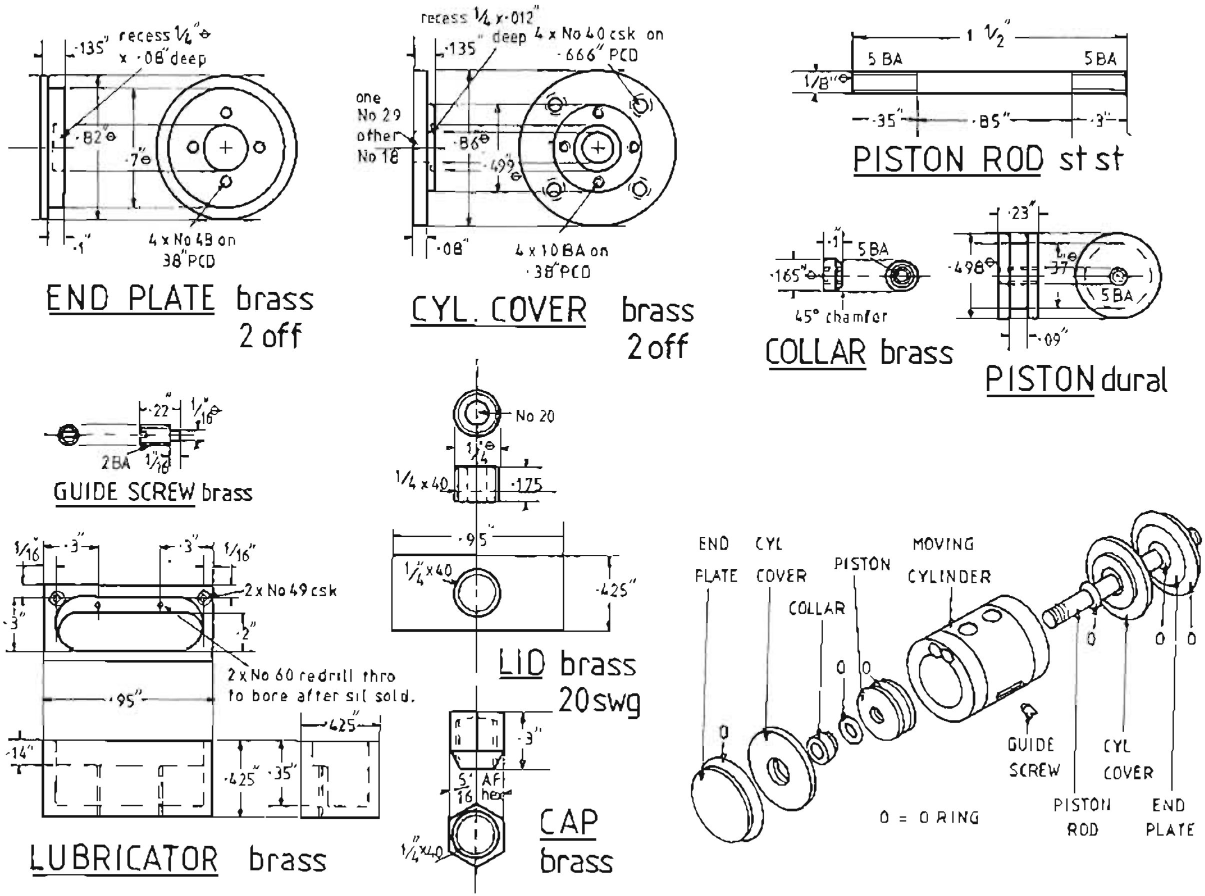
The best way to tackle the main cross hole, which is required to miss both the steam inlet bores and the steam slots, is to clamp the block underside on the cross-slide, precisely along the line of the bed, fore and aft. With the vertical head tilted so that the drill will emerge in the inlet bore already made, set the drill as far back in the hole as possible. Before drilling, sight the position of the hole to be drilled, from all angles, using the ends of drills pushed into the various bores to make sure of missing all but the correct hole.

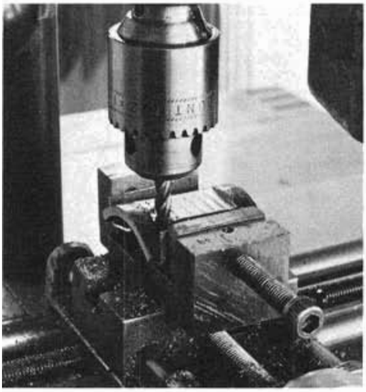
If a mistake is made and the drill appears in the milled steam slot the unwanted hole can be covered with a slip of thin brass, silver soldered in place,

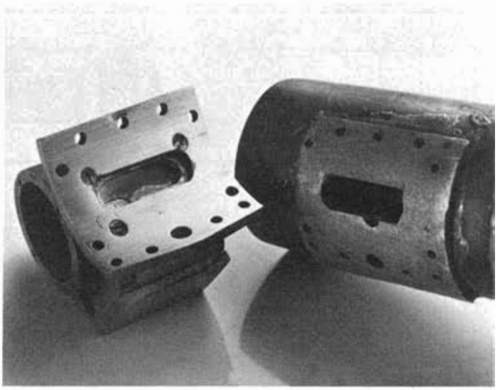



VIA SAFETY VALVE
REGULATOR
TO CYLINDER
STEAM
EXHAUST
BLOCK FLANGE 2off
dural
4 x No 48 on ·95" PCD
·8"
1·075"
·9"
45°
mill 1/16" deep
No 41 at 45°
6 x 10 BA position from safety valve and lubricator
No 23 at 45°
1·35"
No 1 x ·56" deep, tap 1/4" x 40, ·14" deep
2 x 10 BA position from cover
oiling grooves
·854"
2 x No 44 at 10° into No 35 holes, each end
2 x No 35 ·1" deep
mill 1/16" x ·05" deep
4 x 8 BA 5/16" deep on ·666" PCD
2 x No 31 at 12·5°
1·075"
7/8"
1 13/32"
mill slot 1/16" deep with 3/32" mill
4 x 10 BA on ·95" PCD
MOVING CYLINDER dural
No 31
6 BA radial to bore
CYLINDER BLOCK
brass
2 x No 48
3/16" x 40
SIDE COVER 13swg brass


SADDLE
brass
11 x No 42
3 x No 49 csk under
No 22 tap 2BA in situ
silver solder to modified block
mill to flat
mill thro
1 mark out
2 form to curve
3 mill and drill
4 silver solder
CYLINDER BLOCK
MODIFICATIONS ONLY
see basic cylinder block drawings
for details & for full dimensions
plug ·1" deep & sil. sold.
No 31
No 31
1/4" x 40 by ·15" deep
mill ·23" wide x ·1" deep
make plain cover & silver solder
Redrill exhaust 3/16" x ·2" deep
3 x 10BA 3/16" deep


END PLATE brass 2 off
recess 1/4" x ·08" deep
·135"
·82"
·7"
·1"
4 x No 48 on ·38" PCD
CYL. COVER brass 2 off
recess 1/4 x ·012" deep
4 x No 40 csk on ·666" PCD
·135"
one No 29 other No 18
·86"
·499"
·08"
4 x 10 BA on ·38" PCD
PISTON ROD st st
1 1/2"
5 BA
5 BA
1/8"
·35"
·85"
·3"
COLLAR brass
·1"
5 BA
·165"
45° chamfer
PISTON dural
·23"
·498"
·37"
5 BA
·09"
GUIDE SCREW brass
·22"
1/16"
2 BA
1/16
No 20
1/4"
1/4 x 40
·175
·95"
1/4" x 40
·425"
LID brass 20 swg
LUBRICATOR brass
1/16"
·3"
·3"
1/16"
2 x No 49 csk
·3"
·2"
2 x No 60 redrill thro to bore after sil sold.
·95"
·425"
·14"
·425"
·35"
CAP brass
·3"
5/16 AF hex
1/4" x 40
END PLATE
CYL COVER
PISTON
COLLAR
MOVING CYLINDER
GUIDE SCREW
CYL COVER
PISTON ROD
END PLATE
O = O RING


Milling the saddle to fit.


The engine saddle and pad.

and the slot then milled a little wider and less deep. Mill the front off the block for the exhaust pipe.

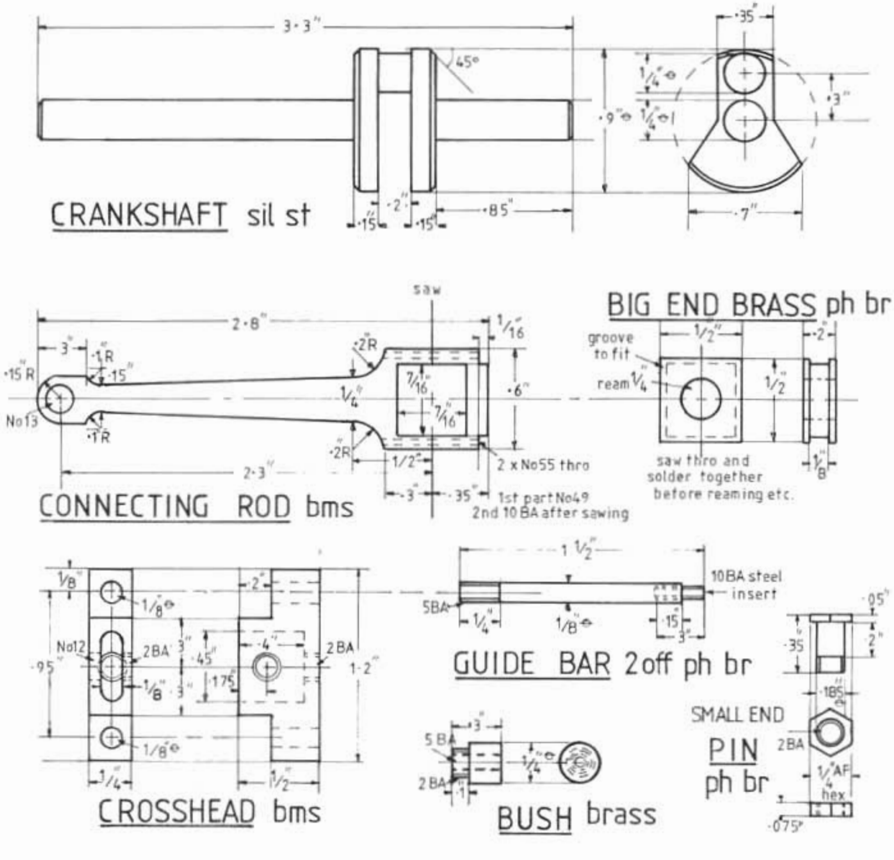
THE ENGINE SADDLE

The engine saddle is made from 1/8 in. brass sheet, starting off with a piece about 1 1/2 in. wide and at least 3 in. long. Anneal the piece and clamp one end in the vice with a suitable diameter to bend around. Relax and check the curve which will certainly be oversize, re-anneal and try again (you will be left with a straight free end) when it should go to diameter. If not, use a 1 1/2 in. dia. former.

Mark out the best part of the curved brass, and cut away and file off the surplus. Hold in the machine vice and mill the flat for the engine base. Mill away the dome part of the saddle and drill the securing holes, turn the work upside down and countersink the three holes. Centre-pop for the saddle securing holes and the water filling hole. Drill these holes, angling the saddle for each row in the machine vice, so that the holes are at right angles to the the tangent of the curve. Do not tap the filler hole until the engine unit is finally secured with screws.

Screw the saddle to the engine block and place on the boiler, getting the engine vertically in line with the hornplates. Mark through with the scriber for all the holes, remove the engine block, and replace the saddle on the boiler, positioning on the marks to scribe in the part of the the pad to be cut away at the lower portion of the dome. Mark around the outer shape of the saddle on the pad so that the pad can be filed away a little and make a neater job of the cladding.

Paint the top flat of the saddle with Easy-flo paint. Make a plug for the exhaust hole to be covered and for the convenient hole (tapped 1/4 in. x 40) and fit these with Easy-flo paint. Paint the side panel with the silver solder paint and clamp on. Secure the saddle in place with three brass screws painted with



Easy-flo and heat up the block, adding a little fluxed stick, when the paint runs, to the dome joints and externally on the saddle joint to ensure a surrounding fillet. Pickle, wash and examine, cleaning up where required. Rub the saddle down on a suitable diameter covered with emery cloth.

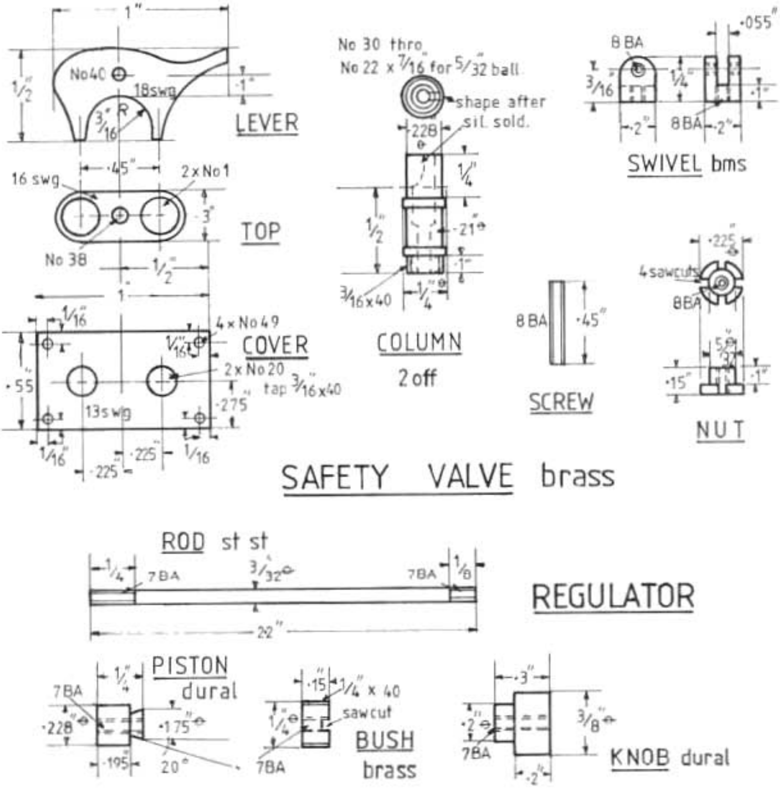
Drill and mill the boiler top, washing out all the bits of copper after tapping all the small holes. Make the motion plate saddle and prepare the pad for the fitting. Mark the front of the boiler with a top centre line for the smokebox as a guide, and try it in place, complete with chimney, to ensure it will be upright. The motion plate saddle is secured in place with a single screw, and it and the smokebox are soldered with Comsol paint, a high temperature solder, using the appropriate flux and avoiding runs. Alternatively it is quite satisfactory to

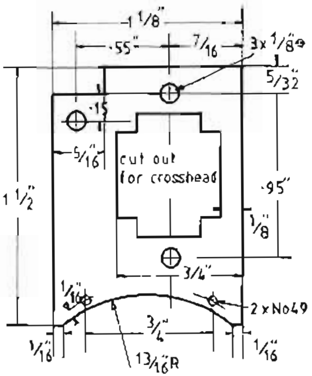
secure the motion plate saddle and the smokebox with epoxy resin. The smokebox is pushed onto the boiler up to its back row of rivets.

Make the rest of the boiler fittings and fit the pressure gauge (0 to 80 psi) and the water gauge glass Loctited in place. Turn all the engine saddle screws and the filler plug.

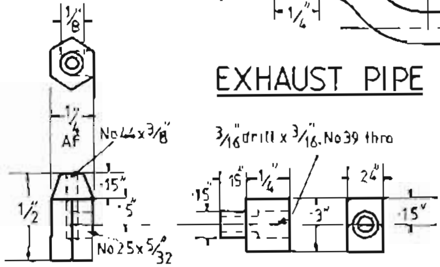
Make the 3 in. diameter flywheel from mild steel (which may be a difficult job on the SL). Cut out the motion plate from 16 gauge mild steel and secure in position. Fit the engine unit on the boiler and secure the saddle all round. Put the crankshaft in its bearings and screw the bearings to the hornplates, tighten the big end on and fit the flywheel so that the big end stays in line with the motion; use a ¼ in. gear collar, pro tempore, at the other end. Oil the motion and the engine and turn over the flywheel when everything should work in line, but a little tight.

Make the spectacle plate and back plate and fit these; they will need working and filing at the angles for a perfect fit, but they must not distort the hornplates.

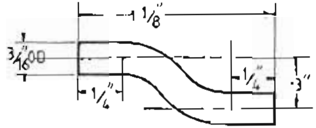




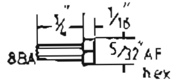
MOTION PLATE 16swg bms



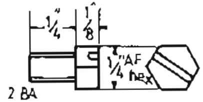
BLAST NOZZLE brass



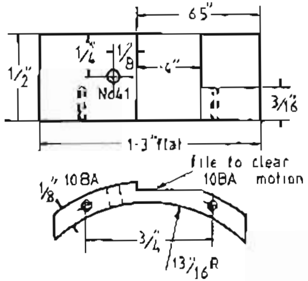
EXHAUST PIPE 20swg Copper



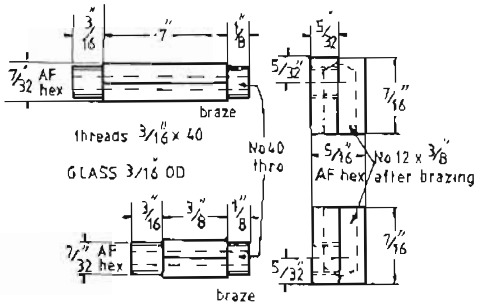
SADDLE SCREW 11off brass



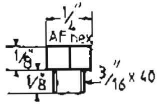
BOILER SCREW ph br



SADDLE brass

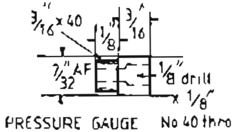


WATER GAUGE brass

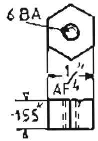


PLUG brass

FOR STEAM BLOCK



BUSH brass



SPACER

12off brass

BETWEEN HORNPLATE AND BOILER

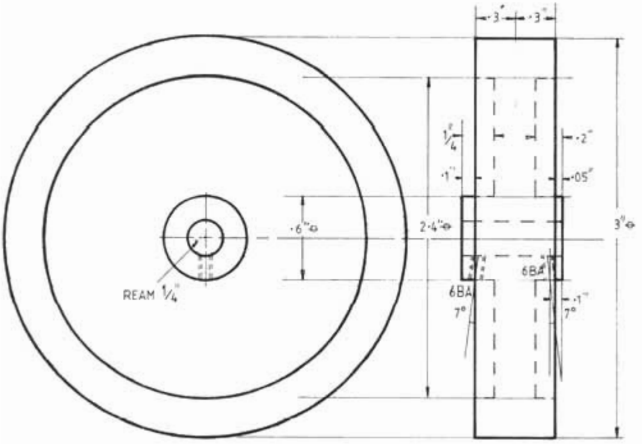
Undo the small end at the crosshead, and the engine saddle screws, and make the exhaust pipe to fit. Secure the safety valve in place, and make a paper gasket to fit over the engine pad using thin good quality writing paper, and, with a little Boss White jointing smeared on both the saddle and the pad, secure the engine unit, complete with the exhaust pipe, tight enough to extrude the surplus jointing compound. Tap the water filler 2 BA.

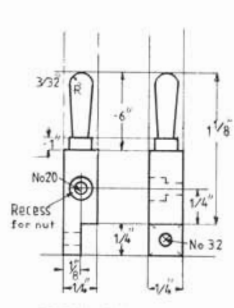
TEST RUN

Clamp the boiler horizontal and fill until the water gauge glass is half full, no more. Screw in the filler screws with a smear of Boss White on the threads. Fill the lubricator with a steam oil, such as Valvata, and secure the cap. Oil the motion. Check that everything turns, that there are no loose nuts and bolts, and no ominous water leaks. If all is well apply heat into the firebox; I used two small spirit lamps, but a small blowtorch is more satisfactory. Too much heat will spill out as yellow flame around the hornplates, but should do no harm.

Check that the regulator is closed, and watch the pressure gauge. When the water starts to boil the level in the water gauge will disappear then fill and go a little mad, but this will settle down as pressure rises. At about 25 psi open the regulator fully and turn the flywheel when the engine should run, gradually gathering speed. Turn the regulator down to allow about 200 rpm. If the engine does not start, close the regulator until the pressure gauge reads 35 psi and try again.

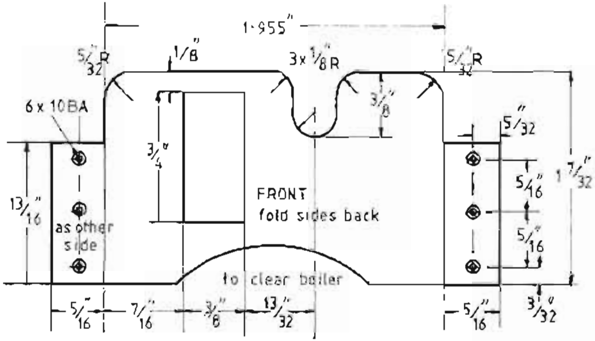
After about two minutes running stop the flywheel and reverse the running for another two minutes, after which the flame should be removed. The water remaining can be checked by tilting the boiler back. Whilst still hot, but no longer above boiling point, check that the engine feels free. If it is still a little



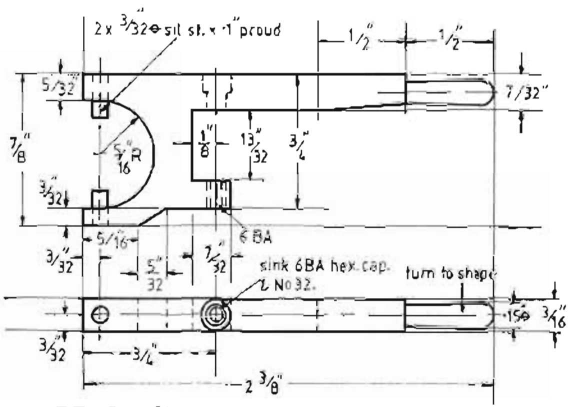


REGULATOR LEVER
steel

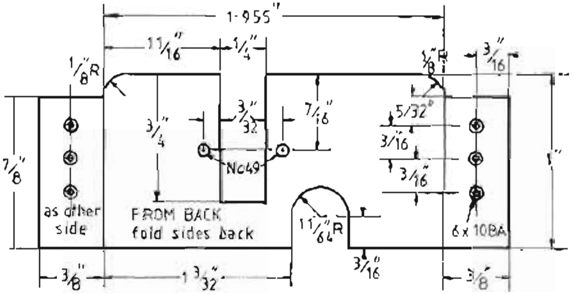
FLYWHEEL bms



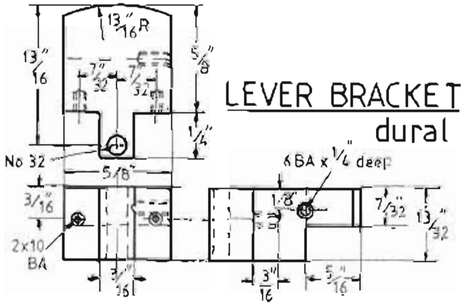
SPECTACLE PLATE 16 swg bms



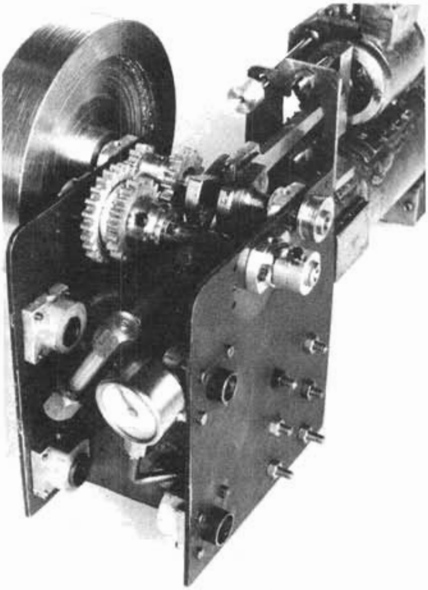
GEAR CHANGE LEVER bms



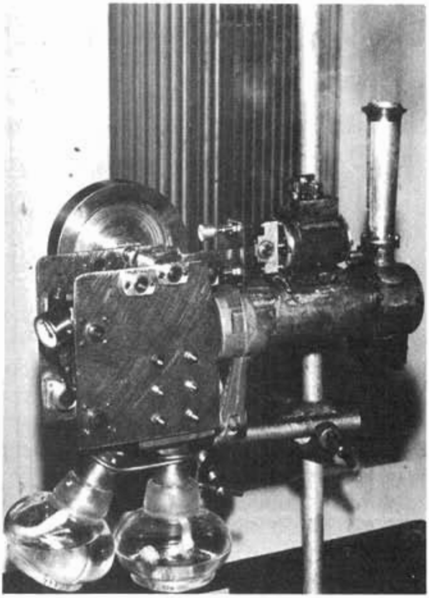
BACK PLATE 16 swg bms



LEVER BRACKET
dural



The hornplates and bearings in position and everything ready for a test run.



The first test run, using two spirit lamps to heat the boiler.

stiff remove the lubricator cap and, with an eye-dropper, remove the water and refill with oil. Refill the boiler to level, as before, replace the filler screws and heat up for another run-in. If the flywheel comes off, file flats for the screws; these will be needed, anyway.

Chapter Eleven

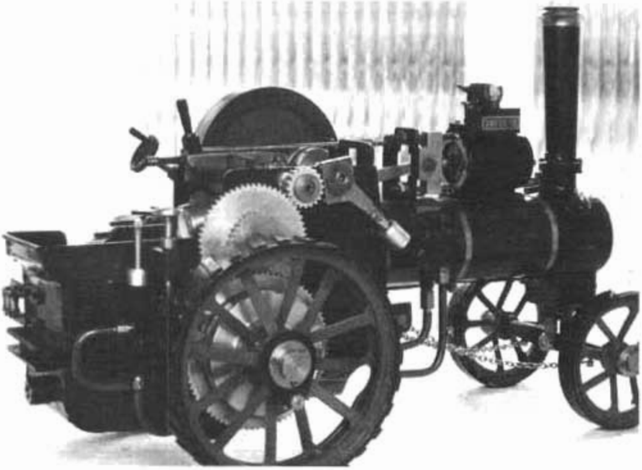
Sweet Sixteen

Section 3 – Tender, burner and feed pump

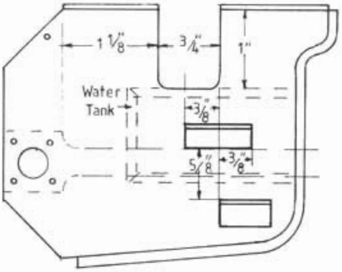
The tender is constructed from 23 swg brass sheet, riveted and Comsol soldered, and has an integral water tank, and various external fittings; it also holds the fuel tank as a removable component. Brass sheet is easily worked and soldered as a box, but care must be taken when thicker brass is soldered on to the thin sheet, at the higher temperature used for Comsol, as the heat becomes localized and can cause bad buckling of the thin brass. The only thick brass to be soldered on to the tender is the by-pass plate and this should be soldered in place after the side has been flanged and drilled.

Cut out two sides with tin-snips and mark out one completely for the off-side, clamping the near-side beneath this for the drilling of the main bearing hole and the four securing holes; check against the hornplate for the top hole as this may have been misplaced during gear fitting. Mark out the near-side as shown, cutting out the doorway. Drill all the holes.

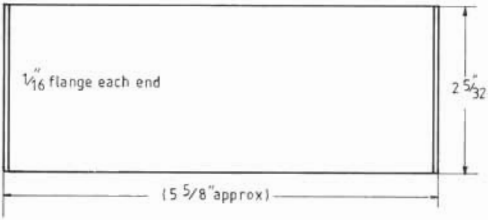
Anneal the two sides and flange the 1/8 in. part back and the 1/16 in. part, at the top, forward. To assist the flanging of the curves little triangles may be cut out, but it can be done without this; either way the flats must match and be flat.



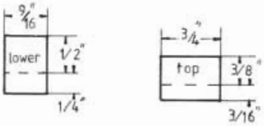
The completed engine. Note the prominent position of the feed pump.



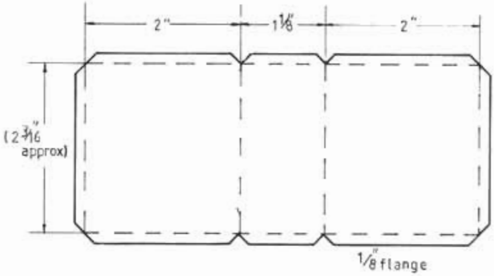
TENDER NEARSIDE main dim. as off



TENDER BACK & UNDER 23 swg brass



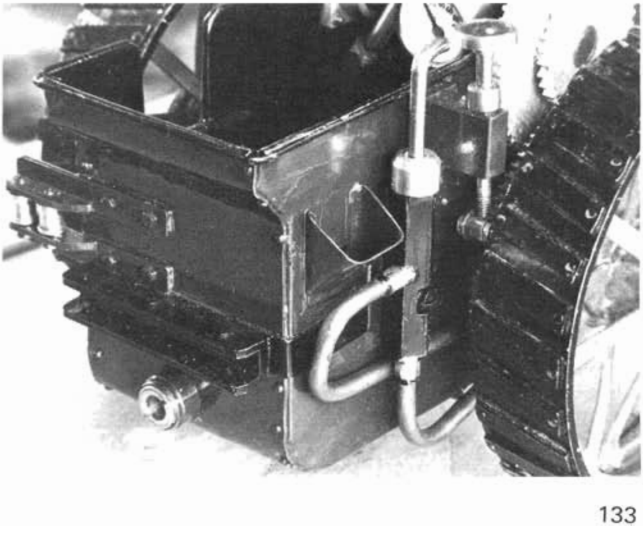
STEPS 16 swg brass



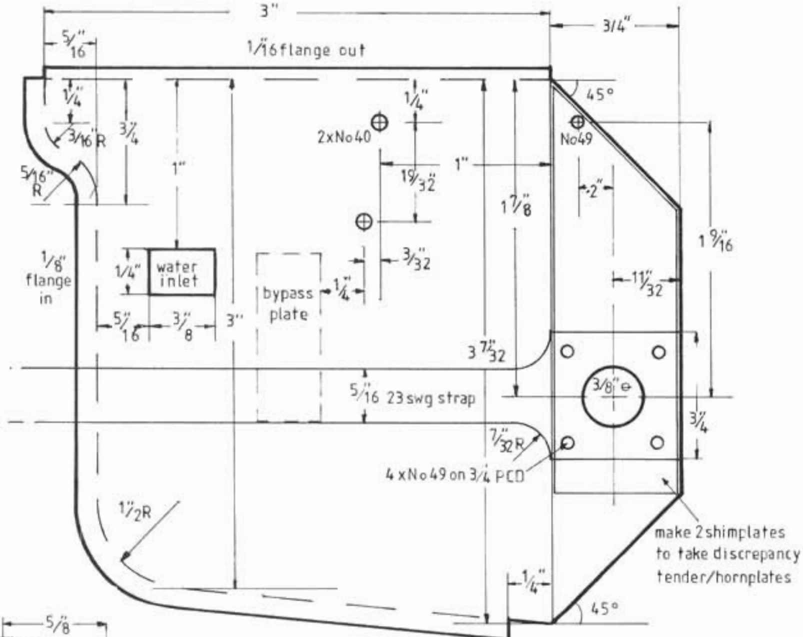
WATER TANK 23 swg brass

TENDER

Solder on the by-pass plate and file out the water hole. Cut out the back-to-underneath from the brass sheet, flange one end and use this end, flange protruding, for the top back, bending the rest to shape along the back curves.

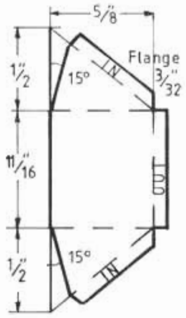


View of tender showing by-pass valve, water pocket and gas filling valve.

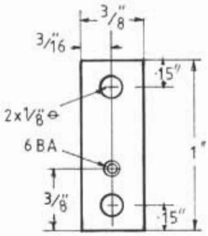


TENDER OFFSIDE

23 swg brass



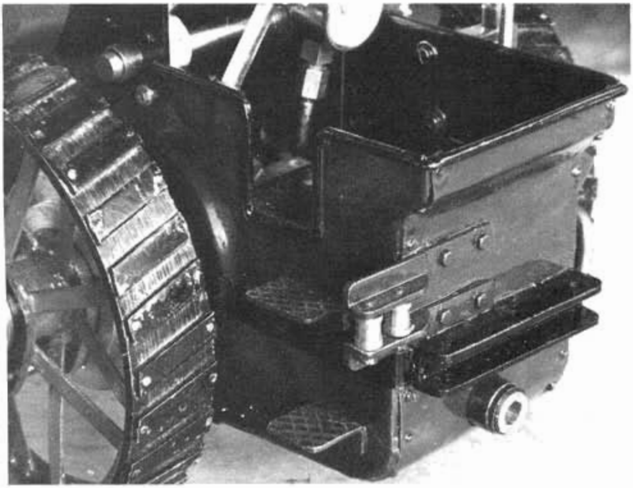
WATER POCKET
23 swg brass



BYPASS PLATE
1/8" brass

Rivet around the top curve with three rivets per side, as shown, using 3/64 in. brass rivets. Keep the sides parallel, and almost cover the flanges with the edges of this back piece. Rivet in the three lower rivets of the back, coming down to the lower curve, but before proceeding check where the underneath will end, cutting off any surplus and making the 1/16 in. flange to be downwards at the end of the run.

Opposite side of tender, showing steps, cable fairlead, draw-bar and other details.



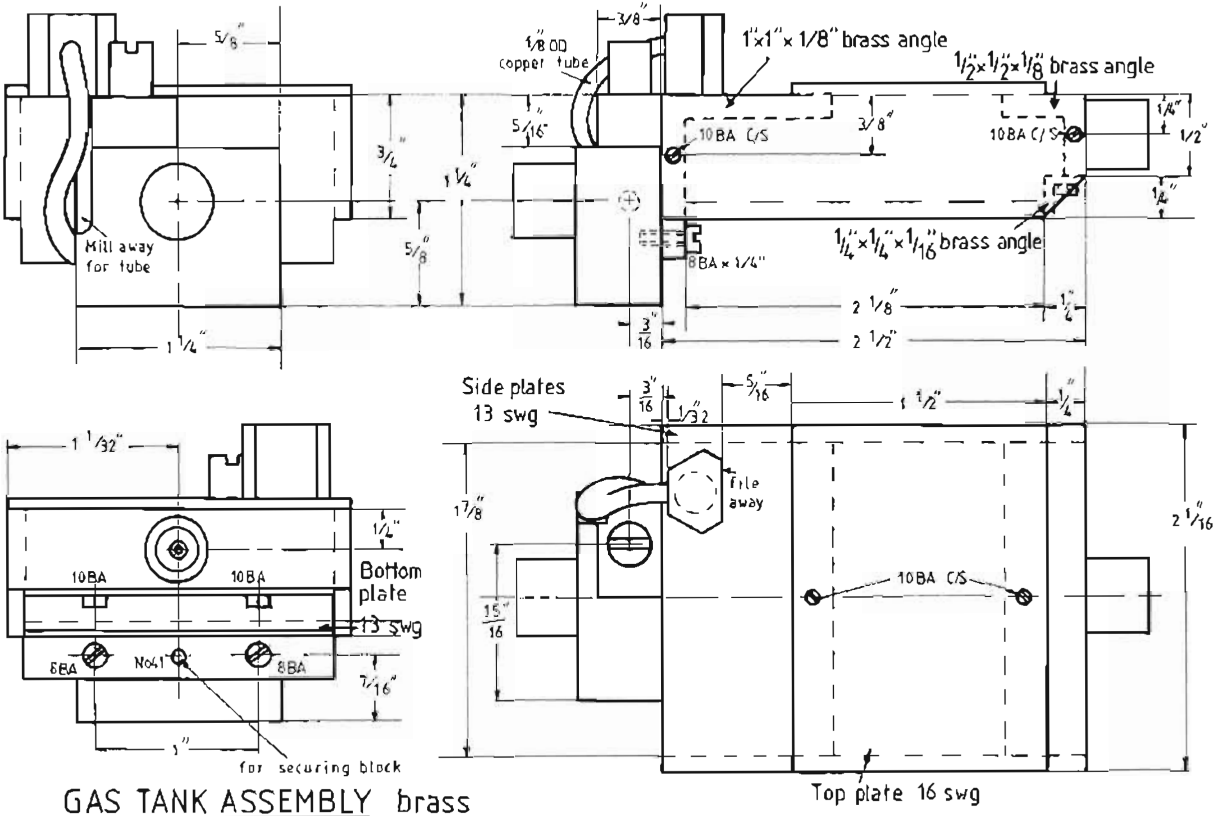
Square off the tender and measure the inside of the parallel sides to ascertain the width of the water tank which can then be marked out, snipped out, flanged and bent, to be Comsol soldered in place. The water tank gives strength to the tender, and holds it square. If there are any small gaps, brass wire can be placed along internal edges, fluxed and soldered in place. Bend a length of 13 swg brass wire to form a beading under the flange around the top edge. Flux around with Comsol flux and, using a small flame and very little solder, run the heat around just locally melting the Comsol to hold the beading with no solder blobs or runs. There is no flange to hold the beading around the access cutaway, so just keep the wire at the edge, cleaning up with a fine file after washing off all the flux, while the box is still hot.

Fit the tender over the main axle bearings after removing the screws and pushing the bearings in. One screw each side of the third shaft bearings also must be removed. Screw the off-side up tight and measure any gap on the near-side to make two plates of suitable thickness to fill this gap between them. Make the draw straps with long tails, then the plates and the straps can be drilled in their pairs, for the bearing holes.

THE GAS TANK AND BURNER

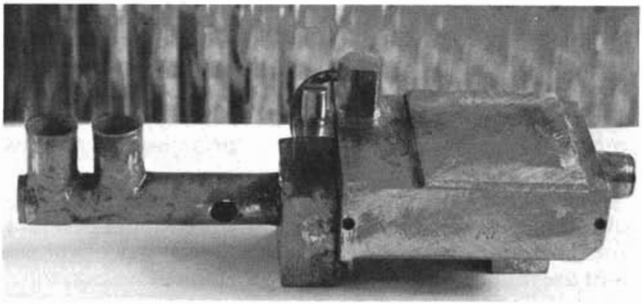
The firing system consists of a fuel tank, a jet block and a tubular burner, the tank being fuelled by means of a standard Ronson fuelling valve. Made mainly of thick brass, the tank is very strong and capable of withstanding great pressures, but the only reason for this is that it is easier to make, employing brazed butt joints on thick brass; butane is a low pressure gas.

To simplify construction brass angle is used at the ends to hold side plates with 10 BA screws, the back end having a length of reversed angle to allow for the bottom curve of the tender. At the rear of the assembly is a bush to take the



GAS TANK ASSEMBLY brass

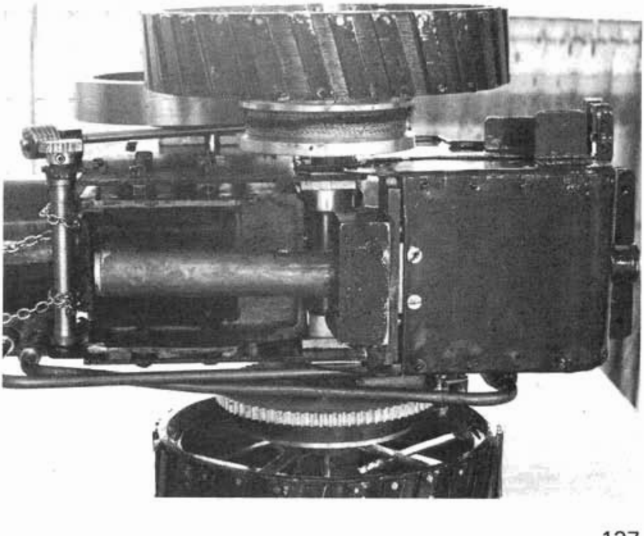
The burner assembly.



Ronson adaptor, threaded 5/16 in. x 40. To prevent liquid fuel being transferred to the burner a dome is incorporated at the front top of the tank, and this has a tube leading to the bottom of the jet block which is separate and has a thin gasket between it and the tank. The jet block inlet has a stainless steel valve sealed with an "O" ring, and when the valve is opened gas rises to escape through a jet with an aperture of .018 in. dia. The gas stream goes to two burners, past two holes where it draws in air to give a good hot flame. So that the flame will be even between the two burners, and not all burn at the far one, a restrictor annulus is fitted between them. This is a compromise and will not completely suit very high or very low valve settings.

MAKING THE TANK

The tank is a brazing job, starting with the angle ends being made, drilled and tapped, and the small under-end fitted. Then make the sides and top to fit,



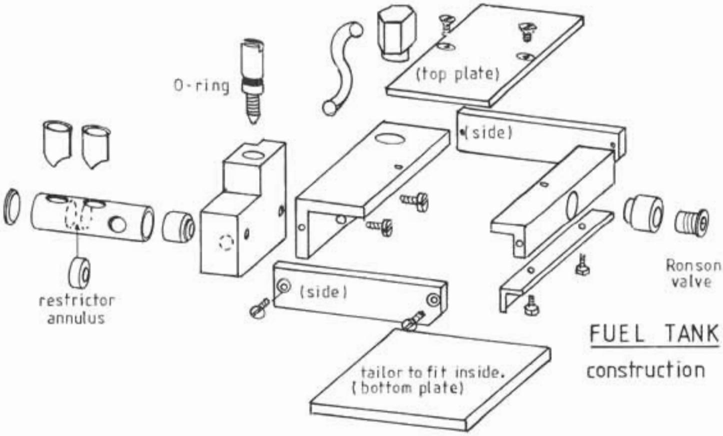
The burner in position, from beneath.

drilling to take the countersunk 10 BA screws. Assemble before brazing and try it in place in the tender, filing the lower back corners until it is just right. Dismantle and flux with Tenacity 4A, putting the lid to one side. Flux the screws and assemble to braze together with Easy-flo 24. Pickle and wash. Tailor the bottom to a good fit, flux with Easy-flo paste and braze in with Easy-flo No. 2. Pickle, wash and inspect for a good fillet showing at all the seams inside and out.

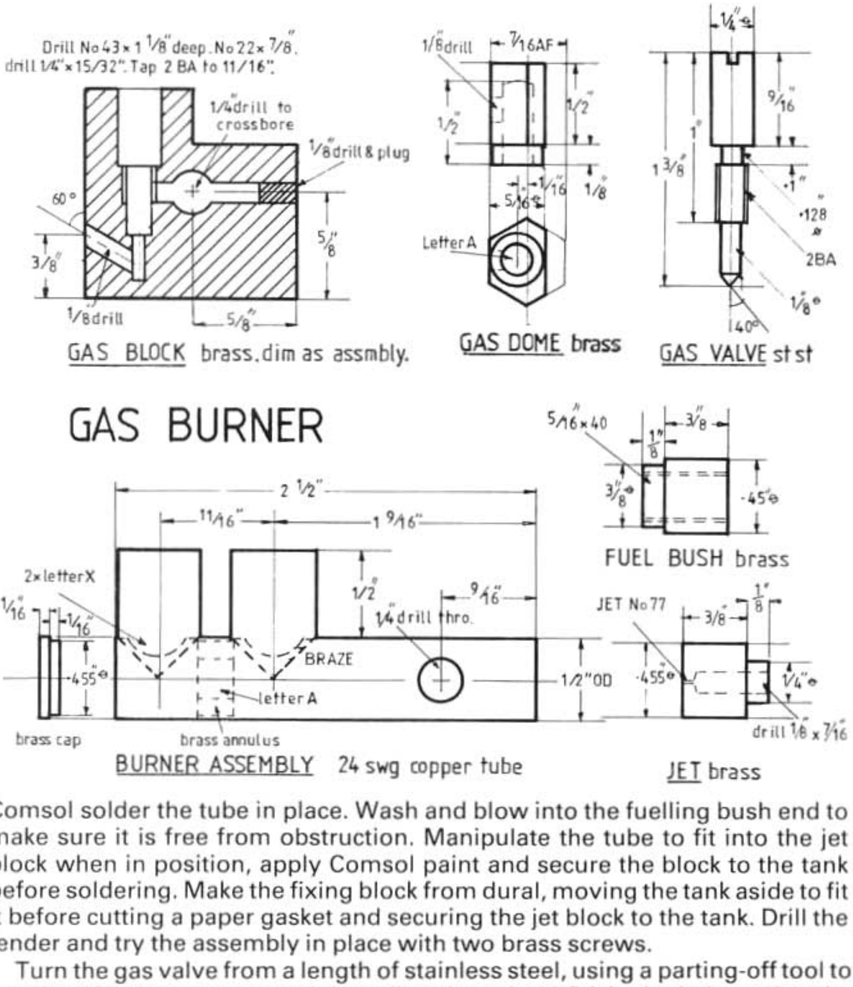
Before fitting the lid drill the hole for the dome and make the dome, drilled letter A; do not drill for the gas tube at this stage. Drill for the fuelling bush and turn the bush and tap in the lathe, but re-run the tap into the bush after brazing. Paint the fittings and lid with Easy-flo paint, and braze in place, applying some thin stick Easy-flo, well fluxed. Pickle, wash and inspect. Drill a 1/4 in. hole in the rear of the tender where the bush should emerge and fit the tank to see where it comes, enlarging the hole until the bush emerges. The front part of the angle should be butted against the lower front flange of the tender. Test the tank by inserting the fuelling valve, and filling the tank with a little butane; listen and smell for leaks, followed by a check with a little taper for minute leaks, if there are no obvious larger leaks. Remove the valve after removing the flame!

Make the jet block, milling a piece of brass to shape with the cutaway channel milled to take the tube so that it does not protrude too far. Drill the gas valve complex hole and the cross-hole, to be plugged, before drilling the angled hole for the tube and the 1/4 in. hole for the jet. There are two securing holes, 8 BA, 1 in. apart, whose position is shown on the rear view drawing. Make the jet in the lathe, then secure it in the three-jaw with the 1/4 in. part forward, and drill the larger hole, to depth. With a pin chuck held in the drill chuck, hold a No. 77 drill and drill the gas jet hole, withdrawing the drill often, and applying little force.

Paint the jet and a plug with Easy-flo paint and push them into place to braze, pickle and wash. Anneal a length of 1/8 in. copper tube, drill the dome and



FUEL TANK construction

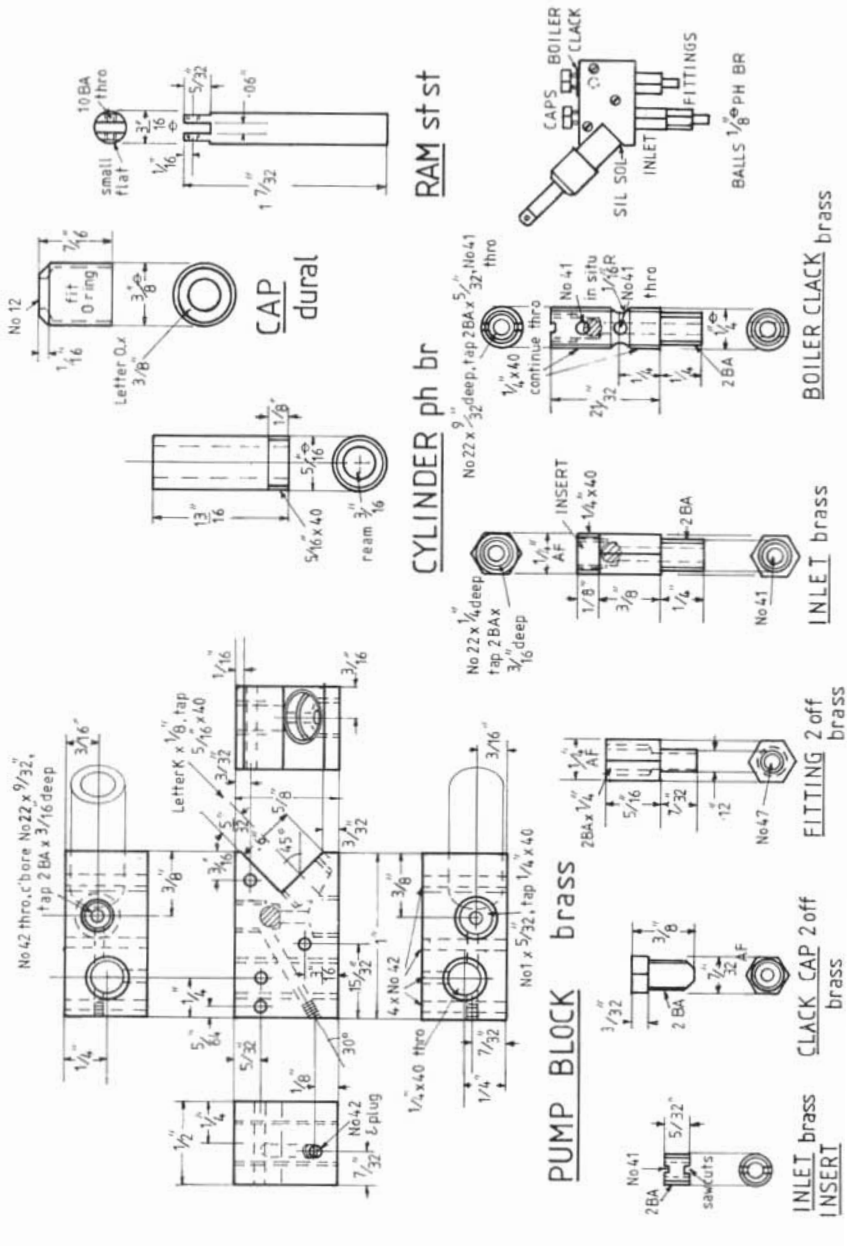


Comsol solder the tube in place. Wash and blow into the fuelling bush end to make sure it is free from obstruction. Manipulate the tube to fit into the jet block when in position, apply Comsol paint and secure the block to the tank before soldering. Make the fixing block from dural, moving the tank aside to fit it before cutting a paper gasket and securing the jet block to the tank. Drill the tender and try the assembly in place with two brass screws.

Turn the gas valve from a length of stainless steel, using a parting-off tool to cut the "O" ring groove, and threading the valve 2 BA in the lathe, using the tailstock dieholder and plenty of tapping compound. Cut the screwdriver slot, fit the "O" ring and try in place, blowing into the fuelling bush to test the valve for complete cut-off.

BURNER ASSEMBLY

The burner assembly is made from thin-walled copper tube. Cut the 2½ in. length and drill the two air holes and the two burner holes while the copper is still hard. Make the annulus and the end cap from brass. Take a length of the


RAM st st
10BA thro
small flat
CAP dural
No 12
fit O ring
Letter O.x 3/8"
CYLINDER ph br
ream 3/16"
No 22 x 9/32" deep, tap 2BA x 5/32", No 41 thro
continue thro
No 41 in situ
No 41 thro
2BA
BOILER CLACK brass
CAPS
BOILER CLACK
FITTINGS
SIL SOL
INLET
BALLS 1/8" PH BR
INSERT
No 22 x 1/4" deep tap 2 BA x 3/16" deep
No 41
INLET brass
FITTING 2 off brass
No 47
No 42 thro, c'bore No22 x 9/32", tap 2 BA x 3/16 deep
Letter K x 1/8, tap 5/16" x 40
4 x No 42
No1 x 5/32", tap 1/4" x 40
1/4" x 40 thro
No 42 & plug
PUMP BLOCK brass
CLACK CAP 2 off brass
2 BA
INLET brass INSERT
sawcuts

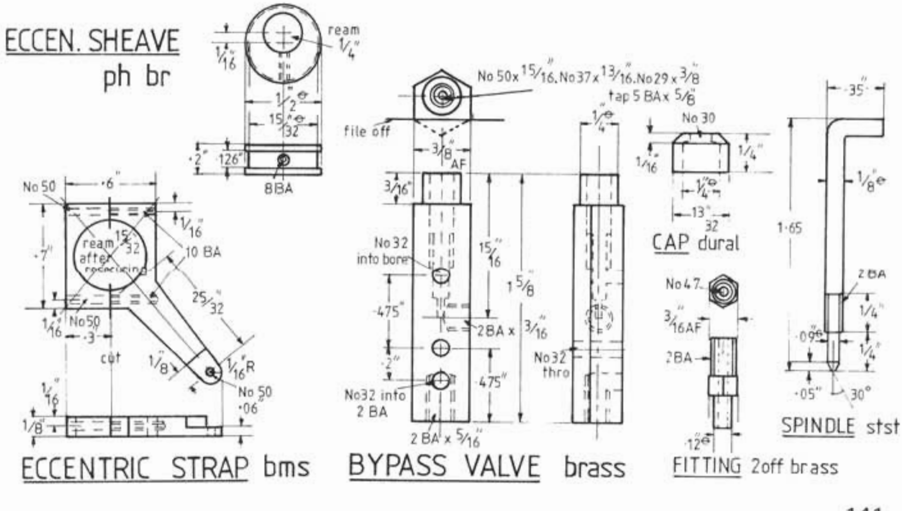
tube, just over 1½ in., and drill a letter Z hole halfway along, cut in half, elongate each half-hole with a round file and gently tap each over the main pipe, flattening the side on to the pipe. Place one side down on the hearth and braze with Phosphalloy: flip over for the other side. Cool down and fit the annulus and the end-cap with Easy-flo paint. Braze the end-cap with a little Easy-flo stick and the paint will hold the annulus. Pickle, wash and inspect.

Fit the burner on to the jet with Loctite Screwlock. Tighten in the Ronson valve and the gas valve, and fuel the tank with a 10 second fill. For fuelling the tank should be tilted slightly down, about 10 deg. from horizontal, and the butane filling nozzle pushed completely and quickly home as straight as possible. With a complete fill the tank is full when the liquid fuel spurts back at the fuelling valve. Leave for half a minute before lighting, every fuelling. To light, open the gas valve no more than a quarter turn and apply a lit taper to the burner. The flame should be a good blue with just a touch of orange at the tip. Regulate down until the flame is all blue, when the tank should last about ten minutes with this short fill.

WARNING. ALWAYS TURN OFF THE BURNER BEFORE REFUELLING. DO NOT FUEL NEAR A NAKED FLAME.

WATER FEED PUMP

The water feed pump is made from a brass block with an inserted and brazed cylinder of phosphor-bronze, and two valve fittings inserted and Loctited. These are the water inlet non-return valve and the boiler feed valve; the second non-return valve is made in the block. With this method it is easy to check each part of the pump separately before final assembly when it would be difficult to pin-point a fault. Pumps as small as this are prone to air and steam locks, but with careful use of the by-pass valve most problems can be avoided.



The pump is bolted to the boiler and will rise in temperature to near that of the boiler, and the passages will be full of steam until the engine in run, then, with the by-pass valve left open, the first running can be used to pass cooling water through the pump until feed is required, and the by-pass closed, when no locking should occur.

THE PUMP BLOCK

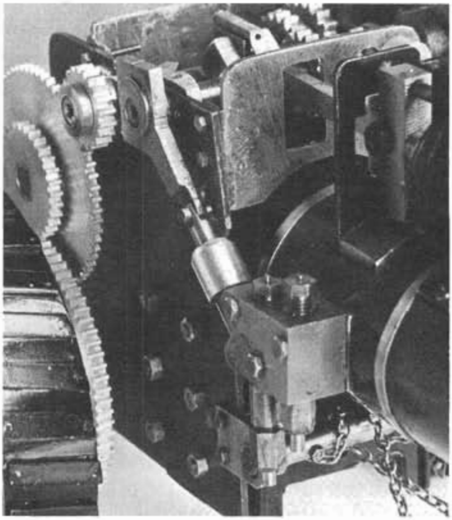
The pump block is made from ½ in. thick brass. Cut out the piece and make one long edge square and finished to the stock surfaces. Clamp to a good 90 deg. angle on the milling table, finished surface down, and mill the other side using a 3/16 in. end mill. Mill the angle from one end in the machine vice and then the other end, square. Mark out the top of the block for the second clack and centre punch, and drill No. 22 for the 5/16 in. Remove the drill and replace it with a No. 41 without disturbing anything, and drill right through. Mark and punch the end for the 30 deg. hole and centre drill a start before using a No. 41 drill into the second clack hole.

Mark out the bottom for the boiler feed clack insert, centre punch to drill right through No. 1. Wind the cross-slide along and back to drill into the hole already present, No. 1 for the inlet valve, just ⅛ in. deep. Mark and centre pop for the cylinder bore, which can be drilled with the work set at 45 deg. in the machine vice, Letter K drill to just break into the inlet bore. Remove the drill and replace it with a 5/16 in. x 40 second tap, then bottoming tap.

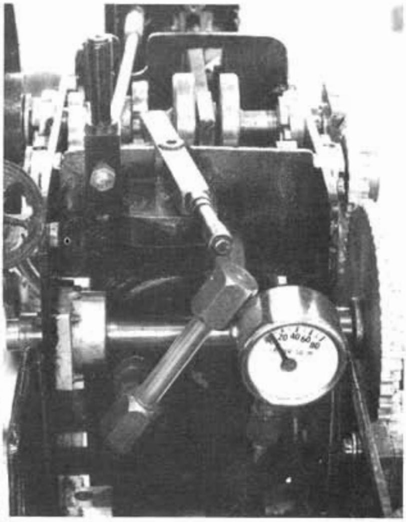
Mark out the back of the block for the four No. 41 holes, and first drill the boiler feed hole just into the clack insert bore, then drill the other three holes right through, with the block clamped on to a piece of scrap aluminium on the cross-slide – just watch for the drill swarf changing from yellow to silver.

Turn the cylinder from 5/16 in. dia. phosphor-bronze, marking the ends square, and drilling through No. 13, followed by a 3/16 in. reamer. Thread the end in the lathe before trying the cylinder in the block. Turn the sharp corners from the stainless steel pump ram and make the small end by hand, finally clamping it and drilling the end No. 54 in the vertical Unimat. When drilling stainless steel start the hole with the appropriate centre drill, in this case the smallest size, as the centre drill will not wander, then follow with the correct twist drill using neat cutting oil as a lubricant and coolant. Try the ram in place, running it in with Brasso if necessary; clean off. Cut a plug from brass rod and paint it and the cylinder threads with Easy-flo paint and insert both. Flux the cylinder where it holds against the block and silver solder the plug and the cylinder, adding a little Easy-flo No 2 stick. Pickle, wash and inspect. Clamp the block in the vice and tap the insert holes.

Turn the inlet and boiler clack fittings from ¼ in. AF hex. brass using the hollow main spindle to feed the material. In both cases first drill No. 41 to just over-length, then No. 22 to precise depth, then bringing up the live centre to turn down the hex., as required. Thread the ¼ in. x 40 then tap 2 BA and part off. Hold the inlet valve in the three-jaw to thread the lower end 2 BA, then the boiler clack, but protecting the thread with a soft alloy sleeve. With the sleeve



Close-up of the boiler feed pump.



Driver's-eye view of the "footplate".

still covering the thread secure in the machine vice to drill the side hole, and then to make the saw-cut.

Use a stainless steel ball to make the seats of the valves, using a short length of 1/8 in. brass rod as a drift over the ball and giving a good thwack with a hammer. The block can be held on a hard surface, and the two inserts held lightly in a vice by their 2 BA ends. Replace the 1/8 in. steel balls with phosphor-bronze balls. Test the valves for leaks with a suck and a blow, from the bottom ends! Make the caps, inserts and fittings, screw in the boiler clack insert with Loctite Screwlock and redrill the feed hole. Set the balls in place and fit the inlet insert, the inlet and the clack caps with Loctite Screwlock, all to allow approximately 1/32 in. lift to the ball (one complete turn of 2 BA thread). Fit the "O" ring on the cylinder and then Screwlock the cap in place. Test the pump with the oiled ram in place, inlet under water and a finger over the by-pass outlet. When the ram is worked water should pump from the boiler feed hole.

Screw in the inlet and outlet fittings with Screwlock; these are to take 5/32 in. O.D. copper tube as are the by-pass valve fittings. Note that the ball valve seats are made using the standard drill-tip angle, and are not flat, that is, not made with the D-bit. The conservative may shudder at this practice, but I have found that, providing the diameter of the hole is between .7 and .8 of the ball diameter, it works well in use, and the seats are easily made.

PUMP ERECTION

Place the pump on its pad and mark through for the three holes, aligning the ram to point to the centre of the crankshaft. Mark out the three holes properly,

using the marks as a guide, and mark the boiler feed hole position, and centre punch. Drill the four holes, tapping the three securing holes. Secure the pump in position temporarily, and turn the eccentric sheave from phosphor-bronze. Turn in the three-jaw chuck for the outside and the groove, part off. Drill and ream the eccentric hole in the four-jaw chuck. The centre of the hole is offset $^{1}/_{16}$ in. from the sheave centre to give a stroke of ⅛ in. Drill for the grub-screw in the vertical mode, the sheave held in the machine vice.

Secure the sheave to the end of the crankshaft and turn it so that the widest part of the sheave is closest to the ram, push the ram right home and measure the distance from the bottom of the groove to the centre of the hole in the ram, it should be $^{25}/_{32}$ in., but deficiences can be adjusted for when making the strap; care must be taken not to make the distance oversize – if in doubt deduct $^{1}/_{64}$ in. Mark out ⅛ in. mild steel for the eccentric strap, using marking out blue. Cut out and drill the top edge in the machine vice for the two No. 54 holes right through. Cut across with a fine saw, tap the lower half 10 BA, and drill the top half to clearance. Secure the pieces together with steel 10 BA screws and punch a number on each half, carefully drill and ream the big end. Measure across the diameter, from the side of the hole to the position of the small end centre, as found previously, drill and file to fit the ram, checking in place before filing. Assemble and check. If the sheave is tight, run it in with the strap using a ¼ in. mandrel in the lathe, with a little Brasso, and then oil. Clean off thoroughly and oil. Assemble the tender on to the hornplates.

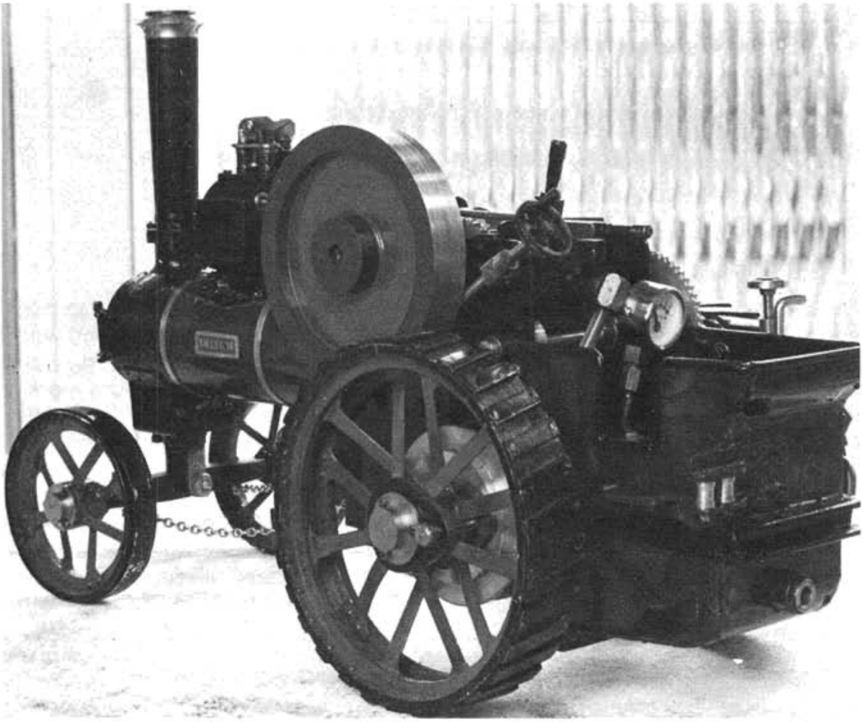
BY-PASS VALVE

The by-pass valve is made from ⅜ in. AF hex. brass with one pair of flats filed off. Turn in the four-jaw chuck to drill the holes and to tap them for the spindle and lower fitting, and to turn down the top for the dural cap. No "O" ring need be fitted since the water level is below the top of the body. Make the fittings and spindle, threading the spindle in the lathe. Ensure that the body holes, when drilled, line up with those on the tender plate. Use Loctite Screwlock as a gasket for the valve, and, now, for resecuring the pump. Bend the copper tubes to fit and secure them with Loctite 641.

TEST RUN

Fill the boiler with water to half the water gauge glass, and fill the tender. Use only distilled or purified water in this engine. Close the by-pass valve and turn the flywheel to pump the water to a two-thirds level in the gauge glass, open the by-pass valve. Fill the lubricator with steam oil and oil the motion. Check that the burner valve is closed and fuel the tank with a ten second fill from a butane refill. Add water to the tender tank and clamp the boiler in a secure vice, or in secured lab clamps.

Open the burner valve and light the gas with a taper, turning back the valve to stop flame spilling out and around the firebox. Check that the regulator is closed and wait for steam pressure to build to around 25 psi. Turn the engine over with the flywheel before opening the regulator a little, and turn the



Another view of the finished model.

flywheel again for the steam to take over. The steam will now be drawing up the flame and the gas can be turned up slightly. Open up the regulator and close the by-pass to see the water level rise in the gauge glass with the pump working. Adjust the by-pass to keep the level about right, and the flame to keep the steam pressure above 25 psi; vary the speed of running with the regulator to see the effects. You should have at least five minutes of running with the gas fill given.

Chapter Twelve

Sweet Sixteen

Section 4 – Wheels, axles, steering, gear-change.

The wheels present no particular problem, given a reasonable ability to rivet, and a great deal of patience during the turning procedures and the hand work. The rear wheel rims are turned from standard Minnie front wheel castings, and the front wheels are turned from solid. Both pairs require a few hours work at the Unimat and the rear wheel requires an increased swing mode to be fitted to either the Model 3 or the SL. The increased swing for the SL is the subject of a chapter in my book "Making the Most of the Unimat".

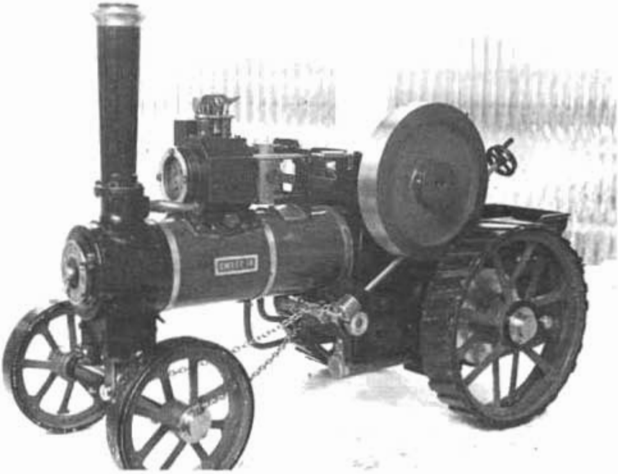
The wheels are made up on a wooden jig to get good centring without wobble, and this is simplified by having the hub and the rim flat to each other on one side; the jig can be flat. The spokes are of mild steel, secured into the hubs with countersunk brass screws before Comsol soldering in place, together with hub-plates. Wheel hubs are to be reamed through after finishing, and all the wheels are free on their axles, the rear wheels being driven by driving pins through the hub plates. My front wheels have spokes which cross over, rim to hub, which is not general in practice, so the purist may deviate from my design by making straight spokes. The rear wheels are straked, and the direction of straking is reversed, near to off-side wheel, so that when the traction engine is driving forwards the wheels tend to be forced inwards.

THE REAR WHEELS

Obtain the castings and measure them to ensure that the outer diameter is capable of producing a finished wheel of the correct diameter. Mark off inside at 120 degs. and file flats on the inside diameter with the three flats measuring the same to the outer diameter with set calipers. Check the casting on the three-jaw chuck, jaws reversed and across the inside diameter, spin to see that the wheel runs true. If all is well remove and drill to take the three screws for plates to limit the fit of the casting over the jaws, to keep the wheel in alignment, as seen in the photograph.

Using the round the corner toolpost accessory, and a round- nose tool, take down the outside diameter of the wheel to concentric, and with the normal toolpost and the same tool, face the rim. Make the double-ended tool shown in the drawing and use it to groove out the side as far as possible. Make three same size blocks to fit the turned rim and reverse the wheel on the chuck; the new rim should now limit the fit. Turn the side to completion including the

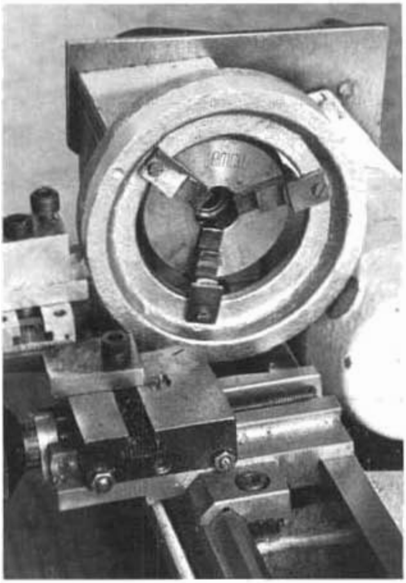
The wheels are always a most attractive part of a traction engine.

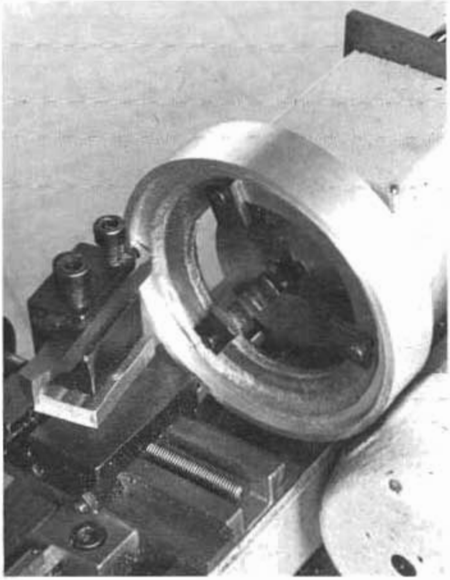


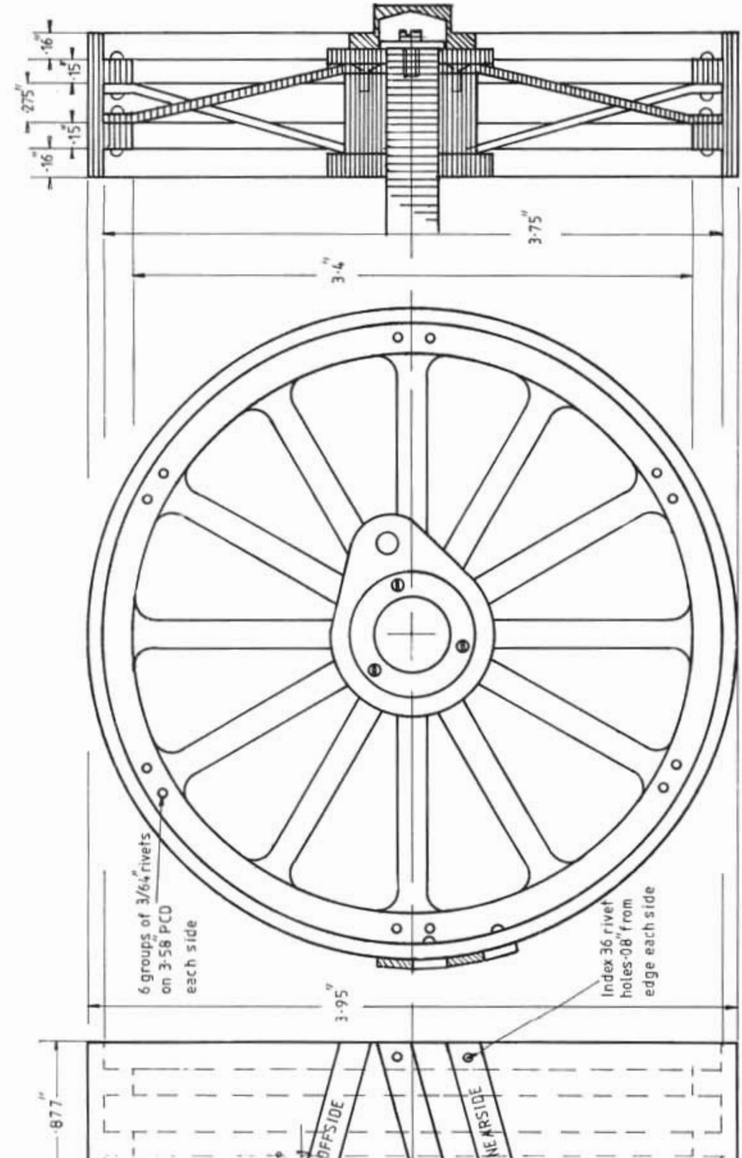
Below, turning the outside and inside of a hind wheel; note the three plates.

central groove when the unwanted annulus drops out. Recover the three plates to be screwed to the other wheel, which can now be turned.

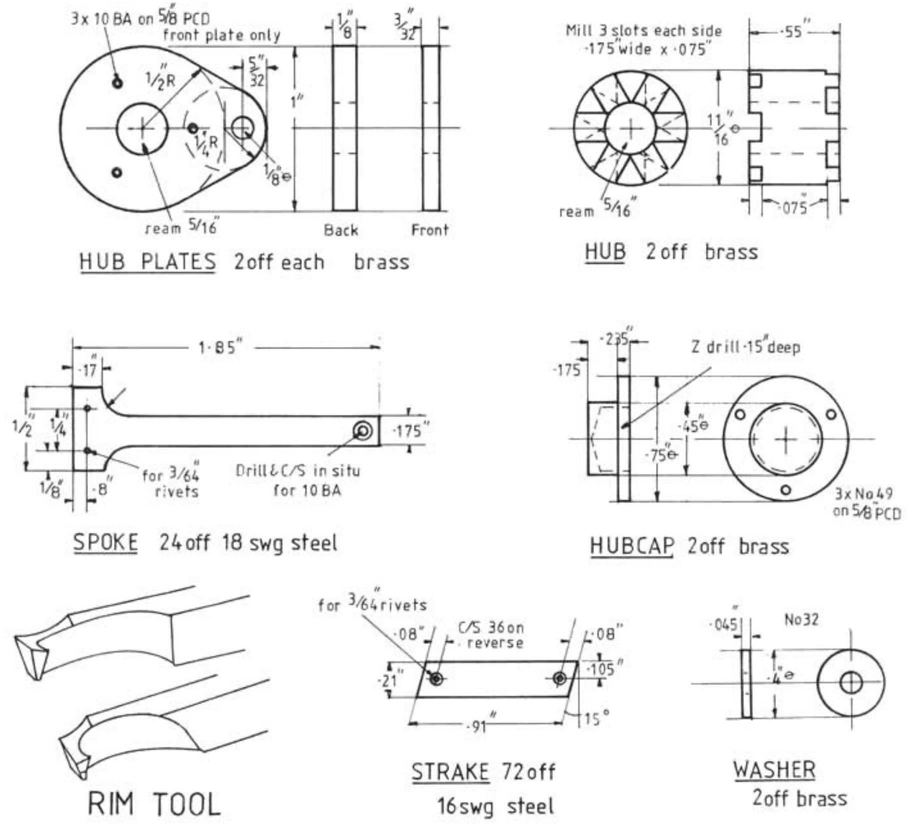
All the holes on the rim are drilled 3/64 in. for the rivets, using the 36 position plate in the indexing attachment. Buy at least six 3/64 in. twist drills as they are





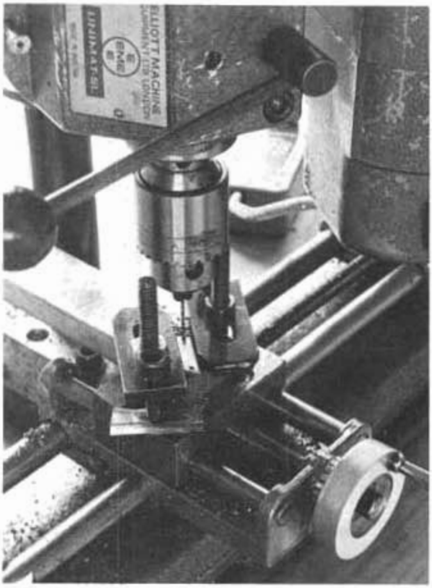


REAR WHEEL 2 off alloy casting

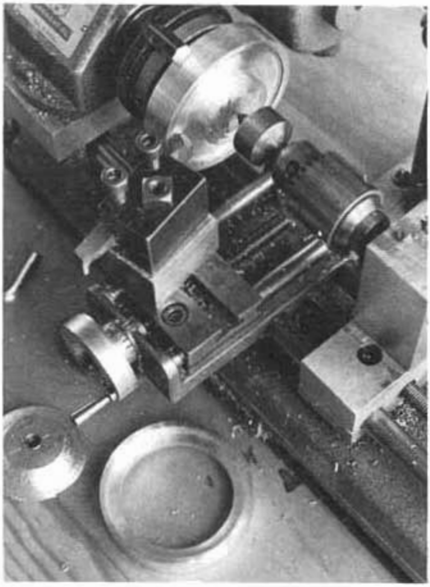


REAR WHEEL COMPONENTS

easily broken, and to minimise the number of broken drills stake out a circumference of holes first, each time, using the tip of the smallest centre drill before proceeding with a now non-wandering drill. Make a few holes in a piece of 1/8 in. dural and obtain some riveting practice. You will need a 40 oz. ball pein hammer, and a riveting snap, the type with both a hole and a cup in the end. A specially shaped riveting dolly will have to be made from 1/4 in. steel to hold in the vice, with a cup made with a twist drill, for the rivets to be held within the rim when spoking, and around the rim when straking. Buy 200 x 3/64 in. brass rivets, 3/8 in. or 1/2 in. long; they have to be cut down on the job with diagonal cutters. Practise cutting the right length above the work to get a good head with no spread brass (too much left) or just a pimple (too much cut off). The strake rivet heads are made in countersinks, which is easier.



Drilling a hind wheel strake.



Turning a front wheel; note centre waste.

The strakes are made from mild steel sheet cut in lengths to the correct width on a guillotine, if possible. They can then be snipped off to the 15 deg. angle marked out as lengths along the material with protractor, rule and scriber. Set up a jig on the cross-slide using the arms of the milling clamps over an alloy drilling plate to drill the holes; use a good cutting oil. 36 of the strakes require countersinking to one hand and 36 to the other, use a small HSS countersink and soluble oil. Rivet the strakes in place: bad riveting can be rectified in the steel by drilling out and replacing the rivet, but when fitting the spokes the head is formed on alloy and must be right first time.

The spokes are most easily made in batches of eight, cut from $\frac{1}{2}$ in. x 18 gauge mild steel, snipped out after careful marking out. Clamp eight together in the vice, a marked surface showing either end and file to shape with a round and a flat file. Use two of these as patterns for the other batches. Make a jig for the rivet holes, as before, and drill them, leaving the countersunk holes for drilling in situ later.

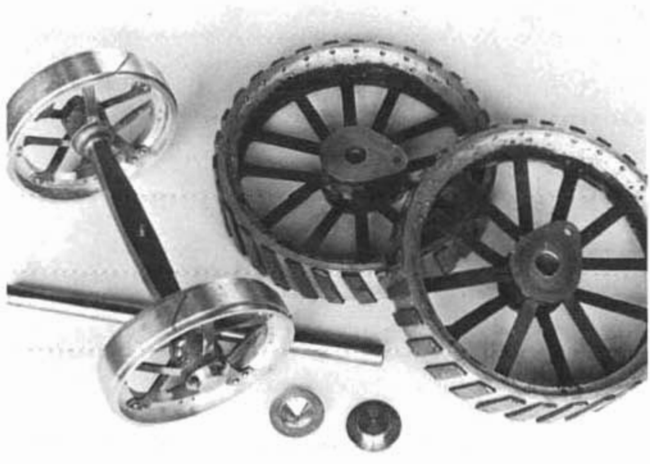
Make the hub plates from the two thicknesses of brass sheet after marking out carefully and centre punching lightly. The plates are shaped by hand after cutting them out with an Abrafile before drilling the axle hole. Cut a length of $\frac{5}{16}$ in. dia. and $\frac{1}{8}$ in. dia. material, and slide the plates on to the larger to line up the eccentrics, clamp and drill the $\frac{1}{8}$ in. holes through, pushing through the pin. Make sure there is a marked out surface front and back, and clamp in the

vice to file to shape with a good file. Index and drill the front plates No. 54, but do not tap the holes until after redrilling upon assembly.

Turn the hubs down from 3/4 in. dia. brass and drill through before parting off and securing the first in the three-jaw on the indexing attachment with the, 36 plate in place. With a 5/32 in. end mill, mill across the diameter and back, check with a vernier caliper set to .175in. when you may be surprised to find that the inside caliper fits. If not take a little more from each side; an end mill cuts a slot wider than its diameter. Index around six and repeat, and repeat again. Before removing from the chuck, mark the position of one jaw on the hub, loosen the chuck to turn the hub upside-down, lining up the mark on the same jaw. Index around three teeth and repeat the milling operation.

Make the spoking jig from a piece of good 5-ply, drawing a circle the size of the straked wheel with a pair of compasses. Drill out the exact centre to take a 5/16 in. dia. bolt shank with about 1 in. unthreaded, and fit this through from the back, and stick on two blocks, top and bottom of the back, to balance the bolt-head. Glue three woodblocks equispaced around the drawn circle, just on the line, and when set try the rim in place; it should be a tight fit.

Fit a backplate and a hub to try one spoke in place, bending it to be flat on the rim and on the hub, and scribe to length just away from the hub bore. Cut twelve spokes to this length, and bend. Rivet six spokes in place, off the jig, and try again on the hub in the jig. If all is well centre punch at the hub for the six screws and drill No. 53, lightly countersink. Tap 10 BA and fit six short brass countersunk head screws. Repeat for the other wheel. Remove the backplate from the jig and complete the spoking of the back of the wheels; the spokes need to be slightly longer.

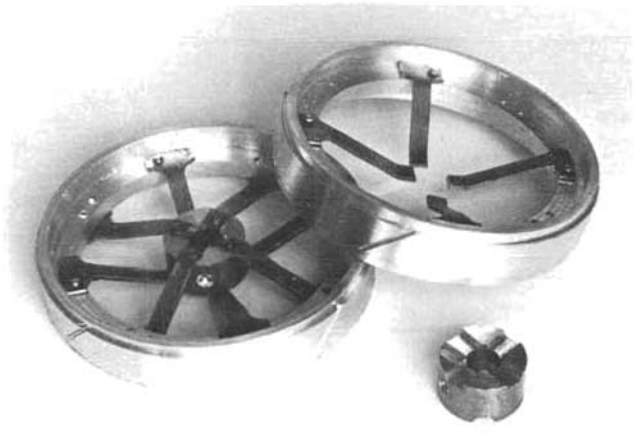


The set of wheels and axles plus rear hub caps.

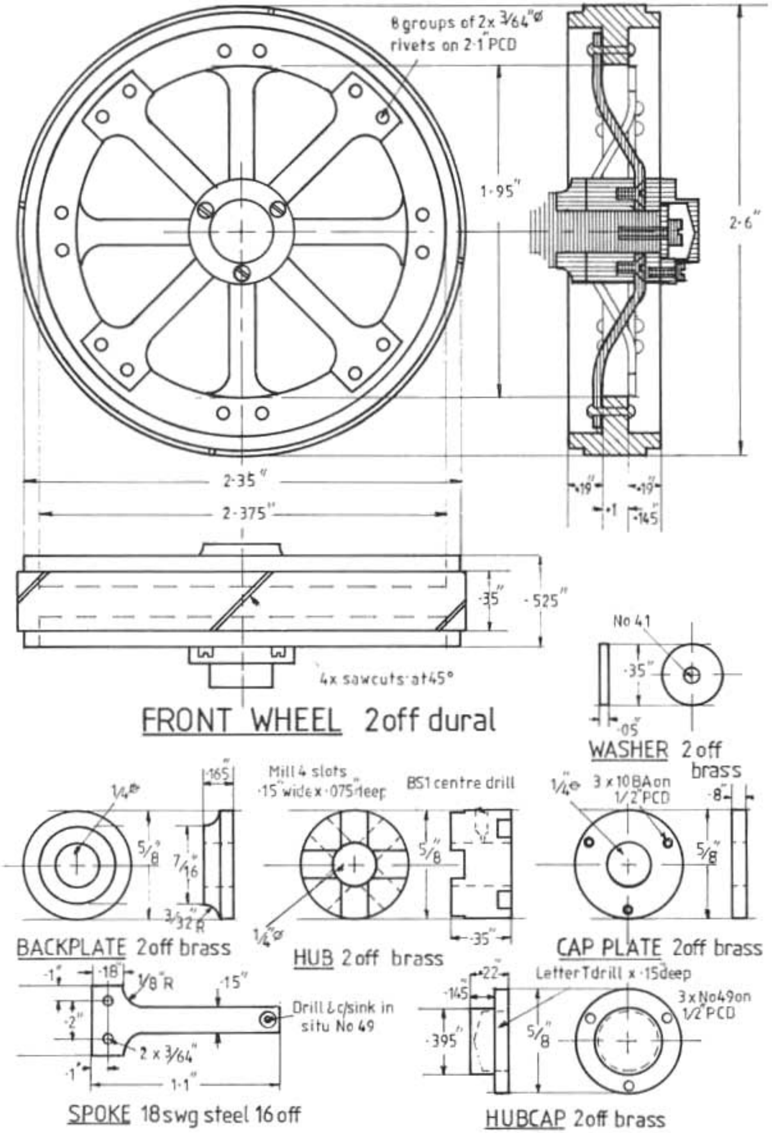
Off the jig take out the hub screws, one at a time, to paint the holes and spoke tops with Comsol paint, replacing each screw before removing the next. Avoid painting the bore. Fit a 5/16 in. dia. alloy rod to the bore, paint the plates with Comsol and slide over the alloy rod, into place, making sure that the backplate is at the back, and that the driving pin holes coincide. Fit a 1/8 in. dia. pin through the pin holes and clamp the hub assembly with a small G clamp through the spokes. If the pin will not go through run a reamer through first. With a small flame gently heat the hub until flux bubbles and the solder flows at either plate. Remove the flame, there will be enough residual heat, and add a little stick Comsol into any apparent gaps, avoiding excess and flows. The wheels can be held by their rims for this operation. When the solder just sets wipe off the still soft flux with calico. Remove the clamp and the rods, which may need tapping out, and ream. Drill the hub-cap securing screw holes to about 1/4 in. deep, and tap 10 BA, make the hub caps and washers. Fit a wheel to each end of the axle and try rolling it on flat ground to see how true your work runs.

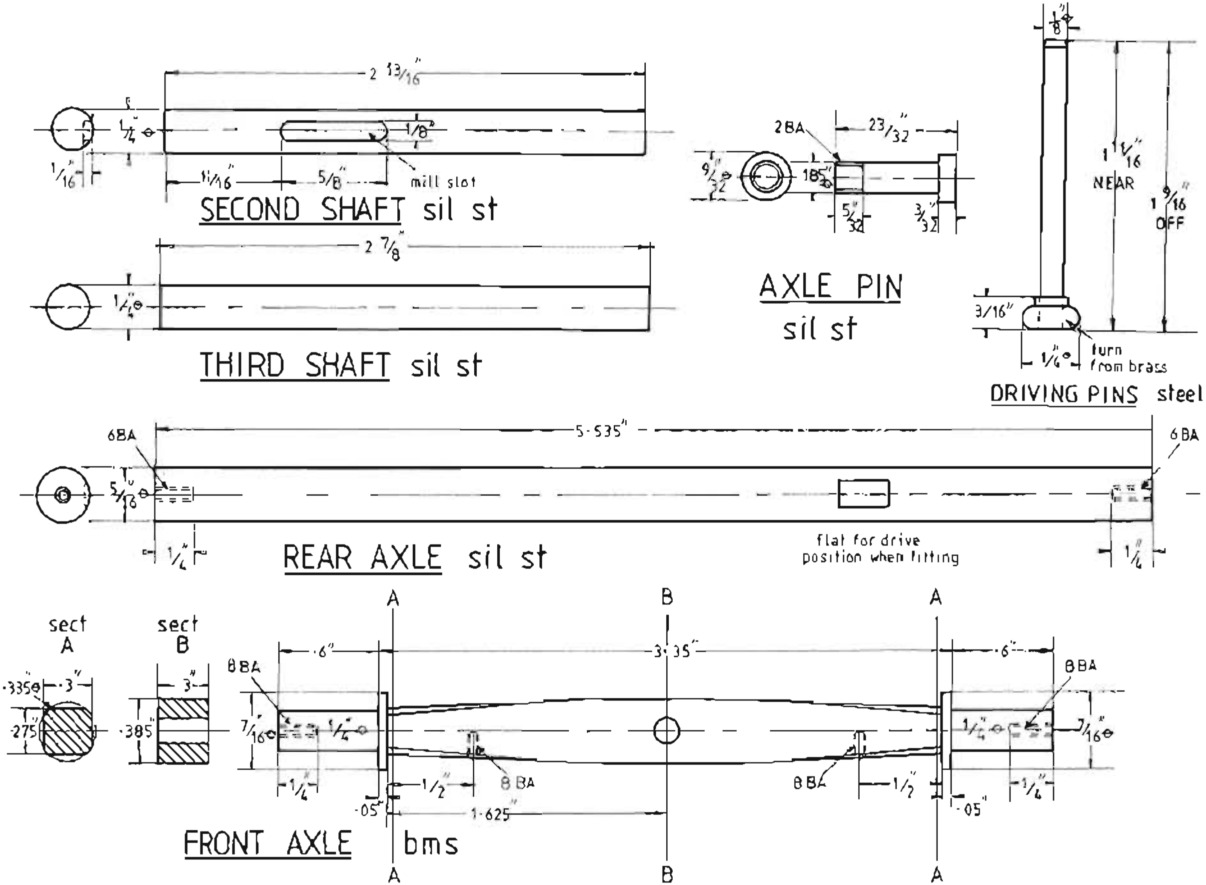
THE FRONT WHEELS

The front wheels are turned from 2⅝ in. dia. dural, first sawing off two blanks .6 in. thick. Secure a blank in the three-jaw chuck, jaws reversed, best side down, and turn the face true. Using the double-ended tool turn the inner rim, grooving across to about 1/2 in. to produce a ring-groove which can be held by the reversed jaws, work reversed, so that the wheel can be turned to thickness and ring-grooved before taking the tool through so that the middle falls away. Finish the inside of the rim before turning the outer diameter for the imitation tyre, which then requires four saw cuts: avoid marking the outer diameters or



Front wheels under construction.


8 groups of 2x 3/64"ø rivets on 2·1" PCD
1·95"
2·6"
2·35"
2·375"
·19"
·19"
·1
·145
·35"
·525"
4x sawcuts at 45°
FRONT WHEEL 2off dural
No 41
·35"
·05"
WASHER 2 off brass
BACKPLATE 2off brass
·165"
1/4"ø
5/8"
7/16"
3/32"R
Mill 4 slots ·15" wide x ·075" deep
BS1 centre drill
5/8"
1/4"ø
·35"
HUB 2off brass
1/4"ø
3 x 10BA on 1/2" PCD
·8"
5/8"
CAP PLATE 2off brass
·1"
·18"
1/8"R
·15"
·2"
2 x 3/64"
·1"
1·1"
Drill & c/sink in situ No 49
SPOKE 18swg steel 16off
·22"
Letter T drill x ·15 deep
·145"
·395"
5/8"
3 x No49 on 1/2" PCD
HUBCAP 2off brass



SECOND SHAFT sil st
2 13/16"
1/4" ⌀
1/8"
1/16"
11/16"
5/8"
mill slot
THIRD SHAFT sil st
2 7/8"
1/4" ⌀
AXLE PIN
sil st
2BA
23/32"
9/32" ⌀
·185" ⌀
5/32"
3/32"
DRIVING PINS steel
1/8" ⌀
1 11/16" NEAR
1 9/16" OFF
3/16"
1/4" ⌀
turn from brass
REAR AXLE sil st
6BA
5·535"
5/16" ⌀
1/4"
flat for drive position when fitting
FRONT AXLE bms
sect A
sect B
·335 ⌀
·3"
·275"
·385"
8BA
·6"
3·35"
7/16" ⌀
1/4" ⌀
1/2"
·05"
1·625"
A
B

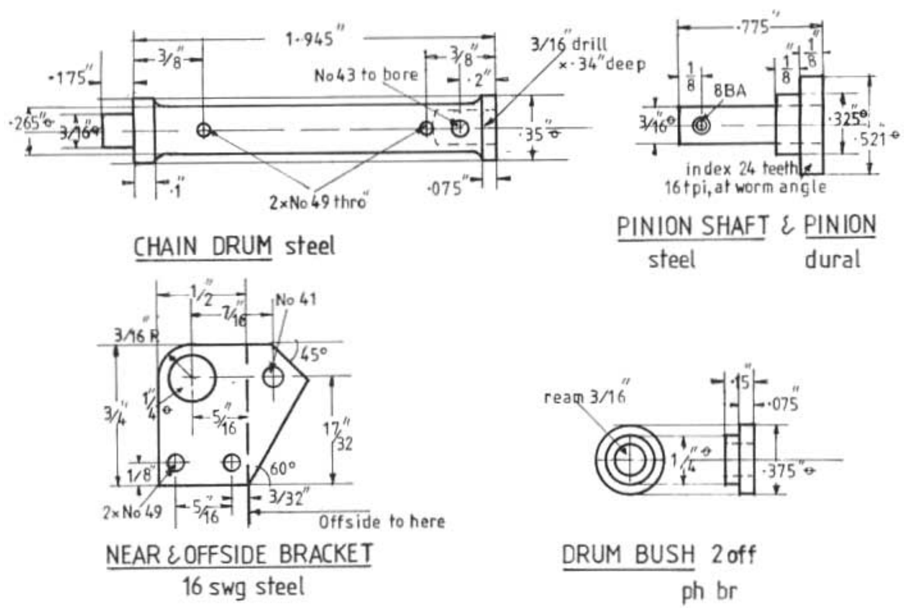
the effect is spoilt. Make the other rim before indexing around using the 40 position plate in the dividing head, five divisions between drilling, and a .2in shift before dividing again. The hubs now have a 90 deg. difference in the milling, and a 45 deg. shift, front from back.

Make a similar jig using a 1/4 in. dia. bolt with a 1in. unthreaded shank length. For the front wheels the cap-plate is placed over the bolt, before the hub, and the rear spokes are fitted first, otherwise the procedure the same as for the rear wheel, except that a 1/4 in. dia. alloy rod is used for the false centre whilst soldering.

FRONT AXLE

The front axle is turned from 1/2 in. dia. mild steel. This is a job which can be turned between two dead centres, using the faceplate and driving dog, except for the final finishing cut at the end of each stub axle, and the drilling and tapping 8BA, for which the chuck must be used. The stub axles are turned first after centring up, then the flanges, and the .335in. diameters just started. By manipulation turn a taper at each end of the inside part to an approximation of the drawing. Finish and drill the ends. The first flat is filed for the front, right across using the safe edge of the file when approaching the flange. Secure this flat against one face of the vice, and, using the vice as a guide, partly file the top flat just straight across, to be at 90 deg. to the first. Use the second flat against the face of the vice and make the third flat parallel with the first. File the first and third flats alternately to be parallel, central to the axles, and the correct distance apart before completing the other two.

Drill and tap the holes as required. Secure the wheels in place and check them for trueness. Assemble the rear wheels on their axle in the hornplates, and position the assembly on a flat surface, with the fork bush resting on the front axle at an edge. With a 6in. steel rule push up the boiler by the fork bush until the top of the boiler is parallel, checking also with the hornplates. Mark the position of the centre of the axlepin hole on the rule, repeat to check for accuracy, and compare the distance with that shown on the drawing (9/16 in.+ 3/32) 21/32 in. Make a note of any discrepancy to be taken out or put in when turning the flange of the fork, to keep the engine level on its wheels. Make the fork from 5/8 in. dia. mild steel, turning down the spindle end only, making the fork by sawing and filing, drill the hole for the axle pin, which is secured with a nut. Make the pin and the fork collar, and assemble after removing a perch bracket cover. Oil and check that the engine is level on its four wheels. Remove the engine unit, motion plate and pump from the pads and make a paper template to fit snugly around the boiler, a little overlong to overlap the ends. Cut a piece of 1/32 in. Hallite sheet to the size of the template and fit this insulation to the boiler, cutting a butt joint underneath. Using thin brass lagging sheet cut a piece to fit with a little overlap beneath; the paper template should be checked over the lagging for the precise size of brass sheet. Make three brass bands 1/8 in. wide, with a 90 deg. bend and a 10 BA clearance hole in each end, to hold the cladding in place, and secure in place to check before painting the clad boiler, and the engine unit, etc.

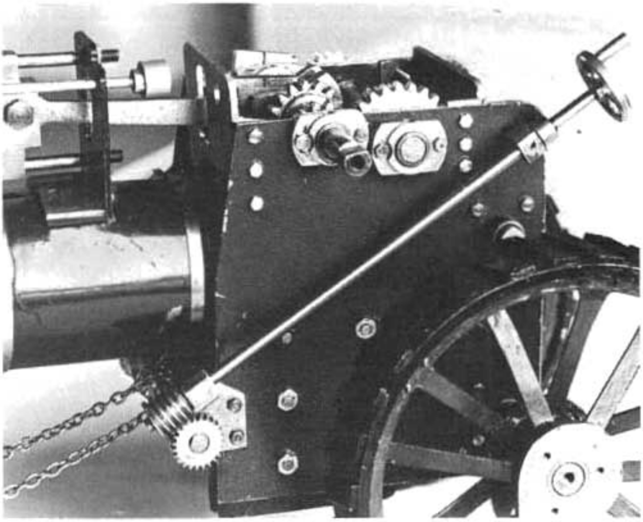


STEERING

The steering is by means of chain on a drum turned by a worm and pinion made as described in the gear cutting section. The chain should have links 5/32 in. to 3/16 in. long and can be obtained from most handicraft shops. When the gears are cut make the pinion shaft and turn the chain drum, drilling the end for

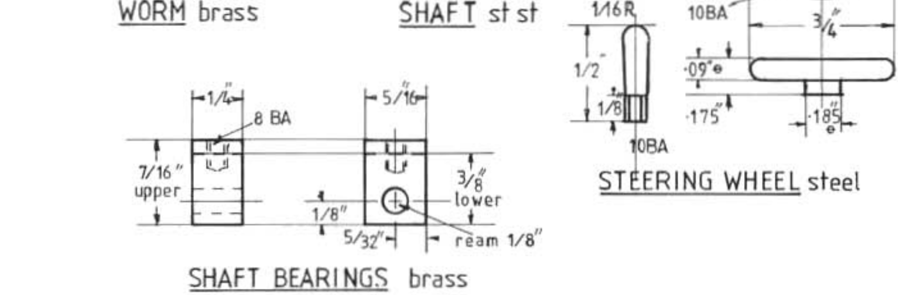
Two-start wormwheel and pinion, with leader.

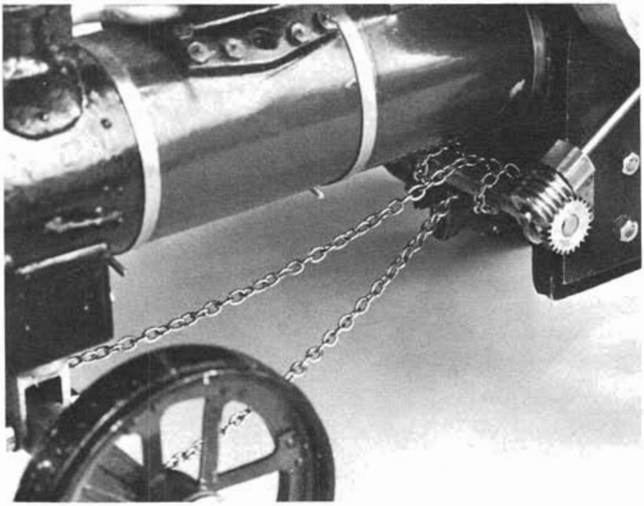
The steering gear fitted in place.



the pinion shaft. Turn and bore phosphor-bronze for the drum bushes. Make the steering shaft, threading the end in the lathe. Make the bush and the shaft bearing, securing the wormwheel with Loctite 641: if you have made the wormwheel with a ¼ in. bore a brass insert will be required for the wheel to fit the shaft, again secured with Loctite 641.

Make the near and off-side brackets, first as a pair, marking out and drilling



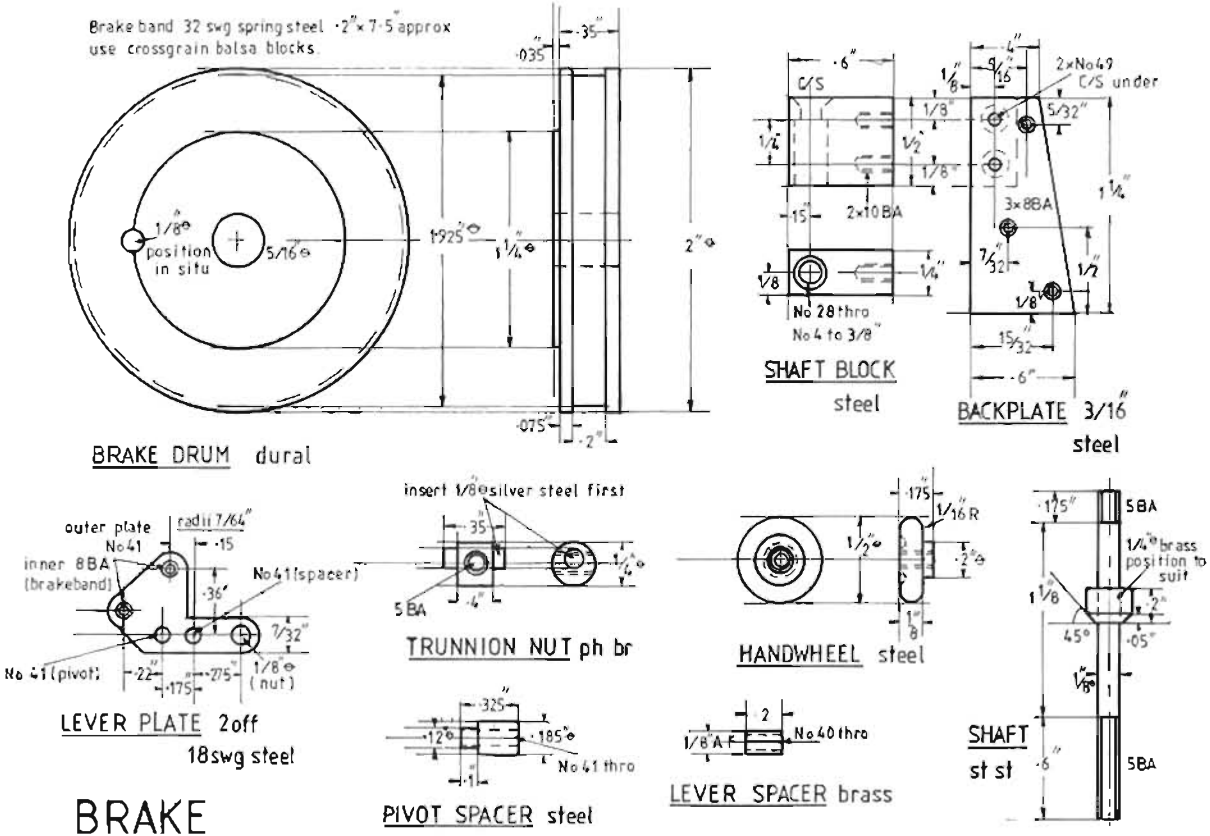


The steering chains; note wrap on drum.

the No. 41 hole on each before cutting out approximately to shape and securing the pair together with an 8BA screw, nut and washer. File carefully to outline and clamp on the cross-slide to drill the larger hole 1/4 in. dia. and the securing holes No. 49. Separate, clean off the burrs and scribe one bracket for the part to be cut off with a fine hacksaw blade. Loctite the bushes in and secure the lower shaft bearing, complete with the shaft and worm, on to the nearside bracket, pinion shaft in place. Assemble the brackets, chaindrum and upper shaft bearing, adjusting the lower shaft bearing if necessary. Mark the top position of the upper shaft bearing for the brass bush to be Loctited on after loosening the lower bearing and pulling the shaft up a little so that the adhesive does not lock the bearing. Turn the steering wheel blank and the handle, and index around the wheel to drill and file to shape the spokes. Fit the handle to the wheel and the wheel to the shaft. Secure the chain with "S" hooks, to the drum and the axle, as shown in the photographs. The chain winding on to the top of the drum should be above the chain winding underneath.

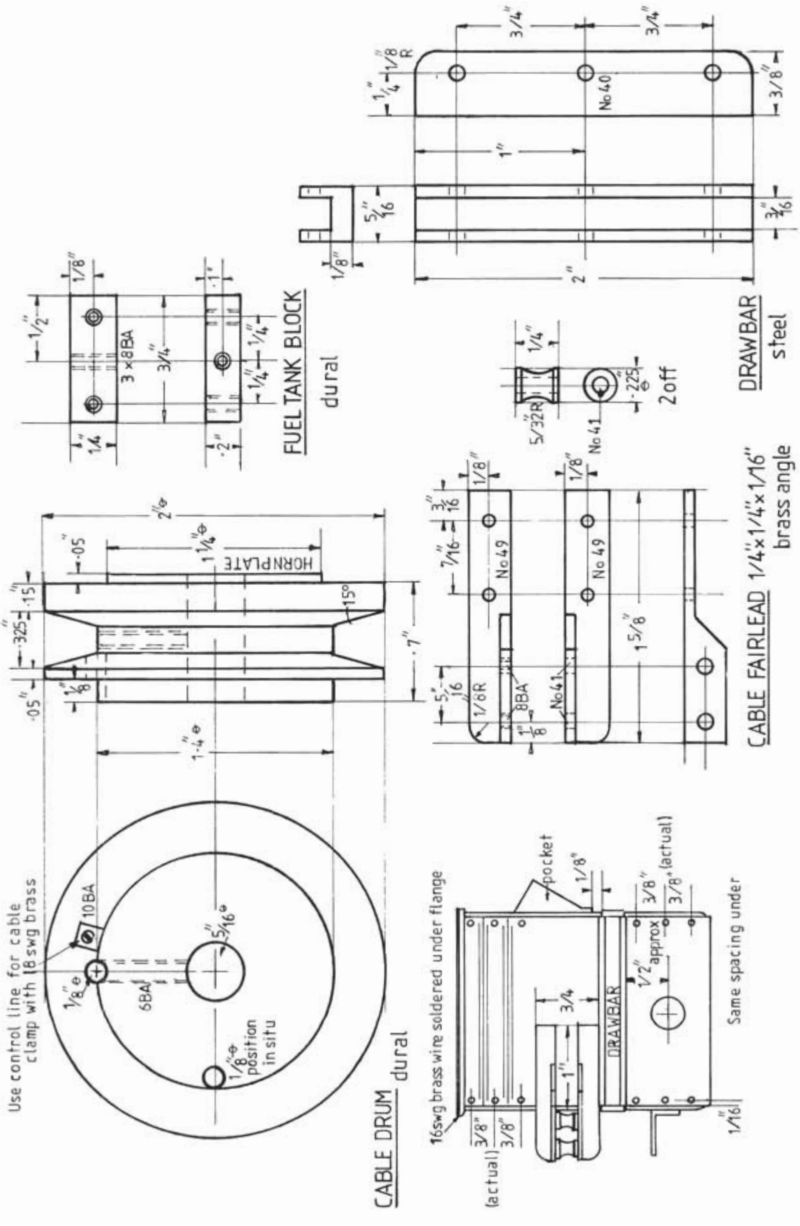
GEAR CHANGE

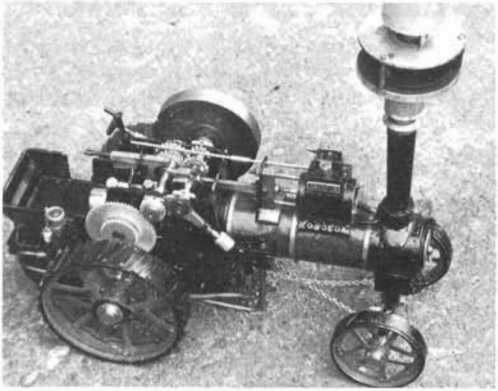
Make the lever bracket from dural, and then the gear change lever from 3/16 in. in mild steel: the handle is turned in the four-jaw chuck. Fit all the gears and collars on the shafts and try the gear change lever in place, filing back for lower clearance. The regulator lever is screwed to the side of the lever bracket, using a tight spring washer. There is no location fitted to the gear change as it seems quite positive without, but there is room to fit a 1/8 in. spring loaded ball into the gear lever if required, to give a low, high and neutral gear lever position on the bracket. (Drawings appear on pages 129/130).



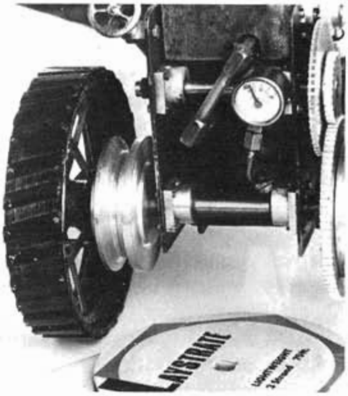
Brake band 32 swg spring steel ·2" × 7·5" approx
use crossgrain balsa blocks
BRAKE DRUM dural
1/8"⌀ position in situ
SHAFT BLOCK steel
No 28 thro
No 4 to 3/8"
2×10 BA
BACKPLATE 3/16" steel
2×No 49 C/S under
3×8BA
insert 1/8"⌀ silver steel first
outer plate
inner 8BA (brakeband)
No 41 (spacer)
No 41 (pivot)
radii 7/64"
1/8"⌀ (nut)
LEVER PLATE 2off 18swg steel
TRUNNION NUT ph br
5 BA
HANDWHEEL steel
1/16 R
PIVOT SPACER steel
No 41 thro
LEVER SPACER brass
1/8 A F
No 40 thro
SHAFT st st
5BA
1/4"⌀ brass position to suit

BRAKE


DRAWBAR
steel
FUEL TANK BLOCK
dural
3 × 8BA
2 off
No 40
No 41
No 49
HORNPLATE
CABLE FAIRLEAD 1/4"×1/4"×1/16"
brass angle
Use control line for cable
clamp with 18 swg brass
10BA
6BA
1/8"⌀
position
in situ
CABLE DRUM
dural
16swg brass wire soldered under flange
pocket
DRAWBAR
Same spacing under
(actual)
approx



Getting up steam with a blower.



The cable drum in position.

COMPLETING THE ENGINE

The brake and cable drums are turned from 2⅛ in. dia. dural in the three-jaw chuck, jaws reversed, first finishing a face, reversing and finishing to width, drilling through ¼ in., bringing up the live centre to turn the outer diameter grooves and raised face before drilling through 5/16 in. Note that the driving gears drive the main shaft direct, otherwise only the cable drum is secured to that shaft, so for the winding operations a short pin should be fitted through the off-side wheel into the brake drum with the brake on, to prevent movement. For normal driving the near-side wheel is pinned to the winding drum, and the off-side wheel to the drive gear, through the brake drum.

The brake drum has a band of spring steel (from an old clock) which is tightened by a lever worked by a handwheel and shaft on the tender side. The two lever plates are made oversize with one No. 41 hole drill in each to be secured together and the other hole drilled and the lever filed to shape. The lever spacer and the trunnion nut go between the plates, as do the annealed and riveted ends of the brake band. The trunnion nut is drilled and a short length of silver steel axis is inserted before drilling and tapping 5BA. The backplate is secured to the tender with two 8BA screws and washers, from inside. To give good braking the band has wooden brake blocks glued around, inside the diameter over the drum. I used 3/16 in. balsa cut across the grain, attached with epoxy resin, using just more hardener than adhesive, to keep it flexible.

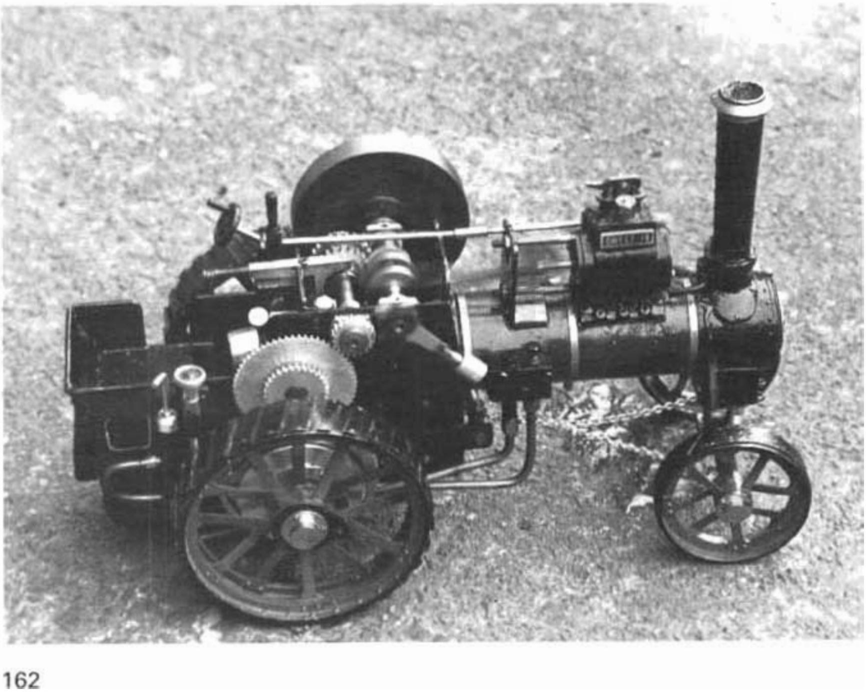
The cable fairlead, the drawbar, the steps, the water pocket and the drawstraps are all secured to the tender with epoxy resin (1 to 1 now), and false hex. heads are fitted to the cable fairlead bracket to make it look correct. However, the cable rollers do roll, and the cable is authentic, being control-line cable: the end should be bent over an eyelet, whipped with fuse wire and lightly soldered.

FINISHING OFF

Take off the rear wheels and the third shaft so that the tender can be removed for painting; any other part which requires painting can be completed now. It is a good scheme to paint steel parts which are likely to be handled, and are not lubricated, to prevent rusting. I etched special nameplates for my Sweet Sixteen in brass, also etching a diamond pattern into the steps before fitting, which adds a nice touch. Wipe a little diluted black on to the chain, to dull it, and polish the chimney top, hub-caps and other brass and copper parts left unpainted. The outer surface of the flywheel should not be painted as this is normally used as a belt drive for ancillary equipment.

Raise steam in the finished engine as before, observing the safety precautions. Do not expect to change gear while driving as no synchromesh is fitted. If a speedy heat-up of the boiler is required use a blower on the chimney so that a higher flame can be used without burning the paint off of the hornplates. A twist of the flywheel will usually be required to start the engine running in gear, although there are positions where the engine will self-start, particularly at top steam pressure. Do not forget to empty the lubricator of water, and to refill with steam oil between runs.

The engine under power



Chapter Thirteen

Auxiliary Pump and Electric Blower

These are aids for getting up steam. The pump provides a water supply into a boiler for both the testing of a boiler under pressure, and for retaining a water level in a boiler whilst getting up steam, before the engine's pump is operating. The blower draws up the fire in coal-fired engines and boilers, and will also be required for gas or spirit fired models to keep the flame in the right direction and avoid the heat spilling from the side of the firebox, until the steam can take over the job of drawing-up.

AUXILIARY PUMP

The auxiliary pump is designed to be made easily and work as well as one made from expensive castings, which can present machining problems on the small lathe. Fittings and valves are inserted separately into a main duralumin block and all components are made on a Unimat lathe. The capacity of the pump is ¼ in. bore x $^9/_{16}$ in. stroke.

The pump is connected to a water reservoir, in the form of a one litre jerrican, by means of silicone rubber tubing, carrying the water to the inlet valve, and while it is capable of withstanding considerable pressure, if used as an outlet tube under such pressure it would need to be fastened with hose clips or it would fly off the unions. To elimate the need for hose clips in this small size, nylon tubing is used for the pressure side between the pump and the backhead. The nylon tube used has an internal diameter of 6mm, which taps ¼ in. x 40, into which brass fittings can be screwed and sealed with Loctite.

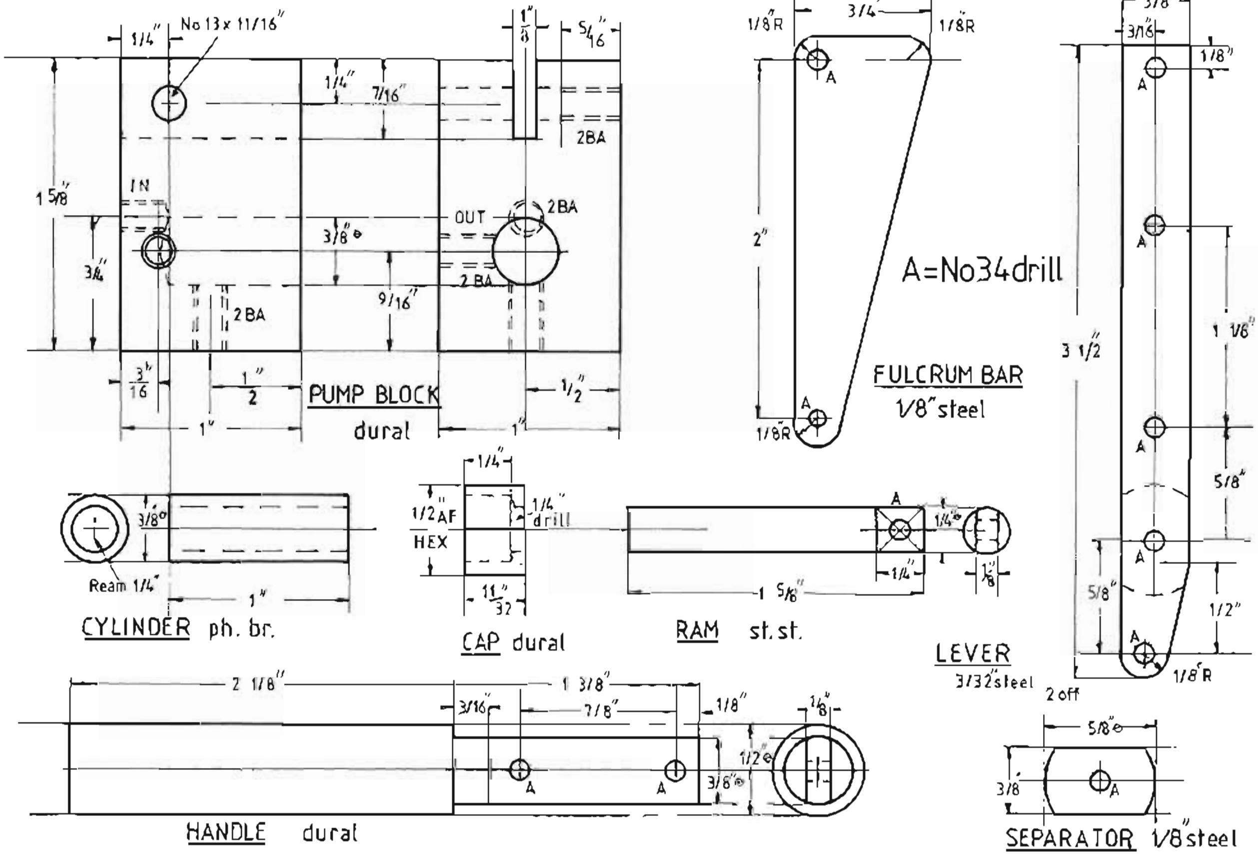
The far end of the nylon tube is connected to a block with a stainless steel lance, made to swivel in the block, and which fits the by-pass valve in place of its spindle. This is used to pump water to the clack, and into the boiler without further fittings.

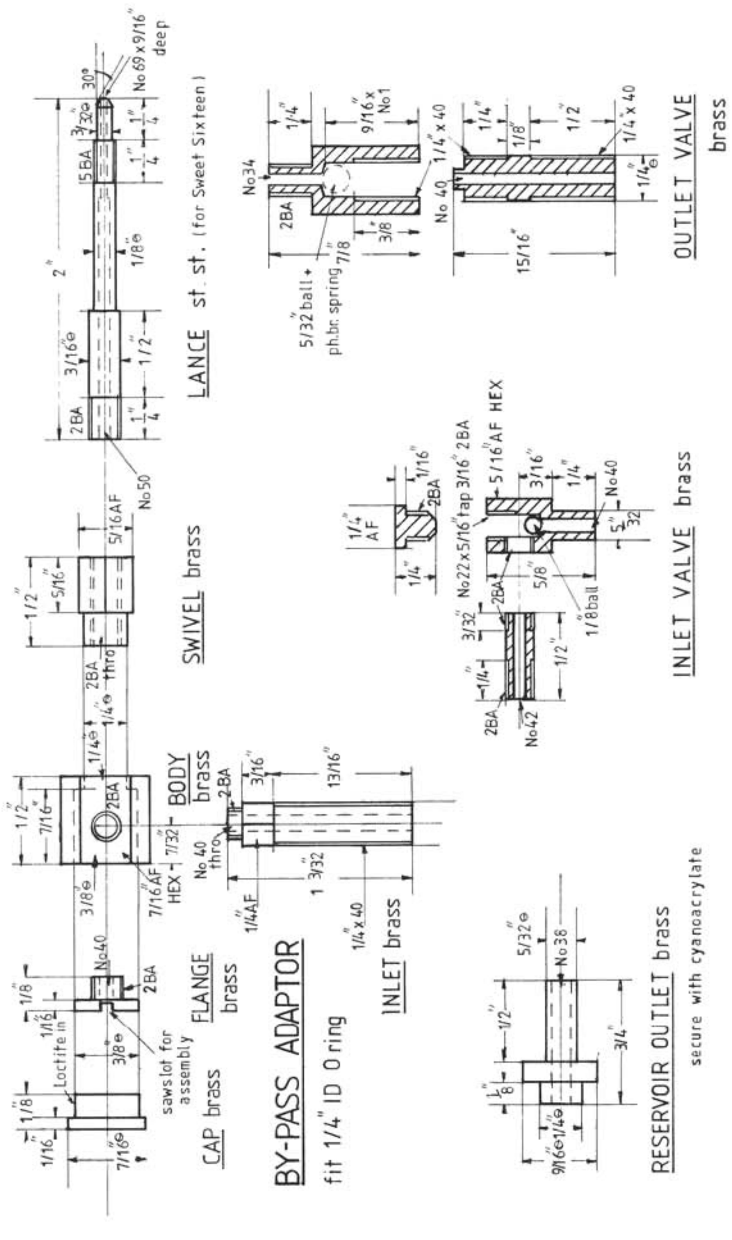
THE PUMP BLOCK

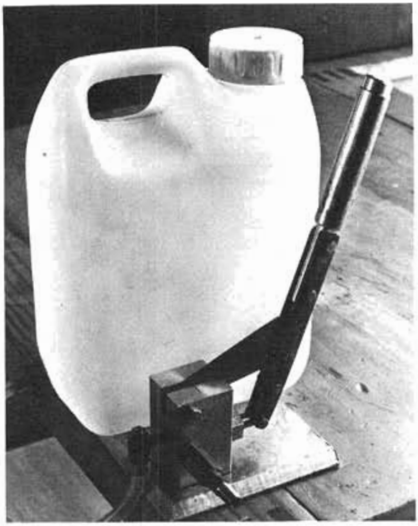
The pump block is made from 1 in. square duralumin stock. Cut a piece just over 1⅝ in long and mark out the diagonals to centre punch each end. Fit the four-jaw chuck and centre up to square off each end with a knife tool, down to the exact length, as close to the centre as possible. Drill one end for the securing screw, No. 22, and take off the centre pip at the other.

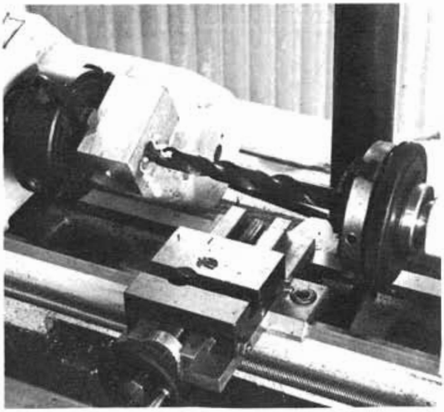
Mark out the block for the ram cylinder and for the two valves. Adjusting the four-jaw to centralize each hole in turn, bore the ⅜ in. hole first, and then the other two to just enter the main bore, tapping each of these 2 BA in the lathe

AUXILIARY PUMP




LANCE st. st. (for Sweet Sixteen)
SWIVEL brass
BODY brass
CAP brass
FLANGE brass
saw slot for assembly
Loctite in
BY-PASS ADAPTOR
fit 1/4" ID O ring
INLET brass
OUTLET VALVE brass
5/32" ball + ph.br. spring
INLET VALVE brass
RESERVOIR OUTLET brass
secure with cyanoacrylate





Left, the completed pump with plastic can.

Above, boring the pump block.

immediately after drilling. Tap the block securing screw hole right into the main bore; this hole is used first for a grub screw to secure the ram cylinder, followed by the main securing screw.

Cut a length of 3/8 in. dia. phosphor-bronze and bore through with a letter D drill before reaming it 1/4 in. Turn the ends square and down to length then clean the outside with emery cloth and check that it fits into the bore without excessive force. Cut the stainless steel for the ram and turn both ends down cleanly, taking off the sharp corners. File one end to a 1/8 in. flat, carefully, in a soft clammed vice, and, holding by the flat, try the ram cylinder onto the stainless ram, easing any tight spots with a little Brasso; clean off. Loctite the cylinder into the block with 601, screwing a short grub-screw tightly into the securing hole. When cured clean off with a cleaning spray, oil, and retap the holes.

Fit up the Unimat in the vertical mode, with the machine vice on the cross-slide and a 1/8 in. end mill in the drill chuck to cut the slot for the fulcrum bar. Cut the near wall from left to right and the far wall in the other direction, with a four division adjustment of the cross-slide hand-wheel in between. This will give a slot with sufficient clearance, but if the fit of the bar is a little slack fit a 4 BA brass screw at an upper front corner to bear against the bar and take up the slack. Drill the hole through No. 22 and then the first 3/4 in. No. 13 and tap through 2 BA. For the back pivot use a 1in. long bolt with only the first 1/4 in. threaded 2 BA.

Drill the hole in the ram and flat, cut out the 3/32 in. and 1/8 in. mild steel a little oversize. Drill just one hole in each of the two lever sides and secure them together before drilling the other holes and filing to shape. Cut a length of

dural for the handle and drill the two holes before returning the Unimat to its lathe form for turning the handle down. File flats on one end down to 1/8 in. To secure all parts of the lever use 1/2 in. hex head 6 BA bolts with 1/4 in. of the shank unthreaded, and when all the nuts are secured cut off the surplus thread and file smooth.

Turn the "O" ring cap from light alloy hexagon stock, drilling through 1/4 in. and counterdrilling 3/8 in. to fit the "O" ring before Loctiting with 222, ram in place and oiled, and the cap not quite pushed fully home. If the "O" ring ever needs changing the cap can be easily wrenched off.

WATER VALVES.

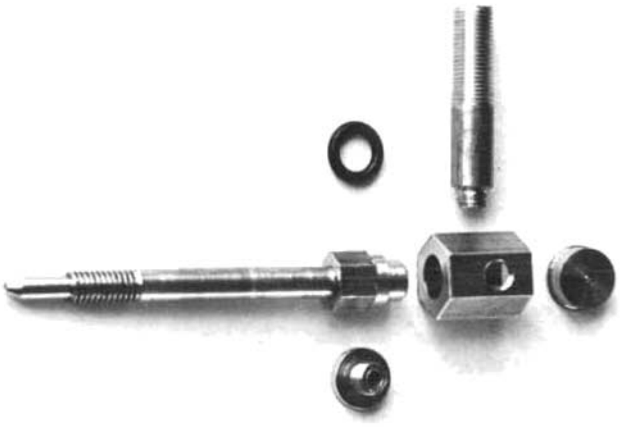
The non-return valves are turned from hexagon brass stock. The inlet valve body is made first, turned, drilled and counter-drilled No. 22 then tapped 2 BA for the cap. Mark a spot for the outlet on one face of the hex. and secure in the four-jaw chuck, two jaws reversed, and drill and tap 2 BA. Make the cap and outlet tube from hex. brass and secure the body into the tube with Loctite 601, making sure it does not protrude into the body. Fit 1/8 in. steel ball, a piece of brass rod, and place the inlet tube loosely in the vice, body resting on the jaws, to give the rod a good tap with a hammer. Remove the ball and replace it with a phosphor-bronze ball of the same diameter, checking the seat with a blow and a suck. If all is well fit the cap to allow the ball about 1/20 in. movement, the equivalent of 1 1/2 turns of 2 BA thread.

The outlet ball valve is lightly spring loaded, providing a more positive seating in the horizontal position. This valve is in line, and no side fitting is required, and the ball is 5/32 in. diameter to provide more room for the spring. The spring is a 1/8 in. I.D. stainless safety valve spring, 24 SWG, from Messrs Reeves, and just 3 1/2 to 4 turns are used, the ends being lightly ground to flat on the fine grinding wheel. The outlet is first screwed into the body until the ball just stops rattling, the end thread is touched with Loctite 222, to surround it, and a further quarter turn applied to just tension the ball. Oil into the hole to prevent migration of the adhesive.

Secure the cleaned-off valves into the pump, using 222. Put the lever action together and mount the pump on to a piece of 1/4 in. thick duralumin, or other suitable material, to give a good bed. Use a 2 BA countersunk screw through the base into the body, fixing the body to the base with Loctite. Oil the working parts.

OTHER FITTINGS

Make the jerrycan outlet from brass, securing it into the base of the plastic can with cyanoacrylate adhesive, pressing well home with a piece of thick rag, and then flushing with water to ensure that no free adhesive survives to stick to unwary fingers. Remember to drill a small hole in the lid of the jerrycan! The silicone tubing for the water supply is obtainable from the local model shop; the size I used is 6mm O.D. and 2.5mm I.D. Fit the tubing, fill the jerrycan with water and give the pump a good test.



Components of the bypass fitting.

The pump, as it stands, can be used for all sorts of jobs which crop up, such as hydraulic testing of boilers, and up to high pressures, given suitable water unions and a good-size pressure gauge. As an auxiliary pump the pump works into the by-pass valve, first removing the existing screw-down spindle and replacing it with a lance of similar dimensions, but hollow.

Make the lance first, turning down the end, threading in the lathe, both ends, before drilling through and turning down the front taper. Use plenty of RTD compound when threading the stainless steel and start with the die well open. The drilling through will need to be carried out from each end to halfway, so, for the top half a larger drill may be used, say a No. 43, which will make the job a little easier.

Make the brass swivel, which is secured on to the lance with Loctite 222. This fits into the brass body and is secured to turn with the flange, a ¼ in. O.D. "O" ring being fitted as a seal, allowing a turning movement. The inlet fitting fits into the side of the body, 2 BA, so that it does not impede the swivel movement or the fitting of the cap which is Loctited in with 601, as is the inlet. The inlet is threaded at its outer end ¼ in. x 40 for the nylon tube, and the flange has a screwdriver slot to ensure a tight fit without needing to be sealed.

In use the tube should be filled with water before the lance is inserted into the by-pass valve and screwed home tight. Further pump action will then produce water pressure to enter the clack against steam pressure, also sealing the engine's own pump valve.

Various lances can be made to fit different by-pass valve sizes. The pump is also for use in the hydraulic testing of boilers, when fitted with unions and a suitable pressure gauge: copper tubes must be used instead of the nylon, in this application.

ELECTRIC BLOWER

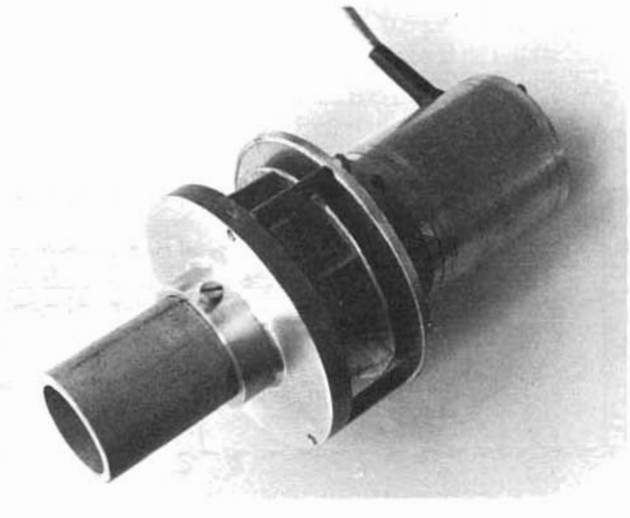
This electric blower is a simply made turbine type, designed to remain cool when drawing up fires in steam boilers and locomotives, and is adaptable for all the smaller gauges by means of interchangeable nozzles. It can be scaled up for the larger gauges if required with little difficulty. It is constructed mainly from duralumin turned on the Unimat.

THE ELECTRIC MOTOR

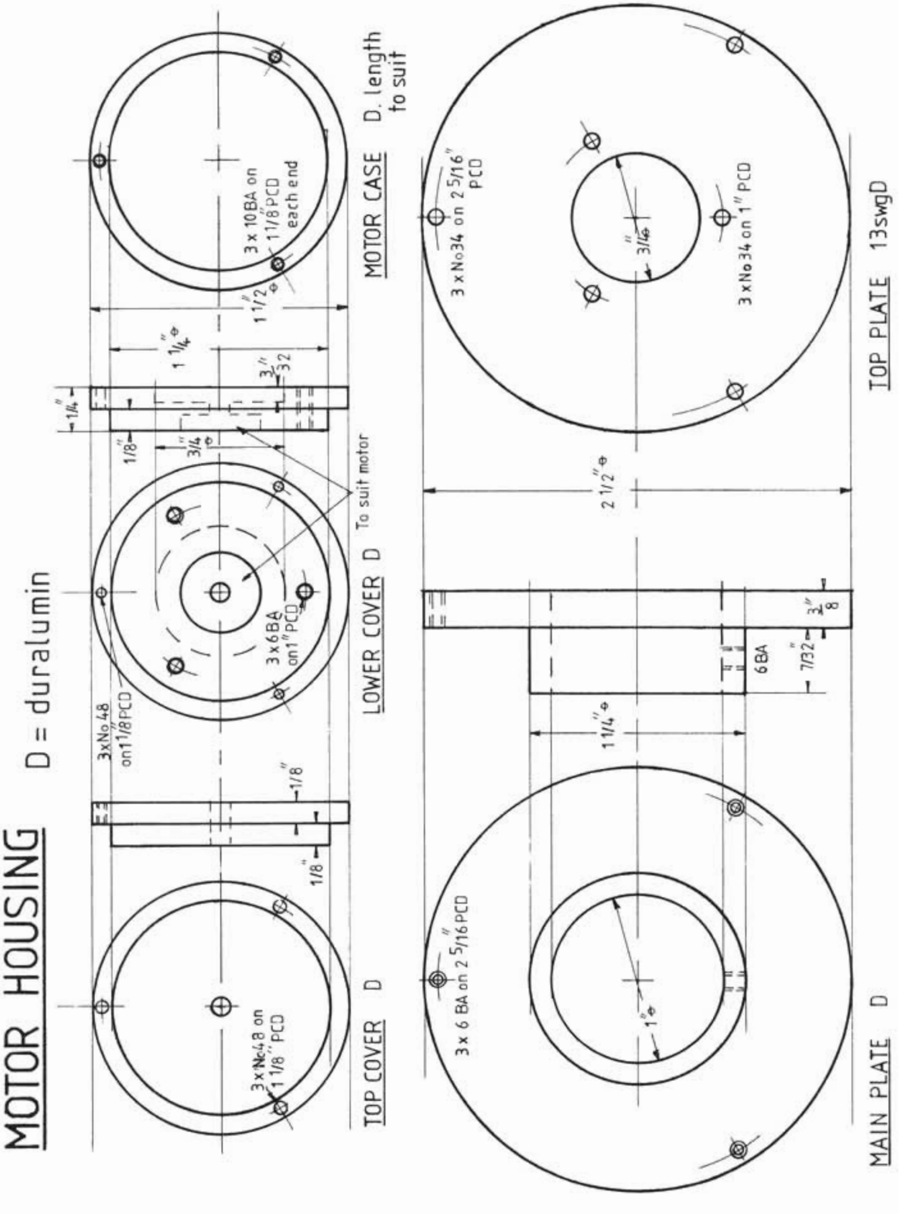
The first objective is to obtain the electric motor, and the secondary objective, the batteries. The motor needs to be powerful 6 volt job, and the cheaper midget Japanese types are not really suitable as the bearings and brushes wear rapidly with prolonged use. The motor I used came from an electric toothbrush, drawing about 250 milliamps when running at speed.

BATTERIES

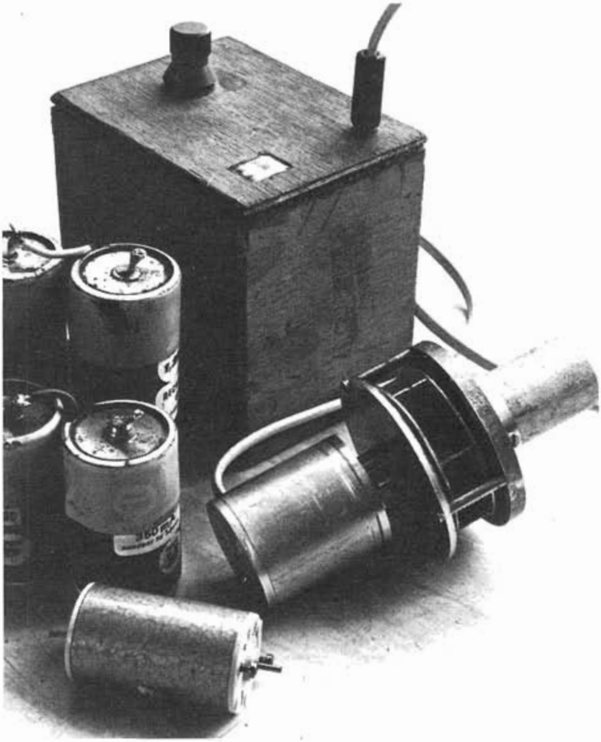
The batteries to be recommended are the rechargeable nickel cadmium cells, rated at a nominal 1.2 volts each. I have used four in series to give a nominal 4·8 volts, with a four-way switch to give 4·8, 3.6, 2.4 volts and off, for a speed control. The four batteries are built into a wooden box with an output jack socket, the switch and a charger circuit with meter indication to be connected directly to a 12 volt battery charger. The batteries I have in use have a 6 amp-hour capacity, but the smaller 4 amp-hour size D will give over 12 hours running time to any of the three motors with one charge. The size D has the same physical dimensions at the HP2 drycell battery. If a faster blow is



The blower complete and ready to use.


MOTOR HOUSING
D = duralumin
TOP COVER D
3 x No.48 on 1 1/8" PCD
1/8"
1/8"
LOWER COVER D
3xNo 48 on 1 1/8" PCD
3 x 6BA on 1" PCD
To suit motor
3/4" ⌀
1/8"
1/4"
3/32"
1 1/4" ⌀
1 1/2" ⌀
MOTOR CASE D. length to suit
3 x 10BA on 1 1/8" PCD each end
MAIN PLATE D
3 x 6 BA on 2 5/16" PCD
1" ⌀
1 1/4" ⌀
6BA
7/32"
3/8"
2 1/2" ⌀
TOP PLATE 13swgD
3 x No34 on 2 5/16" PCD
3/4" ⌀
3 x No 34 on 1" PCD

The blower shown with types of nickel cadmium batteries and a suitable motor.



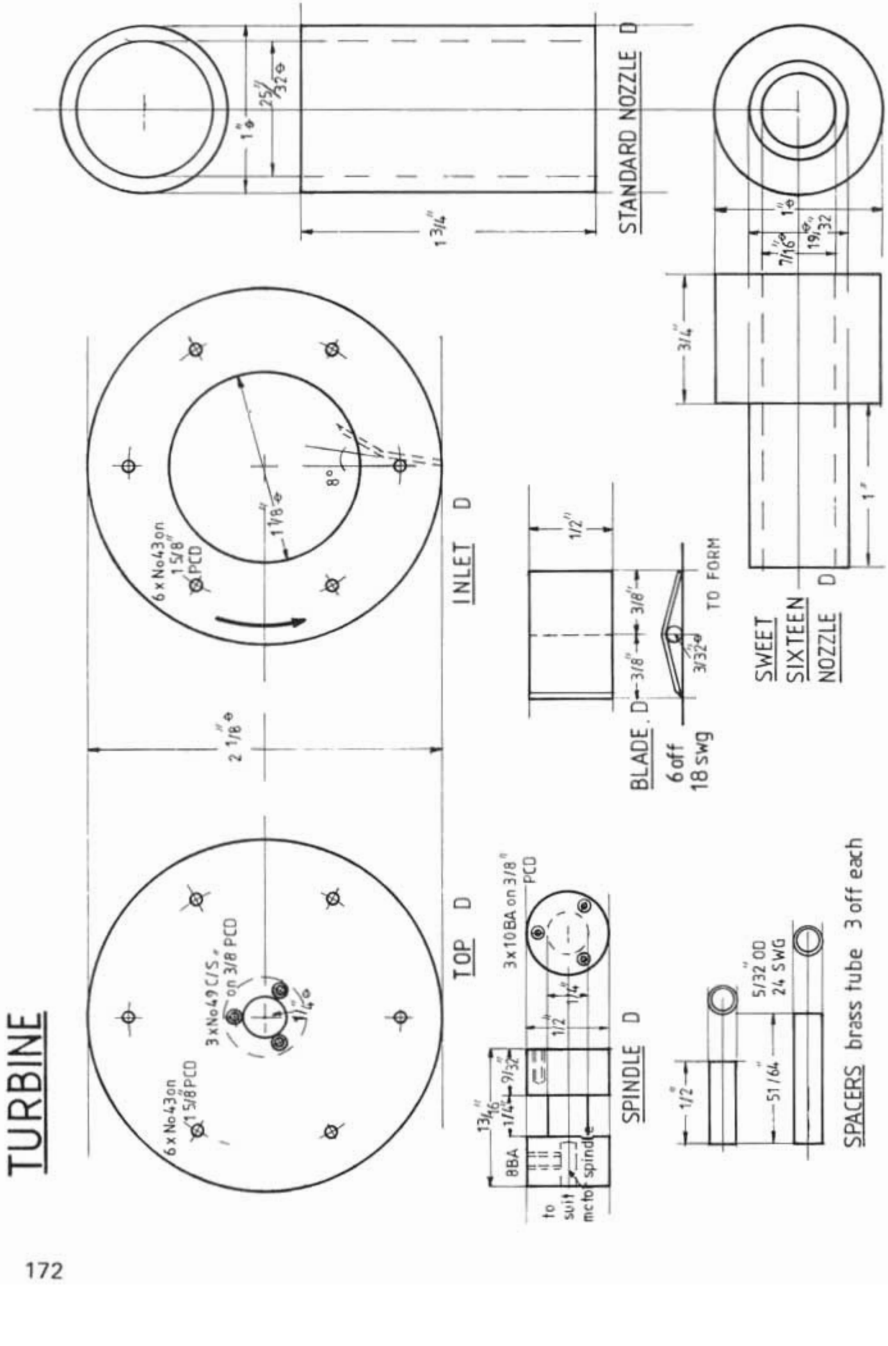
required it is only necessary to add a further nickel cadmium battery, raising the working voltage.

To recharge the batteries a charging current of 1/10th the nominal capacity is recommended, the 4 amp-hour cells being recharged at a 400 milliamp rate for 16 hours, if discharged to the 1.1 volt lower limit. A high wattage current-limiting resistor should be placed in series in the charging circuit, so that over-charging cannot occur.

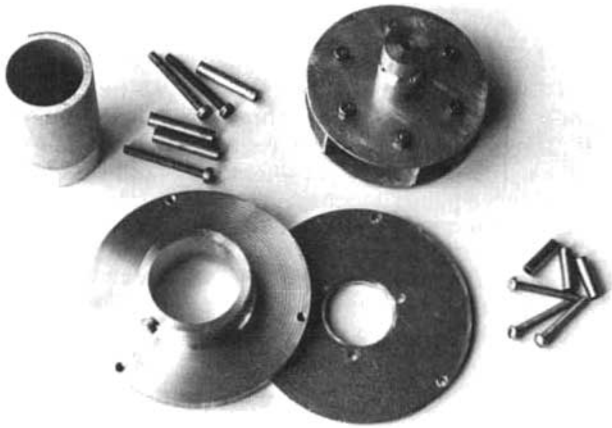
THE MOTOR HOUSING

The motor is contained in a cylinder of duralumin, length to suit the type of motor, capped at each end to hold the motor securely in position. The drive spindle protrudes from one end and the flex from the other. The spindle end is recessed to take the drive shaft, and holds the three pillars to the body of the blower.

It should be noted that all PCD holes (except for those of the turbine and its main spindle) which are to be drilled using the indexing attachment may be left until all the parts are made, so they may be drilled to match.

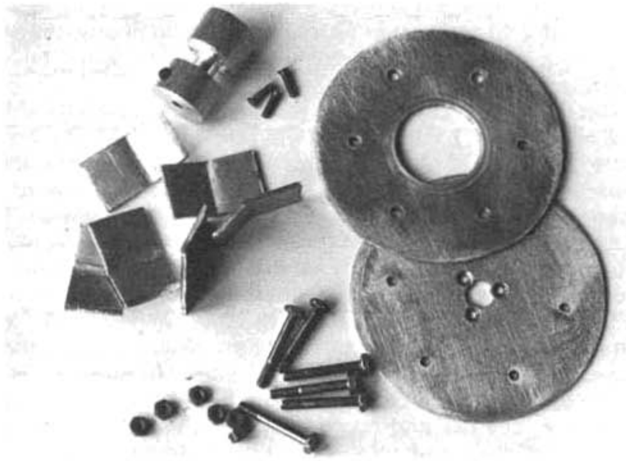

TURBINE
STANDARD NOZZLE D
25/32 ⌀
1" ⌀
1 3/4"
INLET D
6 x No43 on 1 5/8" PCD
1 1/8" ⌀
8°
2 1/8" ⌀
TOP D
6 x No43 on 1 5/8" PCD
3 x No49 C/S on 3/8 PCD
1/4" ⌀
BLADE. D
6 off
18 swg
1/2"
3/8"
3/32 ⌀
TO FORM
SWEET SIXTEEN NOZZLE D
1" ⌀
7/16" ⌀
19/32" ⌀
3/4"
1"
SPINDLE D
3 x 10BA on 3/8" PCD
8BA
to suit motor spindle
13/16"
1/4"
9/32"
1/2
SPACERS brass tube 3 off each
5/32 OD 24 SWG
51/64"

The blower components.



THE TURBINE

The turbine runs at about 8000 rpm with 4.8 volts applied, and is not required to work very hard. It revolves freely between two plates, and is on the end of a main spindle which is quite stout at each end, but turned down in the middle to a small diameter, giving separation between the hot turbine end and that required to stay cool. The nuts and bolt-heads of the turbine are left protruding outside to provide cooling away from the turbine, which may be expected to get rather hot.



Parts for the turbine.

The turbine consists of six blades between two flat sides, with six 6 BA nuts and bolts pinching the sides together on to the blades. The blades are bent towards the direction of rotation at a central hole on the lower side so that air is drawn into the turbine upon rotation, and centrifuged out.

The thin plates are marked out and cut from sheet dural with tin-snips, slightly over-size, put into the three-jaw chuck and drilled 1/4 in. with a centre drill. They are both secured together on a mandrel, between two penny washers. Turning between centres, take light cut with a sharp knife tool until the marked circle is reached. Remove from the mandrel and bore out one central hole to the larger size. Make the alloy spindle.

Fit up the index attachment with the 30 tooth plate and drill the three holes in the spindle, then the turbine top, and countersink. Index and drill both plates for the blade screws. The blades are cut 1/8 in. overlong and slightly overwidth, and drilled one end No. 35 to be secured together with a 6 BA nut and bolt. Fasten in the vice to file to exactly 1/2 in. wide and the end square. Remove the bolt and snip each blade to length before cleaning off on emery.

Mark each blade for the bend and secure them one by one with a hexagon block in the vice to bend first to the hexagon angle, which is too much. Then take a piece of 3/32 in. dia. brass (or the shank of a No. 42 drill) on a flat block and tap each angle down on to the diameter to obtain the correct bend, using a pin hammer.

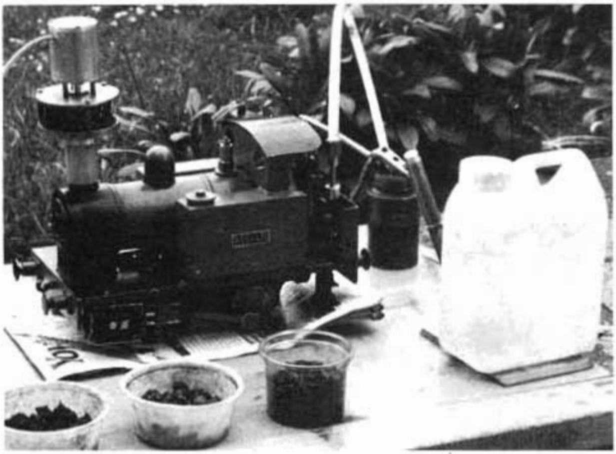
After assembly tighten the nuts to full torque, and check on the motor, running at a slow speed, that the turbine runs without wobble, adjusting where necessary.

MAIN AND TOP PLATES

The top plate is cut from 13 swg flat stock with an Abrafile, first marking out the circle and cutting carefully to a little oversize. Fit into the three-jaw chuck, jaws reversed, and centre drill 1/4 in. Remove and fit onto the mandrel to take down the edge, as before. Return to the chuck and bore out the middle for the turbine spindle clearance.

Cut the main plate from 2 1/2 in. dia. bar, face off both sides, drill and bore out the hole before turning down the rest, gripping the work by the inside of the hole, the large diameter running centre keeping the job in place. With the Unimat it is always quicker to turn down the diameter of a job like this, rather than the face. Increasing the cut as the diameter reduces. This is because firstly a cut of say 2 thou. takes 4 thou. off a diameter, but only 2 thou. from a face. Secondly a good cut from a set diameter can be gauged, but the varying feed needed for a changing face diameter will often be difficult to maintain.

Drill the hole for the nozzle securing screw, and tap. Set up the index attachment with the 30 tooth plate on the cross-slide and the vertical Unimat for drilling the matching holes. With the Unimat as a lathe, feed a length of brass tubing through the main spindle, and, with the running centre brought up in the tailstock and clamped at an appropriate distance, use a parting-off tool to cut the length of tubing. Take the tool through to finish the new end,



Steaming up a small locomotive using the aids.

bring the tool back and tap the tubing through, chuck just loosened, so that the new end meets the running centre without disturbing the lead screw before parting off again. In this way each of the three columns will be precisely the same length, with only the first having to be measured. Repeat for the other three columns.

Assemble the parts together using a touch of Loctite 222 on the threads. Make an appropriate size nozzle to fit the chimney of the model, or set of nozzles if more than one job is envisaged.

To test the blower, switch on to the faster speed and take the nozzle on to some grains of rice, which should be lifted and ejected from the turbine with some force, if not, check that the rotation of the turbine is in the right direction, reversing motor polarity if it is not.

IN USE

In use the blower remains remarkably cool, unlike the enclosed type of blower, and will throw out air, smoke, and steam for hours on end if required, using the recommended batteries. The blower should be switched up to full speed when the fire is lit, but when the coal has become red hot the speed can be lowered while pressure is rising, until it is required to allow the steam to take over the blow. Remember that drawing an excess of air through the fire can actually cool the tubes whilst quickly burning away the fuel in a small firespace.

For smaller models, using a smaller nozzle adaptor, the blow on full speed may be excessive. In the circumstance it is easy to make a new turbine and spindle, the turbine having a smaller "in" aperture, and blades angled a little less, which will provide an efficient blow using less power. Alternatively the lower speeds only can be utilised using the switch.

The Unimat lathe series first appeared in the 1950's and developments have gradually broken down the resistance of engineers who thought it too small to be capable of serious work. Rex Tingey was a radio aircraft and car modeller who bought a Unimat to make accessories not readily available commercially, but he found working on the little lathe so absorbing that he spent increasing amounts of time and ingenuity on extending its scope and developing methods of work and workpieces which have earned him an international reputation. This book brings together a number of designs, including versions of his ingenious 'valveless' steam engine, culminating in a working steam traction engine for which drawings and instructions are provided, along with similar details of half a dozen other projects.

Originally from London, the author spent 22 years in the Royal Air Force as a photographer and photographic instructor; he is now in charge of the B.B.C.'s Belfast colour processing laboratory and resident in Northern Ireland. He is well-known as a contributor to "Model Engineer" and author of "Making the Most of the Unimat", also published by Argus Books and recently reprinted.