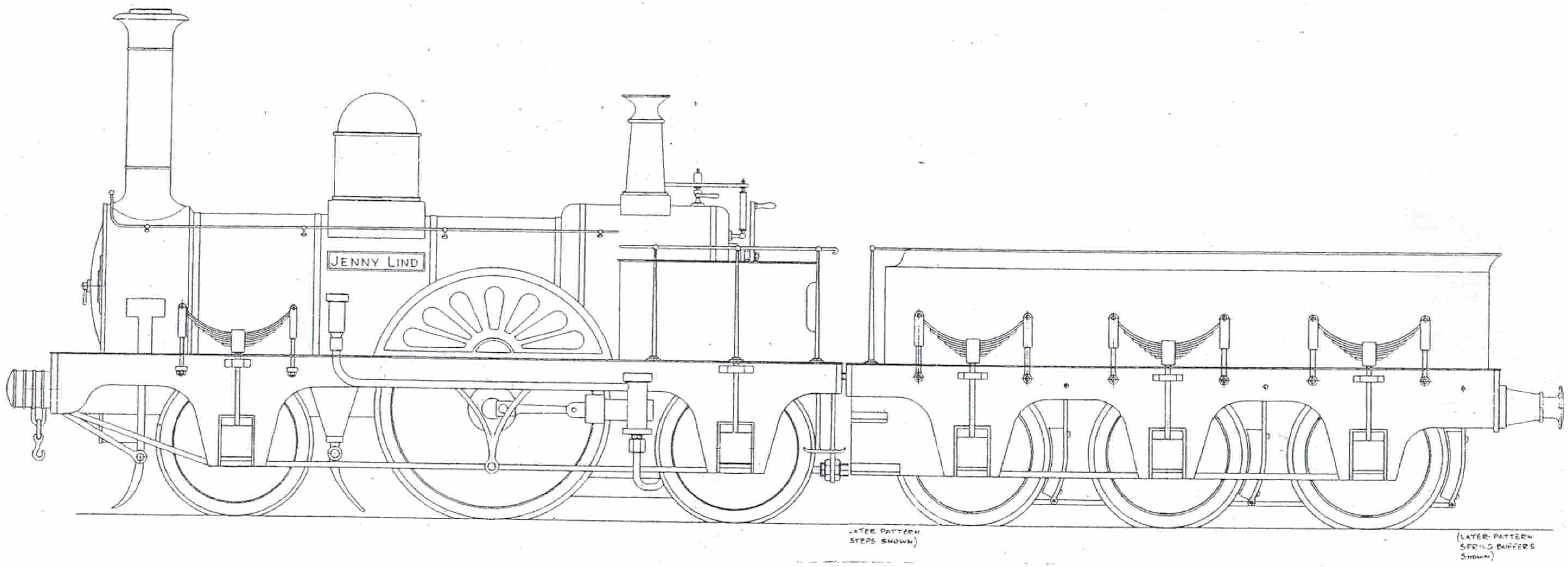
# JENNY LIND by LBSC

## A 3½" GAUGE ADAPTION OF THE E. B. WILSON DESIGN OF 1846




## CONSTRUCTION MANUAL

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JENNY LIND an early type locomotive in $3\frac{1}{2}$" gauge by LBSC.



A desire was expressed by model engineers many years ago for an 'instruction serial' dealing with an old-time locomotive capable of passenger hauling and I now propose to give full details of how to build a $3\frac{1}{2}$" gauge edition of the famous "Jenny Lind" type of the middle of the 19th century. These locomotives were not only among the most successful, but the best looking machines of their time ever put on the road, performing wonderful feats of haulage and sustained spped on many railways; and builders of the little one may rest assured that she will in no way fall behind her big (but now, alas! long departed) sisters in any respect. The full sized engines were a remarkable illustration of the truth of the old saying that "great minds think alike"; for after John Gray was appointed locomotive superintendant of the Brighton Railway in 1846, he designed a single-wheeler of the type shown in our illustration, and a dozen of them were built and put into service. About a year afterwards, and quite independantly, the firm of E.B.Wilson, of Leeds, built the original "Jenny" and eleven sisters, and delivered them to the Brighton Railway following Mr.Gray's batch. Two other designers, also independantly, hit on the same idea, so there is little wonder that the "Jenny Lind" type, as they were called, were successful. Two heads are generally admitted to be better than one, and four certainly should be!

The opinion is still held in many quarters, that small reproductions of the old-time locomotives cannot be successful, as their boilers are too small; but your humble servant always takes an unholy delight in upsetting that kind of theory, and I have found that if the valve gear is so arranged that the cylinders USE every particle of steam instead of WASTING it, a boiler of the correct size for the type of engine, will provide all the steam needed by a pair of correct size cylinders under any condition of working. The reason I selected $3\frac{1}{2}$" gauge for our little Jenny is because it does not make the work so fiddling, and provides a more powerful engine, just right for hauling a living load. The parts came out only a little larger than those of the average $2\frac{1}{2}$" gauge sizes; and calculation is easy, as one inch in full size is 1/16" on $3\frac{1}{2}$" gauge. For instance the cylinders in the Jennies were 15" bore and 20" stroke, therefore ours will be 15/16" by $1\frac{1}{4}$"; the leading and trailing wheels 3" diameter, and the driving wheels $4\frac{1}{2}$" diameter. Messrs.A.J.Reeves and Company of Birmingham are sole suppliers of castings and materials for this model.

The engine is a straightforward job. She has double frames, but only the leading and trailing wheels have outside axleboxes, the driving wheels having their bearings in the inside frame in the usual manner; and the whole of the cylinder and motion assembly is erected on the inside frames. The latter stop short at the firebox, but are connected to the outside frames just ahead of the driving wheels. Although the boiler barrel is only 3" diameter, the firebox section is larger and extends the full width between the backs of the trailing wheels, and is of ample depth; so that even if the barrel were twice the diameter, there would be no appreciable difference in the rate of steam generation. On the original Jennies, the boiler was fed by two pumps mounted on the outside frames at each side, as shown on the drawing, and operated from the pins in the driving wheel bosses. The later batches which appeared in the late 50's had injectors; and you can please yourself which you adopt, as I hope to give instructions for both. The later ones also had spring buffers, and a weatherboard; these can also be added if desired. All being well, I shall describe Stephenson link motion as fitted to the original engines, but loose eccentrics may be used by anybody who wishes to save work and have the engine as simple as possible. The tender is a small six-wheeler, with single outside frames, and the springs above the running board. As the engine has no cab, she is very easy to operate when riding on a flat car behind her. Now to construction:

## Frames

The inside frames are cut from two pieces of $\frac{1}{8}$" steel plate each $10\frac{1}{8}$" long and $1\frac{5}{8}$" wide. Mark one out, drill the holes in the ends, rivet temporarily together, and saw and file to outline. Don't forget the vice top is a fine guide for straight sawing. For the outside frames you will need two pieces of 3/32" steel $15\frac{3}{4}$" long and $2\frac{1}{2}$" deep. Be very careful when cutting away the long centre portion. I have deepened the inside frames for extra strength, as they carry the "works" and don't show; but the outside frames have to be somewhere near the mark, of the appearance of the little locomotive would be completely ruined. The thickness of the material given for them is quite sufficient, as they take no driving stresses and only carry axleboxes of the leading and trailing wheels. They are attached to the leading beam, and the combined sandbox and frame stays keep them in alignment with the inside frames, so when once properley erected, there is no fear of distortion, especially as they are stayed longitudinally by tie rods.

## Buffer and Drag Beams

On the full sized Jennies, the beams were huge chunks of wood, like sleepers; but whilst there was plenty of strength in such hefty baulks of timber, there would be precious little in the small bits of firewood needed to reproduce the wooden beams on Jenny junior, so I have substituted metal beams for the sake of rigidity. However any builder who wishes to copy full size practice, can disguise them with a wood 'overlay' (marquetry veneer from an educational suppliers would be ideal fixed with epoxy resin) The buffer beam is 5½" long and 1¼" wide, made from ⅛" steel. Note the group of holes in each end; the outer ones on the centreline are tapped for the shanks of the "Dumb" buffers, and the upper and lower ones should be countersunk, to suit the screws used for attaching the beams to the distance-pieces between inside and outside frames. The drag beam is only ⅝" wide, and has a slot, shown in drawing, for the drawbar connecting engine and tender. Two pieces of ⅝" x ⅛" angle steel each ⅝" long, are riveted to the drag beam, so that the outside measurement is 4⅝". The outside frames are screwed to these, as shown in plan of assembly.

## Hornblocks and axleboxes

The hornblocks of the oustide frame are shown in the drawing of that component, and are simply pieces of the same steel, cut to the shape shown, and riveted over the openings, on the inside of the frames. No lugs or feet are neccessary as the tie rods act as hornstays, and prevent the axlebmxes dropping out when the engine is lifted; the hornplates whould be set ⅛" above bottom of frame, as shown, to make room for the tie rods. The hornblocks for the driving axle are attached to the inside frame, and are substantial castings. As there are only two, it is hardly worth while setting up a rig in the lathe to end mill the contact face, and the sample castings I have seen, only needed a few ribs with a file, to make them fit the slots in the frame perfectly. They are riveted on with 3/32" rivets, iron for preference, and the flanges filed off flush with the outside of frame, the rivets being countersunk on the outside. Bolt the frames temporarily together, dead in line, and carefully file out the hornblock jaws until they are ⅞" wide, and parallel from top to bottom. It is also possible, and more accurate, to clamp in the vice on the vertical slide and mill the opening. Smooth off the faces to bring the thickness to ⅜" overall, and trim up the lugs at the bottom. (See page 45 for information missed out here.)

The axleboxes are made from cast gunmetal bar which is clamped in the vertical side sideways and a recess ⅞" wide and ⅛" wide is machined from each edge, after one major face has been cleaned up. Always work from this face, and the recess should leave a 1/16" flange on this edge. Finish machining the remaining face, again leaving a 1/16" flange, by holding in the 4-jaw chuck, and then the boxes may be sawn off and machined to finish length. The procedure for the carying axleboxes is the same except that the flange is on one side only. For the carryng axleboxes, the ¼" holes may be drilled in the back as shown, holding in the 4-jaw, or in the vertical slide vice as felt appropriate. For the driving axleboxes, drill and ream a ½"hole in one of them for the axle, in the middle of one of them; then clamp them together, and use the first hole as a jig to drill and ream the second. A 1/16" hole is drilled in the top and countersunk in the top of each box, and two spring pins have to be fitted in the bottom, but these must be located from the holes in the hornstays which are made next. The hornstays are merely 1½" lengths of ⅜" x ⅛" steel, drilled as shown in sketch, and attached to the hornblock lugs by 5BA screws. Carefully fit the axleboxes to the horns so that they slide freely but do not shake endwise; then put them in the horns, put on the stays, and wedge the boxes up against the stays with bits of wood between the top of the box and the hornblock opening. Run the 30 drill through the centreholes, and make a couple of countersink marks on the bottom of the axlebox; remove, drill the axleboxes to 37 at the marked places, tap 5BA and screw in pieces of ⅛" round steel, for the pins. The springs are wound up from 22 swg piano wire and the complete assembly and hornblock and axlebox is shown in the illustration.

## How to erect the frames

I have taken advantage of the construction of this engine, and arranged matters so that after the frames have all been erected and set in correct alignment, the inside frames can be taken out as one unit, by removing a few screws, and the whole of the "works", viz., cylinders and motion, attached to them without interferences from the outside frames or wheels. First af all, make the frame stays. The front supports are two pieces of channel steel (machined from bar) each 1¼" long, ¾" wide, and ½" on the flanges, the thickness being ⅛". A solid block could be used as an alternative shown on the assembly drawing. The two side stays are in the form of sandboxes. Castings will be available for these; solid blocks might be used, but as a single wheeler needs a supply of sand to start a heavy load when the rails are greasy or damp, we might as well fit sanding gear, which is very easily done, details later.

The rear stay is a piece of the same metal used for the front beam, but $2\frac{7}{8}$" in length. It has a piece of $\frac{3}{8}$" x $\frac{1}{8}$" angle riveted to each end as shown in the plan.

When erecting the frames, toolmakers cramps should be used to hold every bit of angle and channel to the frames, whilst the holes for the screws are located by the method I always advise, viz., putting the drill through the hole in the frame, and making countersink marks on the angles or channels, afterwards drilling and tapping the marked spots, for the screws. First set a piece of channel at the front end of one of the main fnames, getting it dead square by resting the frame on the lathe bed, upside down, and setting the channel by aid of a set square; clamp in position, drill and tap the screwholes as mentioned above, and put the screws in, repeating operations on the second frame. Note, the channels are on the opposite side to the hornblocks.

Now set both inside frames on the lathebed, upside down, hornblocks inside, at a distance $2\frac{7}{8}$" apart. Put the rear stay between, right at the end as shown in the plan drawing, check for truth with a set square, then drill and tap the screwholes in the angle ind put the screws in. Next take the back beam, stand it on the lathe bed and put one of the outside frames upside down against the angles at each end of it, holding with clamps, and making certain that the tops of both frames are in contact with the lathe bed for their full length so as to be absolutely parallel. Drill and tap screwholes, and put the screws in. Put the inside frames between, also upside down, and see the tops make contact with lathe bed as before; then line up the fron ends of all four frames, put your clamps on, drill and tap screwholes, and screw the front ends of the outside frames to the outsides of the pieces of channel. Lastly, put the front buffer beam against the front end; adjust frames to correct distance apart, as shown in the illustration, put the clamps on, drill and tap screwholes, insert screws and remove clamps, and the assembly is complete. It isn't O.K. unless both beams, and the tops of all four frames, are all in full contact with the lathe bed; so you know exactly what to aim for. If it lies firm on the lathe bed with no sign of a rock or a wobble anywhere, everything is going fine and you can put the sandboxes-cum-stays between inside and outside frames in the positions shown in the drawing, clamp temporarily, drill the bolt holes clean through the lot, and bolt up. The complete "engine bed" as our cousins over the pond call it, will then be found quite strong and rigid.

<u>Wheels and carrying axles</u>

The pair of driving wheel castings, each with plain centre bosses, and 5 pairs of carrying/tender wheels will be required, for loco and tender. You might as well machine the lot whilst on the job! I have fully described wheel turning many times, but for the benefit of beginners, here is a brief summary. Chuck by the tread in the four jaw and set the inside of the rim to run truly; centre, drill drivers 25/64" and carrying wheels 21/64". With a small boring tool, bore out till a 27/64 and 23/64" drill shanks will enter the respective bores, and then ream out to 7/16" and $\frac{3}{8}$" as required. Do not be tempted to drill out prior to reaming, for if there is a flaw in the metal, the drill will surely run off and the reamer follow out of truth. Face off the back of flange and boss. Reverse in the chuck and face of front of rims and bosses using a round nose tool set cross-wise in the toolrest for all above operations. Now get a disc of metal a little smaller than the wheel; a discarded wheel casting or a chuck backplate will do fine. Chuck in 3-jaw, face, recess the centre about 1/32" deep and 1" diameter; centre, drill and tap $\frac{1}{2}$" any fine thread. Screw in a stub of $\frac{1}{2}$" diameter steel so that 1" projects, and turn this down until the wheel just slides on without shake. Do the drivers first so that the stube may be machined down further for the carryng wheels. Screw it and fit a nut. Don't take it out of the chuck, but put on each weel in turn, tighten the nut, and the treads and flanges can then be finished off. Use the ordinary round nose tool, slightly pointed to get the radius at the root of the flange. Note the reading of the index collar on the cross-slide when the first wheel is finished to size. If all the others are machined to this setting, they should all be the same, but check as you go to ensure this. The flange edges may be rounded off with a file. If the top slide is set over about $2^{\circ}$ to cone the treads, this may be an advantage, but is not absolutely neccessary.

The straight axles are a plain turning job needing no detailing out. Make five of them whilst at it, using pieces of $\frac{1}{2}$" round BMS 5" long. If the three-jaw holds reasonably true, and the mandrel will take the $\frac{1}{2}$" rod, chuck in the 3-jaw and turn a wheel seat and journal at the one setting. On small lathes, centre each piece truly and turn the axles between centres. The journals should be an easy running fit in the holes in the axleboxes, and wheel seats a squeeze fit in the holes in the wheels; but don't overdo it and either split the bosses, or bend the axles when pressing on the wheels on the axles, using the bench vice as a squeezing-on-medium. If they go hard, press the axle out of the wheel again, rechuck and ease the wheel seat with a fine file. There is no need to mount them permanently in the frame until the cylinders have been located

Springs for carrying axles.

The leading and trailing axleboxes, also those of the tender, are furnished with laminated or "leaf" springs, which may either be cast dummies with a working spiral spring concealed in the buckle, or hoop, or may have proper working leaves made from flat spring steel, as on the full sized engine. The latter, are of course, much the best, and the action is very fascinating to watch when the engine is in motion; but they are very tedius and fiddling to make, so that the first mentioned kind are more usually fitted to small engines. I will describe both kinds, and builders can take their choice.

The castings will have the eye-ended hangers of the type shown in the detail drawing which are slightly easier to fit than those shown on the G/A drawing, though either will do. (NOTE: since LBSC wrote these notes, foundry practice and labour conditions have changed so much that the eye-end type prove impractical for sand castings. The alternative type are therefore supplied). As the spindles which transmit the load to the axleboxes are only 3/32" diameter, and a coil spring of this size would be too small, the buckles or hoops are drilled out 3/16", and the top of the spindle is provided with a little piston bearing against a spring of 22swg wire which is just a nice sliding fit in the 3/16" hole. The hangers are cast solid with the dummy springs; so all that is needed to erect them on the frame is to drill no. 41 holes at 1⅛" each side of the centre of the axlebox opening, and ¼" from the top. Drill no. 41 holes through the eye at the bottom of each hanger (these eyes may be machined from bar and press fitted into holes in the castings), and attach them to the frame with 8BA bolts and nuts. The long spindles will require a guide piece, to prevent them slipping sideways off the axleboxes; so fit a small clip, filed up from BMS to the shape shown in the illustration, over each spindle near the top of the frame, and secure it with 10BA screws tapped into the frame. Position the clips as shown in the general arrangement drawing.

Until recently, the great objection to fitting working leaf springs on engines of 2½" and 3½" gauge, was that if they looked right, they were too stiff to flex properly under the comparatively light loading; ;but if they were made flexible, then they looked far too skimpy. The problem of making a spring which both looked right and worked O.O. was solved in a very simple manner by a builder of another model. He made each leaf fromthree or more very thin plates of the same length; so that a six-plate tender spring would, whilst appearing to have only the six plates, in reality have eighteen, each "plate" made up from three laminations. This system answers perfectly and may be used for built up springs for Jenny:-- four for the engine and six for the tender -- by any builder who possesses the neccessary patience. Each spring is composed of 21 pieces, arranged in seven groups of three apiece, to simulate a seven plate spring. The ends of the top, or longest plate are softened in a spirit or gas flame, and bent around to form eyes for accomodating the pins to the hanger tops. If the end is made red hot, and then quickly bent to a small circle with a pair of round nose pliers, the job will be found quite easy. Anneal the ends after bending, in case they chill quickly and are rendered brittle.

To make the hoops or buckles, chuck a length of 5/16" square steel in the 4-jaw and part off 10 half inch lengths. Drill a 3/16" hole through each piece and file it out until it fits over the widest part of the spring; then chuck each buckle again in the 4-jaw, bottom outwards, drill no. 45 after setting to run truly, and tap 7BA. The spring pins are approximately 1⅝" overall length, made from 3/32" silver steel with ⅛" length of thread on one end. Insert a spring in a buckle, see that it is quite central then screw a spring pin or spindle tightly into the hole at the bottom, so that it locks the spring in the buckle and prevents any movement of the plates to either side. The sketch shows the buckle in section.

The hangers are made from 5/16" x 5/3" BMS strip. The easiest way to make them is to clamp a widest side down in the vertical slide vice and adjusting to lathe centre height. A 3/16" end mill or slot drill can now be used to mill out the slot 9/16" deep. Drill the hole at the end for the pin before milling. Cut to length, square off the end and drill centrally no. 46 and tap 7BA for the suspension bolt which latter can be made from a bit of steel 3/16" x 3/32"; chuck in the 4-jaw, turn ⅝" of it to 3/32" diameter, and screw to fit the fork. Cut off at a bare ⅞" from the end, which is rounded off and drilled no 41. One of these hangers is attached to each end of the working leaf spring, by a little bolt through the holes at the end of the fork, and the looped ends of the spring; the complete assembly is attached to the frame exactly as described for the casting type, the spindle under the buckle resting on top of the axlebox, and a clip being put on as mentioned above.

Crank axle (Note. See page 17 for details of axle for loose eccentric valve gear).

This may at first appear to be a bit of a teaser, as it has four eccentics between the cranks, and whole issue has to be "absolutely-just-so", in order to ensure a successful engine; but taken bit by bit, it is really easy. Any reader who is a skilled turner and has a power driven lathe, can turn the complete component from a piece of 2" BMS about 5" long and this makes the best job. To set it out, mark out the ends of the bar exactly as shown for eccentrics only; but add two extra centres, on the two lines crossing the true centre of the bar, each at $\frac{5}{8}$" distance from the true centre and on the same side as the eccentric advance lines. A skilled turner will not need any detailed instruction for the actual turning; suffice it to say that I usually tackle the eccentrics first, then the wheel seats and journals, leaving the crankpins till last. The surplus at each end, containing the centreholes, is turned away with the crank running on its true centres and the crankwebs left either circular or planed or milled to shape as desired.

Less experienced workers had better build up the whole gadget. About the best way I know, is to turn the four eccentrics from the solid, and use this piece as the nucleus on which to build the rest of the axle, fitting a crank on each end of it, and attaching the pieces forming wheel seats and journals to the outside of the cranks. If you can turn a spigot to a press fit in a hole, and have a good hefty vice, there is no need to braze the assembly, as the whole lot can be pressed together as is sometimes done in full size practice. If properly fitted, it will never shift. Otherwise the joints may be brazed. The machining of the parts is the same in either case as detailed below.

Eccentrics

Obtain a piece of $1\frac{1}{4}$" diameter BMS bar hold in the 3-jaw and face each end. The tool marks will indicate the tru centres. Set on a veeblock and stand this on the lathe bed or surface plate if you have one. Then with the point af a surface gauge set to the centremark, scribe a line across both sides. Now set the point 5/64" above centre and scribe two more lines. Turn the piece of bar though 90° checking with a set quare against the lines already scribed, and repeat the procedure. Make a small centrepop with a small and sharp punch exactly at the spot where the two first lines corss, ie., on the true centres. Set a pair of dividers and scribe a circle 5/16" diameter around the true centres. The four points where this circle cuts the offset lines are the centres of the eccentrics. I have marked them 1, 2, 2, & 4 on the diagram. Nothing could be much simpler than thatl. Drill a small centre at each point holding in the 4-jaw and setting each point to run turly with a wobbler or centre finder before drilling.

To turn the sheaves, first mount the piece on its true centres, with a carrier on one end. Rough turn each end to $\frac{1}{2}$" diameter leaving exactly $\frac{3}{4}$" length in the middle at full diameter. Now put the piece on to no. 4 centres and turn the end eccentric with a knife tool; then change the carrier to the other end, reverse the piece in the lathe, and mount on no 1 centres turning that eccentric with a knife tool also. Then change to no. 2 and turn that one with a parting tool, using a slow speed and plenty of cutting oil; finally no. 3 in the same way with the same tool. Mount the piece on its true centres again and turn each end to a full $\frac{3}{8}$" diameter; don't finish dead to size until the cranks are ready.

Crank webs and pins

Each crank web is made from a piece of $\frac{3}{4}$" x $\frac{1}{4}$" BMS x $1\frac{3}{8}$" long. Mark off one of them by scribing a line down the centre and making two centrepops $\frac{5}{8}$" apart. Drill a $\frac{1}{8}$" pilot hole at each mark, then use the drilled web as a jig to drill the others. I find this is a better method for inexperienced workers than soldering the lot together and drilling them in a block. The holes at one end of the webs are opened out with a 5/16" drill and the other holes $\frac{3}{8}$". The ends may be rounded off as shown, or left square and the corners merely taken off, at the builder's choice.

Each crankpin is a $\frac{3}{4}$" length of $\frac{3}{8}$" BMS or silver steel. Chuck truly and turn down $\frac{1}{4}$" of length till it is a driving fit in the hole of the crankweb. The easiest way for a movice to do this is to drill a 5/16" hole in any odd piece of the same steel used for the webs and with the same drill. Now open out one end of this hole the smallest amount with a taper broach or reamer, or even the tang end of a file and turn the end of the crankpins until they will just enter the enlarged part of the gauge hole. Take off the sharp arris from the ends of the crankpin with a fine file before removing from the chuck, so as to give the pins a fair start in the holes in the crank webs when the squeezing process begins. When all four spigots are turned assemble as follows.

Obtain a piece of $\frac{3}{8}$" rod which will pass easily through the $\frac{3}{8}$"holes in the crank webs, and put two of them on it, wide enough apart to allow the crank pin to be placed between the webs at the other end. Now line up the webs with the end of the crank pin, so that the slightly filed ends just enter the 5/16" holes. Put the webs between the vice jaws with a piece of brass or copper at either side, to avoid damage to the webs, and turn the handle. It will probably need some force, but the webs will be forced home on their pins, the piece of rod through the other end keeping them truly in line. Squeeze until the webs are hard against the pin shoulders; and if your turning has been O.K. they will stay put as long as Jenny lives.

Now make another gauge with a $\frac{3}{8}$"hole in it this time, using the same drill as used to make the larger holes in the crank webs and turn the two ends of the piece containing the four eccentrics, to a driving fit as described above. Reduce each spigot to $\frac{1}{4}$" length and take off the sharp edge with a file as before. Wedge a piece of $\frac{1}{4}$" metal tightly between the webs of each crank, and set them on the ends of the eccentric section, so that each crank is at right angles to the centreline of the two eccentrics next to it. If you take a look at the illustration of the end view of the crank axle, you will see that the crank nearest you lies horizontally, whilst a line joining the centres of nos. 3 & 4 eccentrics would be exactly vertical, and therefore at right angles to the crank. It can easily be checked with a set square; if you rest the stock against the two eccentrics, then the blade should be exactly parallel with the crank web. Using the vice as before press each web on about 1/16" or so, and then very carefully check each pair of eccentrics and the corresponding crank again with the set square. If all O.K., squeeze the crank right home. No harm will come to the webs provided that the packing pieces fit properley; these should be left in for the final pressing.

All that now remains is to make and fit the end sections forming the journals and wheel seats. Each one is turned from $\frac{1}{2}$" diameter steel rod. Chuck a length and part off two pieces $1\frac{1}{4}$" plus 1/64" long. Chuck one and turn down $\frac{1}{4}$" length to the same diameter as the ends of the eccentric section using the gauge previously made. Reverse in chuck and turn down $\frac{1}{2}$" of the other end to a squeeze fit in the hole in the driving wheel boss. Press the smaller ends into the remaining open holes in each crank web, remove the packing pieces and the assembly is complete.

If considerable pressure has been needed to force the parts of the crnak axle together no further fixing will be required; if they went together very easily, and it is possible to twist the webs on the pins or shaft, the joints should be brazed. Put one small ring of brass wire around each joint close to the crank webs, cover it with a good quality brazing flux (Sif-flux) and heat up until the whole assembly is hot enough to melt the wire which will flow into the joints. Quench out in water and clean up with fine emery etc. File a slight bevel as shown on the inner web of each crank. Normally the webs will clear the boiler but it is advisable to provide ample clearance to allow for the rise and fall of the axle when the engine negotiates a roughly laid road, or runs through crossing frogs.

Crank axle assembly

The driving wheels can now be pressed on to the crank axle. First of all the axleboxes must be placed on the journals taking care that they are the right way around, and the packing pieces must be replaced tightly between the crank webs. The wheels are then placed on the turned seats at the ends of the axle with the balance weights on the wheels exactly opposite the cranks, ie at 180$^{\circ}$ to that the weight balances the crank and the big end of the connecting rod. The wheels are then carefully squeezed home using the vice as a press as before but note that the fit must not be as tight as between the various pieces of the crank and webs, otherwise the wheel bosses will split, the iron being more brittle.

Balance weights.

Make these from plates of 1/16" steel cut to outline as shown on the sketch and carefully rivetted to the wheels, covering three spokes. The space between the spokes right to the back may be infilled with epoxy resin, filed to shape and then when painted will appear to have been cast in. It is more convenient to have castings made this way, as the wheel may then be used on another loco without the need for a new pattern, or much filing away of metal.

Notes on crank axle assembly.

A medium pressure only should be needed to force the wheels right home. As there are no coupling rods no keys are needed between wheel and axle; but if these went on very easily and there might be a likelehood of the axle turning inside the wheel boss under heavy working, the driving pin of the pump (to be described later) can be made to act as a key. If the injector fitted type is to be built, then drill a number 43 hole $\frac{3}{8}$" deep half in the axle and half in the wheel boss and drive in a piece of 3/32" silver steel, and file off flush with the wheel boss. The complete unit, wheels, crank axle and axleboxes, can then be mounted on the inside frames. The axleboxes should slide freely in the hornblocks and the wheels should revolve without any trace of binding. To enable the motion work to be tested for freedom of working as it is erected, the axleboxes should be fixed in normal running position and this is easily done by placing a little piece of 5/32" metal between the bottom of the axlebox and the hornstay, and tightening up the the spring nuts to hold it there.

Cylinders.

The cylinders are very little bigger than those on a modern $2\frac{1}{2}$" gauge engine and are quite easy to machine., assemble and erect. They are arranged upside down in order t get an efficient steam chest, valves and ports. If the steam chest were placed between the bores as on the full sized Jennys, it would not only entail much close and fiddlin work, but the engine would not be a very satisfactory performer. By placing the steam chest underneath, all the pipe connections are eliminated, steam passing through a central passageway drilled between the bores into which oil is fed, ensuring efficient lubrication to every moving part. The exhaust goes direct from exhaust ports to blast nozzle as can be seen from the sectional illustration. When the engine coasts with steam off, the valves drip just clear of the ports, consequently any steam at atmospheric pressure remaining in the steam chest can circulate from one end of the cylinde to the other; no vacuum is created and no snifting valve is neccessary to prevent ashes being sucked down the blastpipe. Valves and ports can be inspected at any time without disturbing any of the "works" merely by removing the steam chst cover. It will be noticed that on this engine that the valve spindle tail rods work through glands instead of their being enclosed; and this arrangement provides a direct drive for the ratchet lever of a mechanical lubricator, a refinement which the full sized Jennys never had the chance of enjoying. They were among the best of their period as it was; with superheating and mechanical lubrication they would have been absolute marvels, but such refinements were unknown in those days.

How to machine the cylinder block.

First of all, with a file, smooth off the port face and one end. Check off the distanc between the cored holes and distances from holes to port face. If the former are $1\frac{1}{2}$" apart and the latter about 1.1/16"(centre of hole to face) there is no ned to bother about marking out the bores. Put an angleplate on your faceplate and mount the cylinde block on it portface down, securing by a bar across its back with a bolt at each end Let the block square with the faceplate by applying a set square to it, stock against the faceplate and blade parallel to side of cylinder block. Adjust the block so it overhangs the angleplate edge by about $\frac{1}{4}$", and tighten the clamp bolts. Now move the angleplate bodily on the faceplate until one of the coreholes runs truly; if you fully extend the tailstock barrel and run the tailstock up so that the centre enters the cored hole, you can set it truly in less time than it takes me to write how to do it. Tighten the bolts holding angleplate to faceplate and with a round nose tool set cross wise in the rest, take a facing cut right across the end of the block. Next moun a boring tool in the slide rest, and take a cut through the core hole, deep enough to clean away all the rough skin. Use the finest possible feed. It is probable that some balancing will be neccessary to this faceplate fixture, lathe changewheels make a goods weight, as by using a combination of these with a bolt passed through and tightened, oppsoite to the angleplate. Do not attempt to run at a high speed, and do keep your hands well clear of the rotating fixture. We do not want any accidents, do we? Bore out until the bores are 15/16" diameter to a plug gauge which you will have previously turned up. On reaching finish size, pass the tool through several times without increasing the cut to take all spring out of the tool. This should produce a clean, smooth bore.

Reamer owners can put a carrier on the shank of the reamer; and gripping it in their left hand, holding the reamer against the tailstock centre, hold the tailstock with your right. Push the tailstock bodily up unitl the reamer just enters the bore. Then, using a slow speed and some cutting oil, push the reamer right through the bore by sliding the tailstock along the bed. Don't stop, except when you reverse and pull it out again. (NOTE. Do not reverse the lathe, only the motion of the tailstock along the bed. A reamer should never be reversed in rotation.). If the reamer is sharp and you have left only a few thousandths for the reamer to take out (reamers are just what their name implies, and not boring tools!) the resulting bore will be O.K.

Don't under any circumstances slack the bar clamping the block to the angleplate but slack the bolts holding the angleplate to the faceplate, and move it until the second core hole runs truly, when the ceremony, as fully described previously, may be repeated. Finally take another skim right across the end flange to finish it off.

Chuck an offcut of 1" bar in the 3-jaw, and turn about an inch of it to a size that will just allow the cylinder to push on tightly; put it on, unturned end flange outward, and then face off the other end. The block should be exactly $1\frac{3}{4}$" overall length when finished, the flanges at each end being of even thickness.

Some folk prefer to plane or mill the portface and sides of the block, but it is as easy to do it in the lathe. Mount the block end up on the angleplate with the portface outwards; check with a set square, stock to faceplate, and blade to side of cylinder block. Secure with a long bolt through the bore, not forgetting a big washer at the top, under the nut, to prevent damage to the faced flange. With a round nose tool set cross wise in the rest, cut back the portface until it is 1" from the centre of the bore, i.e., with 17/32" of metal between portface and the edge of the cylinder bore.Slew the block around a quarter turn, and set truly as before, set square stock against faceplate and blade against the finished portface. Face off the side of the block until it is exactly 7/32" from the edge of the bore; then slew around a complete half turn, checking with a set square as before and repeating the operation. The block should now measure $2\frac{7}{8}$" overall width, and fit exactly between Jenny's inside frames.

Ports and passages

Mark out the ports as shown on the drawings. The easiest way to cut them on an ordinary lathe is by means of a slot drill (or end mill) held in the chuck and run at high speed. The cylinder block is bolted end up, with the portface at right angles to the lathe bed and facing the chuck, either on an angleplate attached to the vertical slide, or on the saddle, or slide rest. In the latter cases, suitable packing must be arranged underneath the casting to bring each pair of ports level with the lathe centres. A suitable slot drill for the steam ports can be made from silver steel, or the shank end of a broken drill. Grind or file it like a screwdriver then make a tiny nick on the middle of the edge. Back off the edges each side of the nick, harden and temper to dark straw and the drill is ready for use. Feed into cut with the saddle screw or topslide screw, and travers across very slowly with the cross-slide. Take great care not to overshoot the ends. The slot drill will leave the ends of the ports rounded, but this will not make any appreciable difference. The ports should not be less than 3/16" deep; you can go deeper with advantage. The exhaust ports are cut the same way with a 3/16" slot drill. (See notes on last page)

Ports can also be cut by hand. A few holes are drilled on the centreline of each marked space, and run into one slot by carefully chipping with a chisel made from a piece of $\frac{1}{4}$" silver steel.

Three 7/64" holes make communication between bores and steam ports. Make centrepops on the edge of the bore, as shown in the drawing, then drill from these to the nearest port. I usually drill mine by hand, setting the cylinder in the vice at a slight angle, so that if the drill brace is held horizontally, the drill goes slap from the centrepop straight into the port. I also use a drill ground shade off centre so that it drills a hole a little bigger than itself. If the drill catches up and breaks off (an occurrence not entirely unknown among locomotive amateur builders) the bits can usually be shaken out quite easily. If the drilling is done on a machine, set the block in a machine vice at such an angle that the drill will just penetrate the bottom of the port. You can sight this easily "by eye" by checking with the drill on the outside of the cylinder block.

The exhaust ways are very simple. In the top of the cylinder block, that is the side opposite to the portface, drill a 9/32" hole exactly in the middle and about $\frac{5}{8}$" deep. Tap it 5/16" x 40 tpi for the blasp pipe. Now from the inner end of each steam port. Now from the inner ends of each steam port, using an 11/64" drill, drill a hole into the one first mentioned. With a small chisel round off the ends of the holes at the bottom of the ports as shown, which will give a "streamlined exit".

At a point $\frac{1}{2}$" ahead of the exhaust outlet, drill a 3/16" hole right through the cylinder block to the portface. Open up the top of this with a 7/32" drill and tap $\frac{1}{4}$" x 40 tpi for the steam connection. At $\frac{1}{2}$" up from the portface, drill a 3/32" hole into the steam passage, opening up the entrance with a 5/32" drill and tap 3/16" x 40 tpi for the oil connection. File a little bevel on the lip of each bore where the steam passages start, to allow steam to enter the cylinder, and the block is complete.

Pistons and rods

The piston rods are $2\frac{1}{2}$" lengths of 5/32" ground rustless steel. Chuck each in the 3-jaw and put 3/16" of 5/32" x 40 thread on one end, using a die in the tailstock holder. For the pistons chuck a piece of 1" bronze, gunmetal (casting supplied) or rustless steel will do, turndown the rod for an inch length to 1/64" oversize. Face the end, centre and drill down 1" depth with no. 30 drill. Next with a parting tool make two custs, one $\frac{3}{8}$" from the end and another $\frac{3}{8}$" from the end of the first cut; go $\frac{1}{8}$" or so deep. In the middle of the spaces between, turn a packing groove a full $\frac{1}{8}$" wide and deep and then part off the pieces at the cuts first made. Chuck each piece separately in the 3-jaw; open out the centre hole for 3/16" depth with a no. 22 drill and tap the remainder of the original hole 5/32" x 40. Put one of your piston rods in the tailstock chuck, run it up to the piston blank, enter it and pull the lathe round by hand until the plain part of the rod just behind the thread locks solid in the enlarged portion of the hole in the piston blank. This is the finest method I know of for fixing little pistons securely and truly on their rods.

Now chuck each piston rod truly. If the lathe has collets you won't have any trouble in doing this, or if the chuck holds truly, all is O.K., but if not chuck a little bit of brass $\frac{3}{8}$" rod, say $\frac{1}{2}$" long. Face, centre and drill it no. 22 right through. Put a mark on it indicating no. 1 jaw of the chuck, slit it down one side with a hacksaw and replace in chuck in original position, checking by the mark. Insert the piston rod and tighten the chuck. If you have done this job accurately, the piston will now run truly; and all you have to do is to take a lightskim or two off with a sharp round nose tool until it just slides into the cylinder without any shake.

Cylinder covers

The front covers are merely plain turning jobs. Chuck by the extension piece provided and turn to$1\frac{3}{8}$" diameter, face off and turn a register or short spigot 1/32" long and to a diameter which will just fit the bore. Remove from the chuck, saw off the chucking piece, rechuck either by gripping the rim direct in the jaws and setting to run truly, or by gripping in a stepped bush held in the chuck jaws,and face off the other side.

To turn the back covers, repeat the first half of the above process, but be very careful on turning the short spigot an exact fit for the end of the cylinder bore. Then centre it and drill down about $\frac{1}{2}$" with no. 22 drill. Saw off the chucking piece and rechuck as above. True up the faces as far as the gland bosses will allow, then face the bosses themselves to dimensions given. Open out the centre hole with a 9/32" pin drill, to a depth of 5/16" and tap 5/16" x 32 or 40. To make the glands merely chuck a piece of $\frac{3}{8}$" bronze rod turning down an inch of it to 5/16" diameter, face the end, centre and drill no. 22 for about 1" depth. Screw the outside to suit the tapped hole in the cover, then part off two pieces each $\frac{1}{4}$" long. Cross-slot one end of each with a saw or watchmakers flat file. NOTE. The glands should not be too easy a fit in the threads of the stuffing boxes, otherwise they may work out when the engine is running fast(and she will run fast!) and get caught between the crosshead and the cover, resulting in a bent piston rod or some other untoward happening.

The screw holes in the covers should be drilled by jig. This is easily made; get a washer (an ordinary iron bolt washer will do fine) $1\frac{3}{8}$" diameter, chuck it in the 3-jaw by its edge and bore out the centre hole till it just fits over the spigots on the covers. Scribe a line all round it at a bare $\frac{1}{8}$" from the edge, divide into eight equal parts, and centrepop and drill a no. 41 hole at each point. Put this on each cover over the spigot, clamp in position with a toolmakers cramp, and drill no.41 holes around the edge of the cover using those in the washer to guide the drill. Put each cover on the cylinder block in turn, clamp temporarily in position, poke the drill through the holes just deep enough to make countersink marks on the cylinder flange and then make a mark of identification on the cover and adjacent on the cylinder so you can replace cover in exactly the same position. This will also identify which cover goes where. Remove the cover and drill the flanges no. 48 at the marked spots, and tap 7BA. Hexagon screws will look best when final assembly is reached, though the full sized Jennies may well have had square headed bolts, the hexagon bolt coming into general use rather later in the 19th century. Note that the gland bosses on the back covers lie horizontally as shown in the illustration. To locate the guide bar holes, temporarily fix on the two back covers with a couple of screws in each. Stand the cylinder block, port face down, on your surface plate or lathe bed and set the needle of your surface gauge to the centre of a dummy plug screwed into one of the gland holes, and scribe a line across both bosses. Set your divider points at 5/16" apart, and with one point in the middle of the dummy plug, make a mark on the line just mentioned at each side of the gland. Centrepop all four points, drill them no. 40 and tap 5BA. This drilling job MUST either be done on a drilling machine, or in the lathe, as the guide bars MUST be square with the covers and parallel with the cylinder bores. If a drilling machine is not available hold the cylinder block with the back covers attached, against a drill pad on the lathe tailstock and feed it up to a no. 40 drill held in the 3-jaw.

Steam chest

Chuck the casting in the 4-jaw and face off both contact faces, then set out and drill the sixteen no. 41 holes as shown in the drawing. These must also be machine drilled as above. The sides and end of the casting may be cleaned up with a file. The bosses can then be centrepopped and when doing this take care to get the measurements right all ways. The pops on both ends must be exactly 1⅛" apart, ⅞" from the ends of the steamchest and offset so they are ¼" from one contact face and 3/16" from the other. To drill accurately put a no. 30 drill in the 3-jaw and hold the casting up to it bringing the tailstock along and resting its centrepoint in the pop mark of the opposite boss. Then feed the steamchest on to the drill by turning the handwheel. Turn the steamchest end-for-end to drill the other hole putting the tailstock centre in the hole previously drilled. Try a piece of ⅛" round steel through each pair of holes after drilling to ensure they are exactly in line. Open the holes to 5/16" depth with a 7/32" pin drill, tap ¼" x 40, and make four stub glands exactly as described for the glands in the cylinder covers, except that they are ¼" diameter and drilled no. 30.

The steam chest cover is a casting, machined firstly by holding in the 3-jaw by the spigot, and then in the 4-jaw arranging suitable packing beneath each jaw to ensure the plate is flat and equal thickness all round. It may then be reduced in size using the cylinder block port face as a guide. Clamp the steamchest to it and run the no. 41 drill through all the screw holes carrying on right through the cover. Mark the latter so you can identify and replace in the same position when assembling the cylinders. Now clamp the steamchest cover to the cylinder block drilling through again to make countersinks on the portface, remove and drill no.48 to a depth of ⅜" and tap 7BA for the fixing screws or studs. The final shaping of the steam chest casting may now be done using cover and cylinder block as a guide.

Slide valves

These are the correct pattern for the type of engine and are buckle driven as in full size practice. They are made from castings. A rebate ¼" deep and ⅛" wide may be milled all around the upper part of each valve which can be done by gripping the casting edge in a small vice attached to the vertical slide and the screws of cross-slide and vertical slide used appropriately. Do not forget to feed the cutter into the workpiece on each cutting stroke. (Books about milling cutters and operations are available). Reverse in the vise and face off the casting to finish thickness on the working face. To form the cavity, make a countersink in the middle of the valve face with a ⅜" drill; and a little chisel made from ⅜" silver steel will soon chip in out to the dimensions and shape shown on the drawings. It may also be endmilled out using a similar process to that of the rebate.

The buckles are also provided as castings which like the steamchest cover should first be machined to thickness. The bosses may now be centrepopped and drilled out in the same was as for the steamchest, in conjunction with the tailstock centre and tapped 5BA. The cast hole may be filed out to a close sliding fit over the valve, and it is important that there is no end play in the fit.

The valve spindles are made from ⅛" ground rustless steel. The shorter ones are 1.3/16" overall length with a 3/16" length threaded 5BA on both ends. Screw them by holding in the 3-jaw and using the die in the tailstock holder, as ture threads are essential to sweet working.

The valve forks, or valve crossheads, are made from 7/32" or ¼" square steel. Take a piece 2" long or thereabouts, and drill a no. 41 hole ⅛" from each end; then clamp under the slide rest, or in the vertical slide vace, and run it up to a 3/32" slot drill in the 3-jaw. Cut the slot a full ¼" deep with some cutting oil applied. Saw off the pieces a full ½" long, round off the slotted ends, chuck in the 4-jaw with plain end outwards, turn the stem circular for about 3/16", face the end, centre, drill no. 40 and tap to suit the valve spindle.

## How to assemble the cylinders

First make certain that the portface and valve faces are absolutely true and flat by rubbing them carefully on a sheet of fine emery or other abrasive cloth laid business side up on the lathe bed, or surface plate. Wash off all traces of dust in paraffin, especially see that none remains in the ports and passages. Pack the pistons with graphited yarn, the most satisfactory way of which is to obtain a piece of ⅛" square type and cut a ring, which went bent around exactly fits the piston groove. Cut the ends at an angle like a piston ring. This is placed in the groove, and the piston inserted in the cylinder, judicious prodding with a small screwdriver or knife blade being sufficient to coax the packing ring in. The piston will then be absolutely steam tight, yet practically frictionless, the natural spring of the packing keeping it in contact with the cylinder bore, whilst it cannot disintegrate and blow off due to its braided construction. It is one of the greatest mistakes ever made, yet one of the most frequent, to use tight packing; yet we see advocated such dodges as making the pistons in two parts so that they can be squeezed together, to force the packing hard against the cylinder bore. You want the power delivered at the engine's drawbar, not expended in pushing mechanically tight pistons up and down!

Put the covers on with a gasket made from thin sheet jointing between cover and flange. Place a buckel in the steamchest, and screw the valve spindles into the bosses, through the glands on either side; then put a valve in each buckle. Cut a gasket as above for each contact face of the steamchest; place the latter on the cylinder block with the rectangular cover on top of it and secure with 16 screws of 7BA through the lot, or if you prefer you can use specially made studs, or threaded rod (studding), and nut on the outside. Pack the piston and spindle glands with a few turns of graphited yarn around each and the cylinders are complete.

When dealing with the fitting of the outside axleboxes and erection of the frames, I did not describe how to make and fit the tie rods because these are very long and fragile (they cannot be made larger without spoiling the appearance of the locomotive) and are therefore liable to be bent or otherwise damaged as the chassis is turned about whilst assembling and erecting the "works". However the ends of the tie rods form the hornstays for the outside axleboxes, and the latter will naturally fall out without them; so it would be advisable to fit a little temporary horn stay made from 1/16" x ⅛" strip under each outside axlebox which will do the needful until the proper tie rods can be fitted with the rest of the trimmings, when the engine is nearing completion. The above note may save "first attempt" builders from wondering what keeps the outside axleboxes in place.

## Guide Bars.

These are very simple being merely four pieces of 3/16" square silver steel each 2.7/16" long. Chuck each truly in the 4-jaw and turn down a 3/16" length to ⅛" diameter and thread it 5BA with a die in the tailstock holder and be careful to have the threads as true as possible. To ensure sweet working of the crossheads, the guide bars MUST be exactly parallel to the piston rods through their full length; so, after carefully screwing each one into the hole in the boss on the back cylinder cover, check off to make certain the above condition obtains, also see that the tops, bottoms and sides are square and parallel when viewed end on. Always remember that friction in the "works" means loss of power at the drawbar, and in a small type of locomotive this may be serious.

## Crossheads.

The big engines had crossheads with separate slippers, but in the small one we can simplify that job considerably by making each crosshead in one piece with a groove on each side to fit the guide bars and a jaw to accomodate the little end of the connecting rod. A casting is provided, so machine all over first on the rectangular faces, ensure that the sides are parallel and of constant thickness. Hold in the vertical slide vice and mill in the slide bar groove with a 3/16" slot drill to 3/32" deep, then reverse in the vise and mill out the opposite side. Make sure you keep the bottom side from the first groove the bottom side for the second also, in case you have not set the bar exactly at lathe centreheight.

When both grooves have been cut, check against the slide bar assembly and see that the fit between is to a nicety. It should slide freely without shake or spreading the bars apart. The two castings may now be separated by sawing and the slot for the connecting rod may be milled out in similar fashion. Do not attempt to take out all the metal in one cut but use several, with farily high speed to the cutter; 1/16" at a time is plenty. The end may be milled across too at this stage to establish the slot depth at ½". Rechuck in the 4-jaw and set the rectangular section running exactly truly by adjusting a tool point to each corner in turn, face off to length and machine on the boss, centre, drill and tap this no. 32 until this breaks into the jaw slot. Next in the middle of the groove at eachside, and at ¼" from the front end of each jaw make a centrepop, and drill it out with a no. 23 drill until you pierce the slot; then put a 5/32" reamer through both holes at once which will ensure them lining up perfectly to accompodate the wrist pin. This is simply a length of silver steel 7/16" long which should be just a nice push fit in the reamed hole. The same reamer can be used to ream the holes in the bosses, but don't put it right through. Leave these holes a shade on the small side as it is very important that the cross-heads should be an exact fit on the piston rods.

Connecting rods.

The connecting rods on some of the old-timers were wierd and wonderful affairs and contrivances, with all sorts of shapes of big and little ends; and most of them were circular in section. The one shown here is a sort of compromise; it is simple and easily made, het quite "period" in appearance and can be machined up on the lathe. The main part of the rod is made from a 4¾" length of ½" x 3/16" BMS. First of all square off the ends with a file, find the exact centre of each, then centrepop it and drill a little centrehole in each end, with the smallest size centredrill available. Put a carrier on one end and mount between centres. Then with a round nose tool, turn to the shape shown in the drawing, forming the little endat the tailstock end of the piece and leaving ¾" full size at the headstock end, to form the big-end. This operation will naturally leave the narrower sides of the rod rounded and the appearance will suit the type of engine exactly.

The strap is made from a piece of ¾" x 3/16" BMS x 1¼" long. If you have a milling machine, or the use of one, a single cut ⅞" deep with a ½" cutterwill soon form the jaws; but I doubt whether many small workshops and owners can do the job in that easy way! The jaws can be cut by the same process used for the crossheads, if a piece of bar long enough to clamp is available. There is no need to use a ½" cutter as a smaller one may be used if the metal is fed up to it several times and moved a little farther along after each cut until the desired width of jaw is obtained. The metal can also be placed in the bench vise, and the centrepiece sawn out by hand, the jaws being carefully finished with a file until the ½" block at the end of the rod exactly fits. Round off the opposite end with a file as shown in the drawing; then put the strap on the end of the rod. See that it lines up exactly and the bottom of the jaw butts up tightly against the end of the rod; then temporarily solder it in place. Carefully mark out, centrepop and drill the two no.41 holes through the full width of strap and rod, to accomodate the bolts.

Next, on the line where the end of the rod meets the bottom of the jaw, and exactly in the centre, make another centrepop, drill a hole of about ⅛" diameter to act as a pilot hole, and follow up with a ½" drill. This hole must be dead square with the rod, so if no drilling machine is available use the lathe again, with the drill held in the 3-jaw and the rod held against a block of wood supported by a drilling pad on the tailstock barrel. It is hardly neccessary to add that the wood must be true on both sides. Put a mark on the strap and rod so that they can be reassembled at any time exactly as when drilled; then melt the solder, remove the strap, and carefully wipe all the solder off both pieces whilst they are still hot enough to keep it melted.

The brasses are circular, like those in a plummer block, or an automobile big ends. The easiest way I know to make them is to get two pieces of bronze, rectangular section ⅜" x ¾" and 1¼" long. Solder them together by the widest sides so that they form one block ¾" square. Chuck truly inthe 4-jaw, turn down about ⅝" length to a full ¾" diameter; face the end, centre, and drill down about ⅝" depth with a 23/64" drill. Now turn the outside exactly as if you were making two pistons of ¼" wide with a groove in each 3/16" wide and ½" diameter at the bottom of the groove; follow the piston turning instructions previously given, as far as turning is concerned. When the two pieces are parted off, melt each of them apart -- dont mix them up! -- wipe off all superfluous solder, place one pair on each of the connecting rods, making certain that the joint is vertical and put the straps on. The boltsare made from

3/32" silver steel lengths 1.1/16" long, screwed at each end and furnished with nuts. Put the bolt in, that is farthest away from the brasses, then put the 41 drill again through the other hole. If it has been correctly drilled in the first place, the drill will cut a little groove in the front half of the brass and when the bolt is inserted it will engage the groove and prevent the brasses from turning. Carefully ream out the hole in the brasses with a $\frac{3}{8}$" reamer, then try the big end in the crank webs for width. It should fit easily, but without any sign of slackness. If tight give the flanges of the brasses either side a rub with a fine file.

If the rod has been correctly turned, the centre of the little end boss should be exactly $4\frac{1}{2}$" from the centre of the brasses. Drill a $\frac{1}{4}$" hole through it, and fit a plain bronze bush made from 5/16" round rod which should be turned to a tight squeeze fit in the hole. Drill the bush no. 24 in the lathe before parting off, and ream it 5/32" after pressing into the hole in the little end. File off flush with the rod at each side. The same precautions should be observed, to get the hole dead square with the rod, as were taken with the big end; remember my warning about friction in the "works"!

How to erect the cylinders

At the time I made the drawing of the main frame, I had not finally settled on the best arrangement of the cylinders, so it was not possible to include the location of the bolt holes; a separate drawing illustrating the complete assembly is now given. The cylinder block is attached to the inside frames by 7 x 5BA screws at each side, sufficient to hold the whole lot rigid under any conditions of service. The holes may be drilled in each frame separately; or if you care to take the frames apart, which only entails a few minutes work with screwdriver and spanner, the holes could be drilled at one operation with the inside pair temporarily clamped together. To mark out, scribe a line 9/16" from the top of the inside frame, and another 7/16" below that. The four holes in the upper row are a full 7/16" apart, the first beingl.1/16" from the front edge of the frame. The centre one in the lower row is midway between the middle pair in the upper row and the others are $\frac{1}{2}$" each side of it. Drill the lot no. 30 and reassemble the inside frames only.

If the cylinders have been made correctly to the given drawings, the correct position for them in the frames is with the upper edge of the cylinder block 5/16" from the top of the frames, and the front end of the cylinder block itself (not measured from the cover) $\frac{7}{8}$" from the front edge of the frames, measured from behind the buffer beam. However in the case of a small casting (machining errors) check off the correct position by pulling out the piston rods to their full extent and taking the distance from the centre of each to the top of the frame. It should be 1" exactly. Now put the inside frames, with the cylinders between them and correctly located, between the vice jaws, holding them just behind the cylinders and just tight enough to prevent either the frames or the cylinders shifting. Run a no. 30 drill through all holes just enough to make countersinks on the sides of the cylinder block; then remove them from the vice, and take out the cylinders.

The screwholes in the cylinder block are drilled no. 40 and tapped 5BA, but special care is needed with the drilling, so take the following precaution. The upper holes are drilled to a depth of $\frac{1}{4}$", but the lower row must not be drilled deeper than 5/32" or there is a risk of piercing the bores; and to get the right depth and avoid an accident, use a drill with a stop on it. The stop consists of a piece of $\frac{3}{8}$" rod, drilled right through with the no. 40 drill (which can be done in the usual way with the rod gripped in the 3-jaw) and furnished with a grubscrew. When drilling the lower row of holes, put the stop over the drill, leaving just 5/32" of the business end projecting, and tighten the grubscrew; then just that much of the drill will enter the cylinder block at each hole, and all risk of piercing the bores will be avoided. Drilling should be done on a machine whenever available, but if not, do it on the lathe with drill held in the 3-jaw, and the cylinder block held against a drilling pad on the tailstock barrel, and fed up to the drill by turning the handwheel. When tapping, use a "second" tap and be careful to start it squarely and following with a plug tap. The cylinder block need only be temporarily erected for the time being with a couple of screws each side; the full number need not be put in until all the motion work and valve gear is made and erected, and the valves set, when the cylinders are finally erected "for keeps."

Motion plate

A casting for the motion plate is provided and will save a lot of work. Clean up with files so they fit nicely between the frames and the top should be smoothed off, also the curved recess which supports the boiler barrel. A small square file should be used to clean out the recesses for the guide bars, which should be a nice close fit in them, as the bars are not attached to the plate in any way. Smooth off the sides of the rocker shaft brackets, and carefully mark out the holes for the rocker pins. Lay the plate on the lathe bed, or something equally flat; and with a scribing block, scratch a line across the outer side of each lug, $\frac{5}{8}$" from the surface of the plate. (The casting is slightly thicker than stated, and it should be possible to chuck in the 4-jaw and thin down the side opposite the lugs, and ease marking out and subsequent operations). Stand the plate on end, and scribe cross lines at a distance of $\frac{5}{8}$" from the centres of the guide bar nicks. Centrepop the intersection points and drill no. 34 holes by the method described previously for the steam chest stuffing boxes. If these holes are not perfectly horizontal, also parallel with each other and with the motion plate, the valve gear will be upset; so take great care to have them O.K.

The completed motion plate is erected vertically between the inside frames, its upper edge level with the top of them, and the guide bars projecting through $\frac{1}{4}$" exactly. It is secured with 3 x 7BA screws through clearance holes in the frame into tapped holes in the angled side of the casting. Countersunk screws will be neccessary to clear the backs of the driving wheels.

Rocking levers

Owing to the unavoidable difference in the centrelines of the expansion links and the underneath valve spindles, a pair of offset rocking levers will be needed. These can be filed up from $\frac{1}{8}$" x $\frac{3}{8}$" BMS. Make four single levers exactly the same and drill the large ends 3/16". Assemble in pairs as shown in the drawing and braze the joint; apply a little brazing flux, heat to bright red and touch the joint with a piece of soft brass wire which will melt and flow in. Quench out in clean, cold water, file off any superfluous brass, and polish up. Run the 3/16" drill through the centre hole to clean it out; then turn up a couple of bronze bushes, drilled no. 32, squeeze them in, and poke a $\frac{1}{8}$" reamer through.

Carefully mark off the position of the end holes, $\frac{5}{8}$" above and below; the upper ones are drilled no 44., and tapped 6BA and the lower ones are drilled 5/32" and bronze bushed, the bushes being drilled no. 41. With a 5/16" pin drill which has a $\frac{1}{8}$" pilot pin, drill a recess 1/16" deep into the side of the rocker which has the tapped hole in it (see illustration). The pins are turned from 5/16" round bar steel, a simple job needing no detailing out, but take care to have the $\frac{1}{8}$" portion a dead fit in the central bush of the rocker, and the head should just fit the pin-drilled recess.

Valve rods

The bottom ends of the rocking levers are connected to the valve spindle crossheads or forks by flat rods with a fork at one end. Two pieces of $\frac{1}{4}$" square steel $2\frac{1}{4}$" long are required. Drill no. 41 holes at 2" centres in each, then slot one end, as described for the valve spindle forks, and mill, or saw or file into outline. The eye may be casehardened if desired, or it may be bushed in a similar manner to the lower end of the valve rocker. The motion plate, rockers and valve rods are the same for either the loose eccentric valve gear, or the link motion.

Stephenson Link Motion.

Owing to the underneath position of the valves, the link motion is not the same in detail as on the full size "Jennies" but the arrangement shown will give far better results on $3\frac{1}{2}$" gauge than a copy of the original motion with its cramped steam chest and tiny valves between the cylinders. The trouble on these small engines, is to arrange a valve gear that will not only give proper distribution of steam, but be robust enough to stand up to long and hard service without undue wear, without being clumsy; and I have done my best to attain this end, bu virtue of long experience as an actual locomotive builder. There is a vast difference between putting engines on paper, and putting them on the track! It will be noticed that the die blocks are mounted direct on the ends of the rocking levers, and this neccessitates the use of launch type expansion links, in order that the forks on the eccentric rods clear the rockers. The big "Jennies" had the weighbar shaft underneath; and I have retained this veature, and although "in theory" it is all wrong to lift the links by the upper pin, in actual practice it does not matter a bean, and saves a lot of work by abolishing the need for special lifting blocks and pins on the links themselves.

Expansion Links

These are cut from $\frac{1}{8}$" gauge steel plate and is perhaps the most suitabl- and readily available metal for this purpose. The job is merely a matter of marking out, drilling and filing to outline; it would take far longer to rig up an attachment in the lathe to mill the slots, than to do the whole job by hand. Tip: file the slots first and use a piece of 3/16" square silver steel for a gauge, which should slip from top to bottom easily but without shake. Then O.K.file the outline of the link around the slot, for it is annoying, to put it mildly, to spend valuable time doing the outside first, and then making an "apple pie" of the slot. AND be sure the no. 41 holes go through dead square!

When finished, the links may be hardened. Heat to bright red first all over and quench in clean, cold water. Then rub the sides on a piece of fine emery cloth. Lay the links on a piece of sheet iron and hold them over a gas flame. Watch very carefully; have a pan of cold water beside you, and as soon as the links turn yellow, tip them into it mighty quick! Afterwards clean up and polish all over. The die blocks are filed up from the same gauge plate, and hardened as above. They must fit easily but without shake. The pins are turned from silver steel and should not be hardened as they will tend to snap off if too hard, and when they eventually wear they can be renewed quite easily.

Eccentric straps and rods

The eccentric straps castings should be cleaned on the outsides with files, and if supplied as a 'double' casting separated. Centrepop the lugs or ears and drill them through no. 48. Place each strap in the vice with a little over half the lugs showing above the top of the jaws, and saw them across with a fine toothed hacksaw, keeping the blade flat on the vice jaws, which will guide the saw and ensure the cut being straight. Mark each of the halves of each strap so that they can be replaced correctly. Rub each portion on a flat file, to remove the sawmarks and open out the holes in the back halves no 41 drill, tap the holes in the other halves 7BA and assemble with screws to match as shown. (Note that a $\frac{1}{8}$" allowance has been made on the split line of the castings, so it may be neccessary to machine the joint faces slightly rather than file).

Chuck each strap in the 4-jaw, setting the hole to run truly and so that the strap does not wobble; face the side with a round nose tool, and then, with an ordinary boring tool, bore out so that the strap is an exact fit on the eccentric. Use a gauge made from a piece of bar turned to the exact diameter of the eccentric sheaves. This should turn freely in the bored strap but should not shake. After boring all four, put on the 3-jaw and chuck the gauge itself in it.

Clamp each eccentric on the gauge with its unturned side outwards, right at the end with its own screws. A turn of paper around the gauge will prevent the strap from slipping. Face off until the width is 3/16", ie the same as the sheaves. Remove and finish shaping the periphery of the strap, and then drill a small oil hole, say 1/16" in the "step" of the strap, and countersink it, then slot the lug for the large end of the eccentric rod. This is easily doen by holding in the vice/vertical slide and passing past an end mill. The slot should be a tight fit on the rod, so use a smaller cutter, and then adjust height of the slide and remove a few thou from each side of the slot.

The eccentric rods may be made from $\frac{1}{4}$" x $\frac{1}{2}$" BMS, cut entirely from the solid, or else the rod part may be filed up from $\frac{1}{2}$" x 3/32" BMS and a block of $\frac{1}{4}$" square steel brazed on at the end to form the fork. In the former case, the method used is the same as for making the valve rods, and no further detailed instructions are needed, the only extra job being to set the fork ends of the rods to the given offsets; but note carefully -- the rods illustrated are for the right hand side of the engine, and the other pair must be set in the opposite direction toward the left hand frame. To make the built up rods, four pieces of 3/32" x $\frac{1}{2}$" BMS are needed each $2\frac{1}{4}$" long and four $\frac{1}{2}$" lengths of $\frac{1}{4}$" square steel. Mill or file 3/32" nicks about 1/16" deep in the ends of the square pieces, that for the fore gear rod being 1/32" off centre, and for the back gear rod right at the side. Braze the flat strips in using ordinary brass wire as the brazing medium, then slot the ends as perviously described for valve spindle forks and similar oddments. The rods can then be filed to shape, and set as shown in the illustration.

It is of the utmost importance that all four rods be of exactly the same length between the centres of the strap and the pinholes in the forks; and when I say "exactly"

I mean just that, no more and no less. If there is any variation in the length of these rods, it will be impossible to obtain a correct valve setting. Fortunately it is quite easy, using the given method of construction, to get the required results, and here is how to do it. The eccentric straps and rods are assembled on a jig. Get a piece of steel bar, say about $\frac{3}{4}$" x $\frac{1}{4}$" section and 4" long. Scribe a line down the middle and set out two points on it 2.15/16" apart. Centrepop them and drill no 43. In one of these holes, squeeze a 3/32" silver steel peg with about $\frac{3}{8}$" of it projecting; and the projecting part should before fitting, be eased with a file, so that the forked ends of the eccentric rods will just slide over it without shake. The bit of $\frac{7}{8}$" round steel which you just used as a gauge for boring the straps is then chucked in the 3-jaw, and a pip about $\frac{1}{8}$" long turned to a drive fit in the other hole in the bar. Part off to leave a head about $\frac{1}{4}$" thick and squeeze the pip into the hole. The jig is then complete.

To assemble the rods and straps, first file off the wide end of the rod, to such a length that when pushed into the slot in the lug of the strap, the length between centres of strap and pinholes in fork, is the merest shade under 2.15/16". Then place the whole issue on the jig adjusting so that when the strap is lying flat on the jig, over the button head, the fork is on the peg; the distance between centres will then be correct. Without removing the assembly, solder the rod into the slot. The assembly can then be taken off the jig and two 1/16" rivets put through the lug and end of the rod; countersink holes both sides, and file off flush. Clean away any superfluous solder.

Weighbar shaft

The shaft is a length of $2\frac{7}{8}$" of 3/16" round steel rod. The lifting arms are filed up from $\frac{1}{8}$" x $\frac{3}{8}$" BMS, the small ends being drilled no. 32 and reamed $\frac{1}{8}$" and the larger ends drilled no. 14, a tight fit on the rod. They are mounted as shown in the drawing, their innersides being $\frac{1}{8}$" from the centre of the rod, leaving a $\frac{1}{4}$" space between. The reverse arm is filed up from 3/32" x $\frac{3}{8}$" BMS drilling the large end as above, and the small end no. 41. It is mounted 13/16" from the right hand end of the shaft and set at right angles to the lifting arms. Put a piece of $\frac{1}{8}$" round rod temporarily through the holes at the ends of the lifting arms, to keep them in line whilst the arms are brazed to the shaft; this job can be done, the three arms at the same heat, the process being the same as described for the rockers. Clean and polish up, then make a little collar from steel a sliding fit on the shaft and 3/16" wide. Put a 3/32" grubscrew in it as shown.

The lifting links are merely strips of $\frac{1}{8}$" x $\frac{1}{4}$" BMS, $1\frac{1}{2}$" long overall, drilled as shown and filed to shape; whilst the brackets are filed up from $\frac{1}{2}$" x $\frac{1}{8}$" BMS. Drill the bearing hole for the shaft; but the screw holes are located from the drilled holes in the engine frame, when the gear is erected.

How to assemble and erect the gear

The eccentric rods, expansion links and lifting links are assembled and erected as a unit. Put the fork on the back gear eccentric rod over the lower lug on the expansion link, squeeze a piece of 3/32" silver steel through the lot; file off each side flush with the fork. The pin should be a tight fit in the 43 hole; if it is not, due to the drill cutting 'large', or a wrong size drill being used, countersink the holes in fork very slightly, rivet over the ends of the pin and file flush. Then attach the fore gear rods to the top lugs of the links, but this time have the pins long enough to project a full $\frac{1}{8}$" towards the middle of the engine. Countersink the 41 hole in the lifting link slightly, place over the pin extension. rivet over just sufficiently to allow the link to swing back and forth and file flush..

Put the die blocks on the pins, push them into the link slots, put a 1/16" washer next the link, and then screw the pins home into the upper ends of the rocker, putting lock nuts on the projecting ends of the screws. Take off the back halves of the eccentric straps, drop the whole assembly in position with the other halves of the straps against their respective sheaves, and the lower halves of the rockers against the inside of the brackets. Put the rocker pins in -- they simply push through the holes in the brackets -- and put the nuts on. Then couple up the eccentric straps. If all is as it should be, the link will oscillate easily when the wheels are turned; and it should run up and down, over the die block, without shake or bind anywhere, with the crank in any position. The valve rods can now be coupled up to the valve spindle fork and the lower ends of the rockers, by little bolts made from 3/32" silver steel, screwed at each end and furnished with nuts; the screwed parts should be just sufficiently long enough to ensure that when the nuts are tight, the bolt is still free to turn.

The position of the weighbar shaft is 1.29/32" ahead of the driving axle, and $\frac{7}{8}$" below the centreline of motion, equal to $\frac{5}{8}$" below the bottom of the frames. Mark a vertical line on the frame each side, 1.29/32" ahead of the axle centre, as above; and $\frac{1}{8}$" either side of this, at $\frac{1}{8}$" from the bottom of the frame, drill a no. 41 hole and countersink it. Clip the weighbar shaft brackets to the inside of the frame with a toolmaker's cramp, and adjust them so that they are exactly vertical with the bearing pole $\frac{5}{8}$" below frame, and at the distance from the driving axle as given above. Run the no. 41 drill up with the 48 drill and tap 7BA. Put the screws in the right hand bracket, take off the other, and put the weighbar shaft in place, with the reverse arm against the right hand bracket, and a 1/16" washer between them. Replace the other bracket and screw up. Adjust the collar against the bracket so that the shaft has no side play, and tighten the grubscrew; guide the two lifting links between the arms, and put a bolt through the lot, made from a piece of $\frac{1}{8}$" silver steel nutted at both ends. This must also be fitted so as to turn freely when both nuts are tight; and the valve gear is then complete, the setting of the valves being left until after the lever on the footplate is made and fitted.

Loose (Slip) eccentric valve gear

This valve gear is given for the benefit of beginners, as it is simpler than the link motion, and easier to make and fit up. As regards efficiency, it is equal to the link motion in full gear; but as it cannot be notched up like the link motion, and therefore steam cannot be cut off early in the stroke when the engine has got well under way with its load and running fact on a continuous track, I have arranged the permanent cutt-off point to be a little earlier than the link motion in the full gear position. By judicious use of the regulator, the steam consumption can be kept pretty low, and the boiler will be able to supply all the demands made on it. On an ordinary straight up-and-down line, of, say, 60 ft. in length, as found in many surburban back gardens, the loose eccentric gear will give practically same results as the link motion, providing the driver does not mind moving the engine half a turn of the driving wheels by hand, to reverse her; because the length of run is too short to admit of proper notching up and expansive working. It is on long non-stop runs where the link motion shows to advantage.

Alteration to crank axle

A different centre section of the crank axle will be needed, to carry two loose eccentric sheaves or tumblers, and two stop collars. This is merely a $1\frac{1}{4}$" length of $\frac{1}{2}$" round BMS, turned down at each end for $\frac{1}{4}$" length to $\frac{3}{8}$" diameter. If your self-centring chuck is accurate, the piece of rod can be held in that whilst the ends are turned, but if not, it would be as well to use a piece of rod, say $\frac{5}{8}$" diameter, centrepop and drill both ends, and turn the lot bewteen centres, so that the middle part is absolutely concentric with the seats or spigots. Cut the piece of rod a little longer than finished size; turn it so that the centre part is exactly $\frac{3}{4}$" between the shoulders, and the ends $\frac{3}{8}$" diameter, a press fit in the crank webs. The ends can then be reduced to exact length in the 3-jaw, and it doesn't matter whether the chuck holds truly or not.

Eccentric sheaves

Two are needed; and if you have a piece of $\frac{7}{8}$" Diameter BMS handy, chuck it in the 3-jaw, face the end, and part off two 3/16" slices. If not, turn down a piece of steel the nearest size larger, but aim for a smooth finish, as the slightest roughness on an eccentric tumbler not only wears away the strap, but acts as a brake and sets up heating and friction. In the middle of each parted off disc, you will see the true centre indicated by the tool marks. Scribe a line right across it; and on this line at $\frac{1}{8}$" from the centre, make a centre-pop. At the opposite end, make another, 5/32" from the edge; drill them both with a no. 32 drill, and if a drilling machine is not available, use the lathe, with the drill in the chuck and the work held against a piece of wood supported by the tailstock as previously described. These holes MUST go through absolutely square. Then open out the hole nearest the centre with $\frac{1}{2}$" drill, or better with a 31/64" drill and finish with a reamer, so that the eccentrics fit nicely on the middle of the crank axle, and are quite free but without shake or wobble.

It will be observed that there are no flanges on the sheaves. They are not needed as the crank webs and stop collars prevent any side movement of the straps, and this leaves full width available for bearing surface. Squeeze a short piece of $\frac{1}{8}$" silver steel into the hole nearest the edge of the disc, and file it off to leave 3/32" projecting, see sketch.

Stop collars.

The stop collars are made from 1" diameter BMS, held in the 3-jaw, faced, centred and a 1/8" pilot hole drilled for 1/2" depth, and opened out with a 1/2" drill. (or 31/64" drill and ream later). Part off two 3/16" slices, mill, or saw and file a segment out of each one as shown in the illustration. You can mill it in two ways; the collar can be gripped ina small machine vice attached to the saddle, so that it is at right angles to the lathe centre-line, and traversed by means of the cross- -slide, under a circular milling cutter mounted on a spindle between centres. The collar is easily adjusted for height in the vice jaws. Alternatively the collar can be clamped in the vertical slide vise and traversed across an endmill held in the 3-jaw similarly to previous components. In the thicker part opposite the segment drill a no. 40 hole and tap 5BA for a grubscrew, as shown.

Eccentric straps and rods

The straps are machined up exactly as given for those in the link motion. The rod is simpler as it has no fork at the end; merely a drilled and reamed eye, which may be casehardened as described for other small parts. The two eccentrics must be exactly the same length between the centre of the strap and the pin hole, so they should be assembled on a jig, exacly as described for the link motion. The rockers, brackets, bearings for rocking levers, and valve rods are all fitted up as described for the link motion.

When assembling the crank axle, proceed as perviously described, except that when the centre section is pressed into one of the webs, the parts of the loose eccentric gear must be passed on to it before pressing on the second web. Put a tumbler on first, pin outwards, then the two collars, back to back with the cut-away sides outward, and then the other tumbler with its pin towards the collar, after which proceed as already explained. The little ends of the eccentric rods are connected to the upper end of the rockers direct, either by little setscrews turned from 1/4" hexagon BMS with 1/8" left plain under the head; or by set bolts made from 1/8" silver steel, screwed at both ends, one end being screwed into the rocker arm, and the other nutted after the eccentric rod is placed over it. A distance washer of bronze 1/4" diameter and 1/32" thickness and drilled no.30, is placed between the eccentric rod eye and the rocker, to prevent them rubbing, and to keep the eccentric rods properly aligned; see illustration of plan of complete motion.

How to set the valves

Turn the chassis upside down and take off the steam chest cover. Tighten the stop collar setscrews in any position on the axles, and turn the wheels by hand, carefully watching the valve movement. The valves should uncover the ports an equal amount at either end of the movement; if they do not, the fork on the valve spindle must be screwed up a little more, or else unscrewed, according to which port has the greater amount of opening, until both ports open to an equal amount as mentioned above. Next put one of the main cranks on front dead centre (nearest the cylinders) slack the grubscrew in the stop collar, give the collar one complete turn forward, to make certain it is engaging the stop pin in the eccentric properly, and then move it very slowly until the valve just "cracks" the port as the eingemen say. The amount of opening should be about 1/64". Tighten the grubscrew then turn the wheels in a forward directinn until the crank is on back dead centre; the valve should have opened the back port to the same amount; and if so the motion is O.K. for going ahead, when the other cylinder has been served likewise.

Now turn the wheels backwards for a complete revolution, then watch the ports again as the crank arrives at the dead centres. The openings hould be exactly the same as when going ahead. If, however the ports do not oep at all with the crank on dead centre, the shoulders on the stop collars have been cut back too far, and a little piece of brass will have to be soldered on to each of them, so as to push the pins in the eccentrics a little further around, and obtain the neccessary opening. If, on the other had, the ports are well open with the cranks on dead centres, the shoulders have not been cut back far enough, and a little can be taken off them with a small chisel. When both ports on both cylinders "crack" with the cranks on dead centres, whichever way the wheels are turned, the valve setting is correct and the steamchest cover can be replaced. Connect a motor tyre pump to the steam inlet on the top of the cylinders, by a suitable adaptor, and pump air into the steam chest. The wheels should "step-lively" in whatever direction the valve gear is set, and sharp exhaust cracks should be heard coming from the hole in the middle of the cylinder block. If the wheels are gripped between finger and thumb, as tightly as you can hold them, and the pump operated vigorously, you can feel the power the engine will be able to develop under steam; probably she will take the wheels clean out of your fingers! (Or your fingers off - be very careful here!)

Reverse lever

On the original "Jennies", the reversing lever was of the old-fashioned "pole" type with a horizontal grip, and was placed alongside the firebox casing, so that the driver needed arms about as long as a gorilla's to reach it in anything like comfort when in full forward gear. However, this does not apply to the small edition so we are using a similar lever in the same place, to retain the "period" atmosphere. The stand, or sector plate is supplied as a casting which needs little more than surface cleaning and filing on the bottom to make it stand "square". The two bosses should be filed, or machined, carefully to slightly proud of the $\frac{1}{8}$" neccessary for the lever clearance. The sector plate, cut from sheet BMS used for keeping the lever in place, is 3/16" wide, curved on the outside to $1\frac{5}{8}$" radius, and is attached to the lever with 8BA bolts, tapped into the bosses and marked off from the sector.

The lever is made from a $2\frac{3}{4}$" length of $\frac{1}{8}$" x $\frac{1}{4}$" BMS, filed to a slight taper as shown and the ends rounded. Drill a no. 32 hole at the bottom end and ream it $\frac{1}{8}$". At 1" above this, drill a no.43 hole, and squeeze into it a little stud made from 3/32" silver steel, turned down slightly at the end and screwed 8BA. The stud can be screwed into the lever if you prefer it. Leave a full 3/32" of plain stud projecting. Drill a no. 50 hole at the top, and fit into this a little handle about $\frac{3}{8}$" long, turned up from a scrap of $\frac{1}{8}$" diameter BMS; rivet the shank over where it projects through the lever, if the shank is not a press-fit in the hole.

As the latch passes right through the lever on this particular type of gadget, drill four 1/16" holes in the lever starting $\frac{3}{4}$" from the top, and chip them into a slot with a small chisel, which you can easily make yourself from a bit of $\frac{1}{4}$" silver steel. Finish with a little needle file. The little slot could also be milled out by clamping the lever in the vertical slide vice, setting exacly horizontal and then traversing across a 1/16" cutter (or dental burr) held in the 3-jaw A high speed and plenty of cutting oil are needed to produce a clean slot.

The latch rod and trigger are all in one piece, and can be made from a strip of 1/16" x 5/16" BMS about $1\frac{1}{4}$" long. Mill, or saw and file, away until it is only 3/32" wide except for a piece at one end 5/32" long, which is left full length to form the latch. This is inserted in the slot in the lever, and the upper end is bent at right angles to come parallel with the handle at the top of the lever, as shown in the illustration, the bent part acting same as the trigger of the usual type of lever. When the bent part is touching the handle, the latch part at the bottom should just clear the sector plate. A small clip is made from a bit of sheet metal bent to shape, or a small piece of $\frac{1}{8}$" square rod with a slot filed in it to clear the rod, and riveted to the lever with bits of rod, or 1/32" rivets. No spring is neccessary, as the weight of the latch assembly, though next to nothing, is quite sufficient to cause it to drop into the notches and "stay put". It must, of course, work freely, though this does not neccessarily mean leave it "sloppy", otherwise it will kick up a fearful clatter when the engine is running. All that now remains is to assemble the lot as shown in the drawing, and file nine notches in the top of the sector plate and retaining strip, also shown in the drawing; one in the middle, one at each end (you can get the position of these by pushing the lever each way until it touches the spacers at each end, and then allowing about 1/64" clearance) and the other three each side, at $\frac{1}{8}$" centres measureing from the end ones. If the valve gear is made as it should be, and the workmanship is reasonably good, the engine will run at high speed with the lever next to middle and use only a breath of steam at that.

Reverse, or reach rod

This can be made from 3/32" x 3/16" BMS, the centre part being milled, or filed, down to 5/32" for appearance sake. The fork at the end is made by brazing on a little block of steel and slotting it and finishing it off similar to the forks on the ends of the eccentric rods.. Don't drill the eye until the rod has been set over in the two directions shown in the illustration, as the given length between centres is inclusive of the bends. As the reverse lever is not attached direct to the frames, but to the side platform, or running board, and these components are not fitted until the boiler is on, the lever can be fixed up temporarily by means of clamps, whilst the valves are being set. Drill 2 x no. 40 holes in the bottom of the stand, in the bent portion, and screw it to a length of ⅜" angle. A toolmaker's cramp can then be used to hold the angle to the frame. When the lever is vertical, the reverse arm on the weighbar shaft should be vertical also; the approximate position of the centre of the lever is 1" ahead of the centre of the trailing axle, or 3" from the frame maeasured from inside the drag beam.

How to set the valves (link motion)

If the crank axle with eccentrics turned solid with the centre part, has been made correctly to given dimensions, and assembled with the eccentrics in proper relation to the cranks as explained in previous instalments, the only valve setting operations will be the adjustment of the forks on the valve spindles, and slight correction of valve lengths on individual jobs. I find that amateur locomotive builders, especially "first timers" are prone to make slight errors in port cutting an so on. Maybe somebody gets a port with a ragged or oblique edge; in in correcting it, the measurements are of course altered from the given dimensions. In such cases, adjusment of the valve length may be neccessary to get the correct setting for efficient operation.

Put the lever in forward gear; turn the engine up-side-down, and support it on wood blocks under the beams. Take off the steamchest cover and turn the wheels by hand. The steam port should appear as a black line at the edge of the valve lap, when the crank is on the corresponding dead centre. If you get too much opening at one end, and none at all at the other, the valve fork should be adjusted on the spindle till the openings are even. If you get a big opening both ends, the valves are too short; if no opening at all, they are too long, and a little should be filed of each end. It is most important to keep the exhaust cavity exactly in the middle of the valve. If one lap is longer than the other, the engine will run jerkily and the exhaust beats will be syncopated. When both ports crack on both dead centres. on both cylinders, with the lever either forward or back, then the valve setting is correct and the engine will probably give the builder a pleasant surprise by the speed and power it shows on the track combined with low fuel and water consumption.

Boiler feed pumps.

The feed pumps now to be described are a simplified copy of the type fitted to the first of the Jennies. The final development of the class, which appeared in the early 60's, had no pumps at all, but were provided with injectors; and if any builder wishes to make his engine conform to this development, he can leave out the pumps.

The pumps are different to any I have yet described in this series, as the valve box is located at the side of the barrel instead of at the end of it. The barrel is made from a 1.3/16" length of ⅜" diameter bronze rod, parted off in the 3-jaw. Centre and drill down to within 1/16" of the end with a ¼" drill. Screw 3/16" of the outside with ⅜" x 40 die in the tailstock holder; and at 5/16" from the blind end, drill a ⅛" hole from the side into the centre hole. The gland nut is turned from a piece of ½" bronze rod held in the 3-jaw; face, centre, drill down about ½" with a ¼" drill, open out with 11/32" drill for 5/16" depth and tap ⅜" x 40, parting off at ⅜" from the end.Chamfer the edges and put a few slots in as shown in the plan sketch. The ram is a 1¾" length of ¼" round rustless steel. One end is rounded off, cross-drilled and slotted, by the same process as described previously for valve forks. Note carefully: to prevent the pump ram locking in the barrel, due to water trapped in the end portion beyond the outlet, either reduce the diameter for ¼" length by turning 1/64" off it, or else file a flat on it. The extreme end of the ramshould be turned slightly conical to match the end of the hole as left by the drill. This prevents airlock.

Valve box

This is made from 1" of the same rod as for the barrel. Chuck in the 3-jaw, face, centre, drill right through no. 32, open out to ⅜" depth with 7/32" drill, bottom to 7/16" depth with a 7/32" "D" bit, slightly countersink the end, tap ¼" x 40 using tap in tailstock chuck and skim off any burr. Reverse in chuck, and repeat operations on the other end, except that the "D" bit need not be used; poke a ⅛" reamer through the remnant of the small central hole. At ⅜" from the bottom -- that is the end not "D" bitted -- drill a ⅛" hole from the side into the central hole; this should just cut into the enlarged portion, as shown in the section of the valve box. File a half round groove, 1/16" deep right over the hole, and fit the pump barrel to it so that the hole in the latter coincides with the one in the valve box. A small bracket ¾" wide, is then bent to the shape shown in the section through valve box, and attached to the pump barrel by a couple of 8BA screws; this bracket can be made from 1/16" sheet brass, Pump bracket, barrel and valve box can now be silversoldered at the one heating; and after pickling, washing off and cleaning up, put the ¼" drill down the barrel again, in case the screws have come right through. Don't forget that one pump has to be right handed and the other left handed; the right hand pump is shown, the bracket going inside the frame and the valve box outside.

Seat at 5/32" rustless steel ball on the "D" bitted seating, by the usual hammer blow via a bit of brass method, and make a cap to suit from ½" round rod.

The full size Jennies had round covers. Allow the ball 1/32" lift but taper off the plug as shown, because both feed and bypass pipes are fitted direct into the side of the chamber, and the plug must not block the outlets. Drop a similar ball into the other end, and measure the distance between it and the end with a depth gauge. A depth gauge for jobs like these can be made in a few minutes. You need 1" of ¼" square rod, 3" of 3/32" round rod and an 8BA screw. Drill a no.41 hole in the middle of the square rod, drill a no 48 hole in the side so it runs into the first one and tap 8BA. Put yourpiece of wire through the first hole and clamp in any desired position by the screw. To use -- this is for novices' benefit -- rest the end of the wire on the ball in the valve box, let the square rod drop down on the end of same, tighten the screw, remove gadget, and the bit of wire projecting below the square rod is the distance required to gauge.

Chuck a piece of round ½" rod in the 3-jaw, face, centre deeply, turn down ¼" of the outside to ¼" diameter, and screw ¼" x 40 with the tailstock holder. Part off at 9/16" from the end. Re-chuck with screwed end held in a tapped bush, in the 3-jaw. Turn down the end for a bare 1/32" less than the distance gauged above, to ¼" diameter and thread ¼" x 40. Centre, drill no.32 and put a ⅛" reamer right through, and skim off any burr. Seat a 5/32" ball on the hole and assemble as shown in the drawing. As this pump is so close to the frame, there is very little room for unions on the bypass and delivery pipes so they had better be fixed direct into the delivery ball chamber when the pipework is in hand after the boiler is made and erected; so for the present merely drill the holes to receive the pipes, one 5/32" in the front of the valve box and another ⅛" in the side of it, both being about 7/32" from the top. The bypass pipe passes through the bracket; drill the hole through the bracket, into the valve box, and then enlarge the one in the bracket to 9/64" so as to afford easy clearance for the pipe when being fitted -- see plan sketch.

Connecting rods for pumps

The pumps are driven from crankpins in the driving wheel bosses, instead of by eccentrics in the usual manner, so little connecting rods are used something like those on an outside cylinder engine. The rod itself is made from a piece of 3/32" by ¼" BMS, filed to shape, offset as shown and drilled no 41 at the eye end. The big-end(some "big end" at that!) is a little block of bronze ⅛" x ¼" x 5/16" long. Saw a groove in one end and file down the end of the rod until it fits tightly after the manner in which the eccentric rods are fitted to the lugs on the straps; then silversolder the joint. Clean up and drill the hole no. 32, taking care to get it 1.7/16" from the pin hole in the eye end; ream ⅛". The little rods are attached to the pump rams either by bolts turned from 3/32" silver steel and nutted 8BA on each end, or by plain pins slightly rivetted over at each end, merely enough to prevent them coming out when running.

Drill a no. 48 hole in each driving wheel boss, ¼" from centre and tap it 7BA. Saw off twopieces of ⅛" silver steel a full ⅜" long and turn down ⅛" of each end to 3/32" diameter and thread to match the hole. Have the threads tight so that they donot come loose whilst the engine is at work. If you prefer, drill the holes no. 32 and use pins turned down at the outside ends only, for the retaining nuts, the inside ends being filed very slightly taper, so as just to start in the 32 holes; they can be then pressed in just far enough to show a full ⅛" of the plain part projecting beyond the boss of the wheel. To erect the pumps, put the crankpin on back dead centre, in the position shown on the general arrangement drawing of the whole engine. Push the pump ram right home and put the "little big end" over the crankpin. Lift the pump into position, with the frame between the valve box and the bracket; then move the pump back towards the rear of the engine, to the extent of 1/32" only. The ram will then be drawn out of the barrel by that amount, and will have the correct clearance for efficient working. The pump is then in its correct location; see that the barrel is horizontal, and in line with the driving wheel centres, as shown in the general arrangement mentioned above, and it may then be attached to the outside frame by two 5BA bolts put through clearance holes in both frame and bracket. A 7BA nut and washer prevents the connecting rod coming off the crankpin.

Mechanical lubricator.

A mechanical lubricator was a refinement that the full size Jennies had never a chance of enjoying; but as they did not use superheated steam, the tallow cups and other more primitive oiling devices of the period served their purposes very well. However, we are not only using superheated steam on Jenny junior, but bronze cylinders and to ensure perfect working and eliminate wear as much as possible, a regular supply of heavy grade cylinder oil is obsolutely essential. The following notes show how this can be guaranteed.

The lubricator itself consists of a small tank with a pump in it, the pump being of the oscillating cylinder pattern and working in the oil. I have experimented with the other types, such as the ordinary twin-valve pump with stationary barrel, driven by an eccentric, or by a slide crank, both direct and driven; but the first mentioned pattern beats the lot for absolute reliability. I mention this because correspondants who have had no previous experience with these small gadgets, seem to be under the impression that there is a liklehood of the oil pushing the contact faces apart and simply circulating around the tank instead of going to the cylinders. Nothing of the kind happens, for one of these little pumps on test pushed the needle of a 360-lb. pressure gauge right up against the side of the case, and bulged out the Bourdon tube inside it. As about 100-lb. pressure is the utmost they are ever called upon to pump against, there is obviously a very large "margin of safety".

The best position for the lubricator is ahead of the cylinders between the front covers and the buffer beam, which renders it very accessible for filling. The front section of the running board or platform, commonly known as the "cylinder flap" among the enginemen, is made detachable so it can be instantly removed at any time. It is located to one side, in front of the left hand cylinder, and the ratchet lever is operated by a vertical driving arm attached to the tail ord, or spindle, of the right hand slide valve. The upper end of this is slotted and engages with a headed pin screwed into the lower end of the ratchet lever, the complete assembly being shown in the illustration. There is no undue strain in the tail spindle, or excessive wear on the gland, as the lubricator needs only a very little power to drive it. Oil is fed direct into the steam passage between the cylinders via a short oil pipe and a simple spring loaded check valve; so that the steam, on its way to the cylinders, takes up the incoming oil, atomises it and delivers the spray to every moving part, each receiving an equal share.

Container

The oil tank or container, can be made fron thin brass, say 20 swg, and it measures 1½" long, ¾" wide and 1⅛" high; so cut a strip of metal 4½" long and 1⅛" wide. Draw lines across it at 1½", 2¼" and 3¾" from one end, then bend at these lines to form a rectangle. Stand this on a piece of similar metal approximately 1⅝" x ⅞" and put the whole lot in a small brazing pan. I keep a special one for small fittings, it is about6" square and 1" deep, bent up from rustless steel sheet with a layer of asbestos cubes in the bottom. An ordinary tin would do just as well, and coke or evencinders from the domestic grate dojust as well as the cubes. Mix up a little brazing flux, or similar to a paste with water and smear it all round the bottom of the container, and up the joint at the side. Heat to a bright red with blowlamp or gas torch, and apply silver solder once the flux starts to melt. When the melted solder has run round all the joints, allow to cool to black, then quench in acid pickle. Well wash in running water. File off the projecting edges from the bottom, and clean up the corner joint. Drill a 5/32" hole in the centre of the bottom plate and another one 3/16" diameter, in the middle of one of the short sides at ¼" from the top.

Pump stand

This is made from a piece of 5/16" square brass 1⅛" long which may be parted off from a long piece held in the 4-jaw, or sawn off a little over length and then chucked in the 4-jaw and faced each end till correct length is reached. Centre truly in the chuck and drill no 30 hole about 3/16" deep in one end tapped 5/32" x 40. At the opposite end cut out a piece ½" long and ⅛" thickness, to form the step as shown. This can be done by either sawing, filing or milling; for the latter grip in the vertical slide vace and traverse it under a cutter held in the 3-jaw, adjusting for height as required. Mill or file a recess 1/32" deep lower down on the same side as shown in the drawing.

As the holes for the bearing bush and the pump cylinder trunnion pin must go through the stand dead square, they should be drilled on a drilling machine, or in the lathe. In the latter case put the drill in the chuck, and hold the work against a flatpiece of wood held in its turn against a drill pad in the tailstock. The bearing hole is drilled 5/32" and tapped 3/16" x 40. The trunnion hole is drilled no. 41, and on the opposite side to the recess, it is pin-drilled 3/16" diameter for about 3/32" depth, to take the end of the trunnion spring. The ports are drilled with a no.55 drill; the right hand one goes through into the central hole, and be careful not to snap off the point as it breaks through. The left hand one is only drilled about 1/16"deep, and a little groove is chipped with a very small chisel from the hole to the bottom of the stand. The port face may now be trued up by rubbing first on a dead smooth file laid on the bench, and finished on a piece of fine emerycloth laid on your surface plate.

Pump cylinder

Part off another piece of the 5/16" rod, 9/16" long this time. Centre truly in the 4-jaw, and drill right through with no. 32 drill. Open out the end to about $\frac{1}{8}$" depth with a 3/16" drill and tap 7/32" x 40. Ream the rest of the hole with a $\frac{1}{8}$" reamer held in the tailstock chuck. Scribe a line down the centre of one side, make a dot on it 5/64" from the untapped end, and another 3/16" above that. Pass a no. 55 drill through the former, right into the centre hole. Drill the upper one no.48, but don't break into the centre hole if you can help it; However if you do there won't be any harm done provided the trunnion pin screws in properly. Tap this hole 7BA. Cut a $\frac{7}{8}$" length of 3/32" silver steel and screw one end for a 3/16" length as above and the other to suit the hole in the pump cylinder. True up the cylinder face same as you did for the port face, screw in the trunnion pin and poke a $\frac{1}{8}$" reamer through the bore again to clean off any burrs. Turn a tiny cylinder cover to fit the untapped end of the cylinder bore, drive it in and solder over it for "safety first"; Be careful however not to block up the passageway. Make a tiny gland to fit the tapped hole; chuck a bit of $\frac{1}{4}$" hexagon rod in the 3-jaw face, centre and drill no 32 for about $\frac{1}{4}$" depth. Turn the outside to 7/32" diameter for $\frac{1}{8}$" length and screw 7/32" x 40. Take a skim off the end, to reduce the screwed elngth to 7/32" (this ensures a full thread to the end) and part off to leave a 1/16" head. Screw it into the cylinder, and put the $\frac{1}{8}$" reamer through in its place.

The ram is a piece of $\frac{1}{8}$" diameter silver steel approximately $\frac{3}{4}$" long with a no.48 hole cross-drilled at one end. The distance of this hole from the end should be $\frac{5}{8}$" - see drawing. Put it in the cylinder, and pack the little gland with two or three strans of unravelled graphited yarn, so that the gland will screw practically home without causing the ram to work stiffly. Put the trunnion pin through the hole in the stand and secure it with a little spring made from 24 swg steel wire and held in place with a nut.

Crankshaft and bearing

The crankshaft is a piece of silver steel 3/32" diameter and $1\frac{3}{8}$" long. One end is screwed 7BA for a 3/16" length and the other end $\frac{1}{8}$". A ratchet wheel, 7/16" in diameter and with 34 teeth is squeezed on to the first mentioned end of the shaft, so that it is $\frac{1}{4}$" from the end.

The crank is a plain disc turned from $\frac{3}{8}$" round BMS held in the 3-jaw. Face, centre, drill no.48 for about $\frac{1}{4}$" down, and tap to match the end of the shaft. Part off at $\frac{1}{8}$" from the end. At a bare $\frac{1}{8}$" from the centre, drill a no 54 hole, tap it 10BA and screw in a bit of steel, $\frac{1}{4}$" long, turned from 3/32" steel with a 10BA thread on the end. Its diameter will just clear in the no.48 hole in the pump ram.

To make the bearing, chuck a piece of 5/16" hexagon brass with about $1\frac{1}{8}$" projecting from the chuck jaws. Face the end and centre, drill down a full inch no 41. Turn down the outside to 3/16" diameter for 13/16" length and screw it 3/16" x 40;part off to leave a head 1/16" thick. Pull the rod a little further from the chuck, drill a no.21 hole and tap about 3/16" deep with 3/16" x 40. Part off a 3/32" length, thus making a locknut.

Check Valves

Chuck a piece of 5/16" round bronze in the 3-jaw, face, centre and drill down about ⅝" with no. 43, open out to 3/16", and bottom with a 3/16" "D" bit to ⅜" depth. Countersink the end very slightly, tap 7/32" x 40 but do not go deep enough to damage the seating and skim off any burr. Part off at 9/16" from the end. Reverse in chuck and turn down a ⅛" length to 5/32" diameter and thread 5/32" x 40. Poke a 3/32" reamer through the hole to obtain a true seating for the ball. At 7/32" from the tapped end of the check valve body, drill a no. 30 hole in the side and fit a nipple in it. Chuck a piece of ¼" bronze rod, turn down about ⅜" of it to 7/32" diameter and thread 7/32" x 40. Face, centre deeply with a centre drill and then drill down about ⅜" deep no. 50. Part off at 5/16" from the end for about 1/16" until it fits tightly into the hole in the check valve body. Squeeze it in and silver solder the joint. To make the cap, hold a piece of 5/16" rod in the 3-jaw, turn down ⅛" of it to 7/32" diameter, and screw 7/32" x 40. Centre and drill down about 3/16" depth no. 30. Part off at ¼" from the end, reverse & chamfer. (Hexagon bronze rod here!). Seat a ⅛" rustless steel ball in the usual manner, put in a little spring made from 30gauge wire on the ball and screw in the cap; see drawing of lubricator section.

The delivery oil check, or clack, which is screwed into the cylinder block is made in the same way as regards the "internals". The exterior differences are, that the tail is larger being screwed 7/32" x 40, and countersunk for a union. The nipple at the side is turned from 5/16" rod, screwed 3/16" x 40 to fit the tapped hole in the front of the cylinder block, and has a shoulder 1/16" thick left behind the threads, to form an oil tight joint against the end of the cylinders. These alterations are clearly shown in the sectional detail sketch.

How to assemble the lubricator

Put the stem of the check valve through the hole in the bottom of the container and screw the stand on to it inside the box. Put the bearing through the hole in the end, run on the locknut inside the box, and then screw the bearing into the top of the stand. When same is vertical, with the check valve underneath screwed up tightly run the bearing in until the head just touches the side of the box; then run the locknut back and tighten up. The pump will then be held rigidly in position. Push the cylinder to one side, insert the crankpin through the hole in the ram, and then line up the crank centrally with the bearing. Poke the crankshaft through the bearing screw it into the crank and the job is done. Pour a little oil into the tank, and turn the ratchet wheel by hand in a clock-wise direction. Oil should almost immediately appear at the outlet nipple on the check; and if you put your thumb over it, and hold as tightly as possible, you will find you are unable to prevent the oil coming out when the ratchet wheel is turned. "Force feed" in very truth!

Ratchet gear and drive

This is illustrated and is practically self explanatory. The ratchet lever is filed up from a bit of 1/16" steel strip to the dimensions given, and drilled as indiacted. A ratchet pawl is filed up from 3/32" steel (gauge plate is ideal as it can be hardened), and pivoted to the lever by an 8BA screw with a short bit of plain under the head. These pivot screws are easily made from silver steel. Adjust the screw until the pawl works easily without being sloppy, and burr over the projecting bit of thread so that the screw won't come out on the road, when Jenny is getting well into her stride. Put the ratchet lever over the end of the crankshaft so that the pawl engages the teeth of the wheel, and secure with a nut. If that doesn't fit tightly when the lever is still free, burr the thread likewise. The lever must swing quite freely without having end play.

A stationary pawl is fitted at the top of the box, over the ratchet wheel to prevent the latter turning backwards and simply oscillating the movement of the lever. This is pivoted on a little stud, screwed into the box and nutted inside. Both pawls are controlled by little springs of 30 swg wire as shown, the moving pawl spring being anchored at a hole in the lever, and the stationary one on a 10BA screw in the box.

The driving arm is also made from 1/16" steel, to dimensions given, and is slotted at the top to accomodate the screw at the bottom of the ratchet lever. The lower end has a little block of 3/16" square rod silver soldered to it. This is drilled ⅛" and furnished with a set screw as shown for attachment to the valve spindle tail.

To erect the lubricator, drill two no. 40holes in the front buffer beam and countersink them. Put the lubricator in position as shown, clamp temporarily with a toolmaker's cramp, and poke a drill through the holes again, carying on right through to the side of lubricator. Remove, see that no chips are left inside the tank, and replace securing with a couple of 7BA countersunk screws with nuts inside the box. Attach the drive arm to the ratchet lever by a screw as shown, and put the drive arm on the valve spindle tail, adjusting it so that it just clears the gland at the extreme backward position. The ratchet pawl should just click one tooth with the reverse lever in next notch to middle and the spindles at minimum travel. A cover for the lubricator can be made if desired from a piece of 22swg brass with an angle soldered to each end so that they fit tightly inside the box; or the cover may be omitted altogether, as the cylinder flap comes right down on top of the lubricator, and will prevent ashes, etc,. getting into it, if kept closed when the smokebox is cleaned out.

The connection between lubricator and cylinders is the essence of simplicty and is shown in the general arrangement sketch. Screw the oil delivery check into the hole in the front of the cylinder block, with a smear of plumber's jointing on the threads, and connect the tail end of it to the nipple on the check under the lubricator, with a bit of 3/32" copper pipe furnished with a nut and coned nipple at each end.

## The Boiler.

The boiler which I am now going to describe, seems ridiculously small for a 3½" gauge locomotive when compared with modern standards. Actually it is smaller than many 2½" gauge engines, as the barrel is only 3" diameter against the usual 3¼" or larger., and the overall length of the firebox outside wrapper sheet is only 3.3/16" against the 5" or so of a modern 2½" gauge engine. Nevertheless, from my actual personal experience of building engines and putting them on the track instead of merely putting them on paper, I can assure all builders that there will be no difficulty in getting all the steam required, and a little to spare. Many years ago I exposed the "Big-boiler" fallacy by rebuilding a 3½" gauge Great Northern "Stirling" 8.ft. single-wheeler with a "scale" boiler and firebox. It was a perfect success in every way, generating all the steam needed by a pair of "scale" cylinders with proper valve gear and correct valve setting. The proportions of boiler and cylinder capacity were practically the same as on "Jenny" and the "secret of Success" lies in proportioning the amount of water carried, to the amount of heating surface you have available to keep it at the right temperature. Maintenance of temperature is the "all in all" of any boiler, either large or small. If you maintain the temperature, you get the steam. I once turned a kiddies toy engine from an absolute failure to success, by fitting a smaller boiler which the methylated spirit burner could easily maintain at the required temperature. Another point frequently ovelooked is that no matter how big the boiler is made, the size of the grate is determined by the frames and wheelbase. JennY's grate is the largest possible for the size and type of engine, and is ample for our purpose.

## Flanged plates

These can be quite easily made from annealed copper sheet, beaten over a former of BMS or even hardwood. Allow a good ⅜" or more around each when marking out the copper before cutting this from the sheet. Anneal the copper by heating to red and allowing to cool, or speed up the process by plunging into cold water. Special arrangements have been made for the castings suppliers to have available ready flanged plates, already marked out for drilling which will save a lot of time, and hopefully will not be too expensive.

## Throatplate and backhead

These are both made on the same former. On one of them at 1.11/16" from the top and on the vertical centreline, make a dot and scribe a circle 2⅞" diameter. Cut this piece out, with a metal piercing saw, or drill a ring of holes, close to the line but inside it, and chisel the piece out, finishing the hole to the line with files. The hole will just touch the flange at each side. There is no need to drill any holes in the backhead yet as this has not to be fitted till last operation.

## Firebox wrapper

Rund a bit of soft copper wire, or better still, lead fuse wire right around the throatplate flange.Straighten it out, and you have the exact length of the wrapper sheet, which is 2⅞" wide and cut from 16 gauge (now 1.6mm) sheet copper. Soften this and bend it to an arch shape as shown in the section; this canbe done by hand over