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Chairman—Mr. W. A. Stanier M.I.Mech.E.

"LOCOMOTIVE ERECTING"

by

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The erection of a locomotive is a matter requiring the greatest accuracy, as the subsequent performance of an engine is largely influenced by the care with which its parts are fitted together. This Paper deals with the methods employed in the building of a new engine. It does not include repair work, and is mainly a description of the methods adopted in the Great Western Railway shops at Swindon.

The erecting shops are arranged with a central traverser road running the whole length of the shops, the pits, over which the engines are built, branching off at right angles on either side. Over the pits, and running in the same direction as the traverser, are overhead cranes. It will be seen that any engine (or truck containing material for an engine) can be moved up or down the shop without interfering with the other pits. This requires more ground space than where pits are arranged parallel on either side of a straight through road ; but in the latter case everything has to be done by crane.

In addition to the main lifting cranes, a small overhead crane is used to expedite the hydraulic riveting, which is mostly done at one end of the shop, and light jib cranes are fixed to the roof columns for handling the smaller work, such as axle boxes.

Drilling machines are arranged on one side of the shop in order to drill angle-iron work, &c. Pneumatic drilling machines save a large amount of time and labour, and have entirely superseded the old ratchet brace for work actually on or about the engine, except in a few special cases where for lack of room it is not possible to use a pneumatic drill.

The Works Manager supplies the erecting shop foreman with the necessary drawings, and amongst these are a general arrangement or frame plan, and an angle-iron drawing. Each detail on the latter drawing is numbered, and also numbered on the general arrangement to correspond. By this means the position of each angle is readily ascertained, and any detail can be quickly identified by reference to the two drawings.

The cross stays are taken in hand first, as they will be required as soon as the frames are in position. The holes in the cross stay angles are marked off from the stay plates and sent to be drilled, after which the angles are riveted on so that they overlap the edge of the plate by $\frac{1}{32}''$. The stays are then sent to the machine shop where the angles are planed to a standard width gauge.

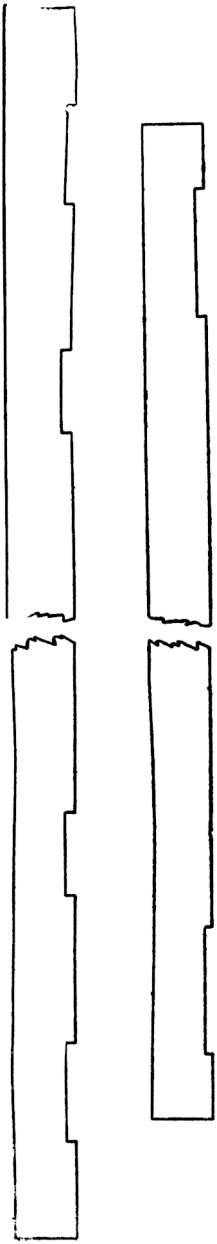
The frames as supplied, slotted and drilled, are placed on low trestles so that the insides are uppermost. A centre line, running the whole length of the frame, is marked off from the top edge, and should pass through the horn centres at the correct distance down, thus checking the slotting. The line is centre-punched so that it can easily be seen for future reference, as most of the work has to be measured or checked from this line. If the cylinders are inclined, a centre line to the correct inclination is also marked off, and this should pass through the horizontal line at the driving centre.

The angles and frame stiffeners are placed on the frames in their correct positions (obtained as previously mentioned), marked off through holes which are already in the frames, and are then taken away to be drilled. Inside motion plates and other castings are also placed on the frames and marked off, but only broaching holes are drilled in them, these being opened out when the castings are finally set.

The frames are now turned over and another centre line is put through the driving centres like on the inside, and is centre-punched as before. A line, representing the under side of the footplate, is struck, and the stiffeners, or footplate supports, are brought up to this line and marked off. The angles and box angles at the leading and trailing ends, which have previously been marked off the frames, are again marked off from the buffer beams.

The frames are now ready for standing up, and to facilitate this, cast iron bottle neck stands with a screwed claw top are brought into position.

FIC 1



FIC 2

These are adjusted for height by simply turning the nut. The frames are placed on these stands, care being taken to arrange them at parts of the frame not required for brackets, &c, four each side being the usual number for a modern engine. The frames are kept at the correct distance apart by the stays and box angles, which have been previously marked off. A liberal supply of bolts is required at this stage, as nothing can be finally riveted up until the frames and cylinders have been set. The stands are adjusted so that the frames are level, and to test this a spirit level is placed along the top of the frame, and also on a straight edge placed across the frames, to ensure that both frames are at the same height.

The driving horns are now fitted, and great care is taken to ensure their faces being square with the frames, parallel to one another, and vertical. The frame surfaces are just as they leave the rolling mills, and are not planed, as was the practice some years ago. A slight unevenness will sometimes occur, and this has the effect of throwing the horns out of square, to remedy which a light chipping must be taken off the plate. The horns are held in position by temporary bolts through small holes in the horns and frame, which are subsequently opened out. To test for squareness, a long straight edge placed across the engine should have both horns (or all four if a double-framed engine) in line. Each pair on either side is tried for squareness and also for width by a hardened cylindrical gauge (Fig. 1), whose ends are dead

true and parallel. This gauge must just be movable between the two faces all over, and it is obvious that should horns be out of square or not parallel the gauge will not fit. A plumb line is tried on the horns from time to time to ensure them being vertical, for if horns are true to plumb, and the frames true to spirit level, one must be square with the other. The frame gauge is also tried across the horns, and this, shown in Fig. 2, has been made to the right dimensions : if the horns are set true it will just slip over the edges. This can only happen, firstly if frames are the proper distance apart, and secondly if the horns are in the correct position on the frames. The cylinders are next placed on or between the frames and cramped in position so that the centre line on the frame and the cylinders are level. Then lines of fine twine are put through as follows :—An arm of thin plate (Fig. 3) is fastened to one of the cylinder cover studs at the front end and reaches to the centre of the cylinder. A very fine line

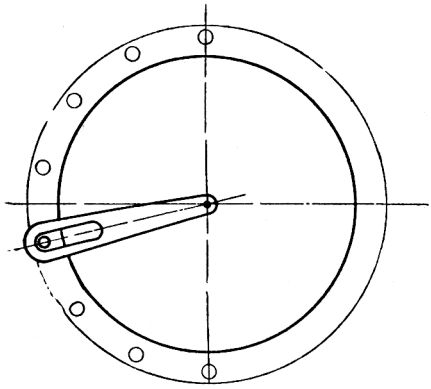


FIG 3

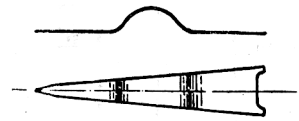
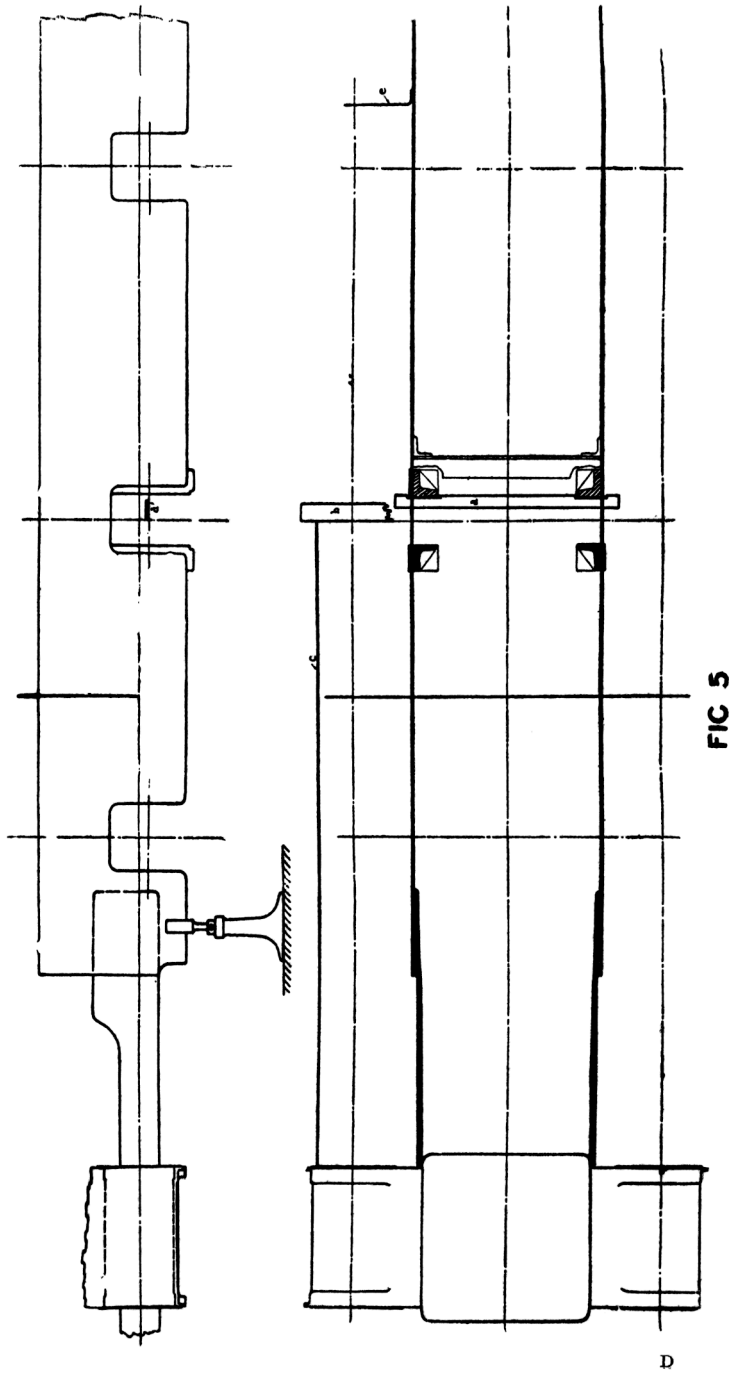


FIG 4

passes from this through the cylinder barrel to an angle bracket at the trailing end of the frame, the distance from line to frame being accurately measured. The line is adjusted for height by putting a long straight edge across the top of the frames, and trying a gauge between the underside of this and the line. In the example shown by the diagram the driving centre is $2\frac{1}{2}''$ above the wheel centre. To ensure the line passing truly through the cylinders, a gauge (Fig. 4) is used, which must just touch the line when tried in any position round the cylinder barrel. At the stuffing-box end the same thing is done by means of inside callipers.

Should the line as set from the top of the frame not be true in the cylinder, the cylinder must be tilted up or down to rectify this. The



FIC 5

line is next tried along the frame at different places, to test the latter for straightness. A " length gauge " is next tried, whose overall length is that from the cylinder face to the driving centre. This is tried with one end on the cylinder face and the other just passing a straight edge resting on, and cramped to, stretchers between the driving horns, the straight edge, of course, being half way between the faces and the requisite distance up. If the cylinders are found long to this gauge they must be brought bodily back. If, however, one side is tight or slack to length gauge, then the horns are not square with the cylinders.

One frame should be moved forward or backward as required, and the horns and line checked over again. An L square off the straight edge, running through the horns, would be a further check for squareness.

The frames are also checked by means of cross trammelling (Fig. 5). This is done as follows :—A small centre punch mark is put on the top edge of the frames directly over the centre of each of the horns. A trammel is set to these marks across the frames at the driving horns, and then tried at the other horns. Next the trammel is set between right hand driving and left hand trailing. This same setting has then to agree when tried between left hand driving and right hand trailing. The opposite sides and also the diagonals being equal, the four centre pops represent the corners of a rectangle, hence everything must be square.

Now summing up :

(1) The frames are true to cross trammel.

(2) The cylinders are true to the length gauge from the horns.

(3) The cylinders are square with the horns.

(4) The horns are true to the frame gauge.

(5) The horns are square with the horizontal centre line.

The whole is checked by the foreman, before broaching or riveting, who does not pass it unless correct in every way.

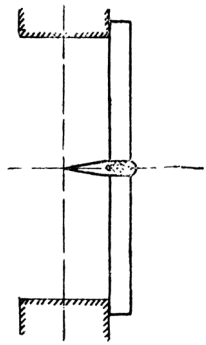
The holes in the horns and cylinders are now broached out, and turned bolts are driven in. The frame stiffeners, cross stays, buffer beams and angles, set to correct position by the erector and held by temporary bolts, are next riveted on. The boiler with smokebox is placed on the frames, the smokebox marked off, removed, drilled, then replaced and finally fixed. The lines are then checked to see that riveting has not distorted the frames, or that dropping the boiler on

has not twisted the cylinders round, due to the smokebox being out of line.

The motion plate is now set to the cylinder line, and the holes broached out to receive rivets or driving fit bolts, after which the slide bars may be put up. These latter when properly set must be true with the cylinders in every respect, and therefore the cylinder line is used in setting ; liners at each end greatly facilitate this work.

The bars must be parallel to one another as well as to the centre line ; and a gauge (Fig. 4) is used for this work. Should the bottom bar, for instance, be too near the line, a thicker liner is inserted at the cylinder end, and a little filed off the liner at the motion plate end. This is continued until both bars are true with the line, which of course makes them parallel with one another.

To ensure the bars being parallel with the frame, or true sideways with the cylinder line, a motion bar gauge (Fig. 6) is used, the movable finger of which is set to the line, and if tried, on the opposite side, should just touch. If such is not the case, the bars must be moved sideways and the finger re-adjusted.



FIC 6

When correct, the holes in the motion plate are broached out, and cheese headed bolts driven in, so that the heads are flush, or slightly below the faces of the bars.

The cross head is now fitted between the bars by filing and scraping the faces of the slippers until a good bearing is obtained : when finished there should be no side play.

The frames and motion bars are now finally checked with the cylinder line, and are passed if everything is found correct.

The axle boxes, as received from the fitting shops, are checked by means of a special gauge (Fig. 7) to see that the bearing portion is central with the side faces. A gauge (Fig. 8) is also used to ensure that the flanges are of equal thickness and true with the bosses.

These precautions are very necessary, and it will be readily seen that should the bearing portion not be central, the centre between the wheels would be short or long, and all the care in setting the cylinders would be useless. The error, if on a driving wheel would be felt both on the

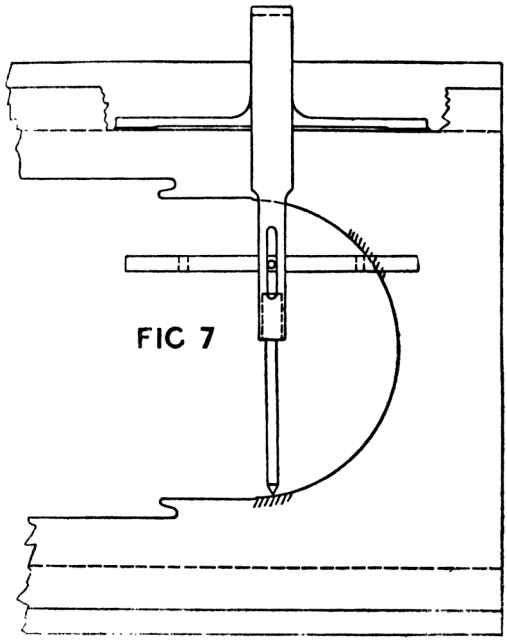
coupling rod and in the piston clearance. In the former case either the rod would not go on, or if strained on, would run hot. In the latter case, the cylinder clearance would be greater at one end of the stroke than the other.

After gauging, the axle boxes are ready for " jumping, " *i.e.*, being fitted up in the horns. A stand with a movable bolt, and a stout wooden hand spike is used, and the method adopted is that of alternately levering the box up the horns and then holding it while the bolt is taken out and placed higher up, where a fresh purchase can be taken. The horns have a thin film of marking smeared on them, and by means of this the box is filed and scraped when taken down again, and the whole operation is repeated until a good face bearing is obtained. When finished, with ties up in place, it should, in the case of a driving box, require some effort to move it up or down, being somewhat easier for boxes of carrying wheels. They are passed by an inspector if satisfactory.

About this time the bogie or pony can be commenced. It is built as a separate arrangement, the frames and angles being assembled, and the wheel centres cross trammelled in the case of a bogie, as in the engine.

The spring hanger brackets can now be set to their correct distances on either side of the wheel centres, and riveted or bolted up. The hanging bar brackets or foot plate supports can also be riveted on, and the hanging bars (*i.e.* the long angles which support the footplate) can be secured in place. The brake shaft brackets are bolted up with temporary bolts to the dimensions shown on the drawing, and a straight edge tried through to bring them in line. If the shaft is tried up and the caps bolted on, any slight error is made manifest, as the shaft will bind and not move freely. This may be due to a slight unevenness on the frames, and can be rectified by a light chipping ; but as the bracket surfaces are comparatively small, and the bearings fairly free, very little trouble is experienced in this direction. The reversing shaft can be fitted up in a similar manner. When the necessary adjustments are made the holes may be broached out and the brackets secured with driving fit bolts.

The magnesia boiler covering can now be plastered on, and this is usually done with steam in the boiler in order to dry it quickly. Com-



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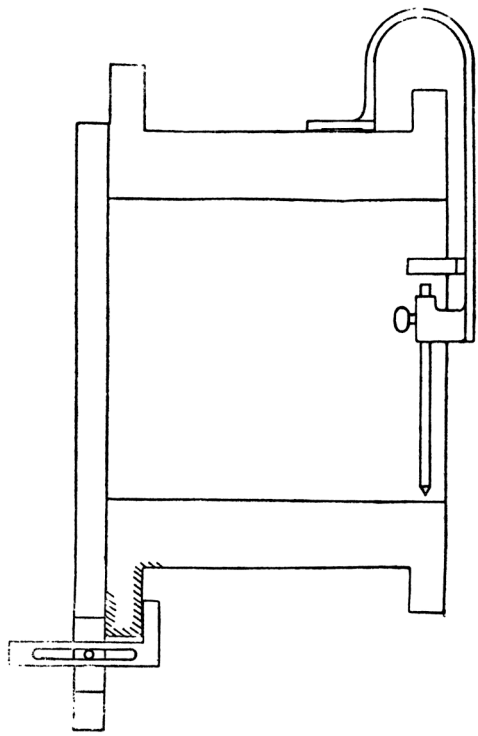


FIC 7

FIC 8

mencing at atmospheric, the steam pressure is gradually raised to 60 or 100 lbs per square inch as the work proceeds, the supply being obtained from a pipe service at the end of the pit. When properly dried, the magnesia is covered with sheet steel cleating secured round the barrel and firebox by steel bands. The cylinders are also treated in a similar manner.

The foot plating can now be marked off if a tender engine, or tanks tried up in the case of a tank engine. In the former the foot plates are taken to the punching machine to have the holes punched out ; and in the latter case the tanks are placed on their sides so that the holes may be more conveniently drilled, after which they are replaced and bolted down, or riveted down in the case of the footplates. On a tender engine the splashers can be fitted up and riveted in position, and the ash pan can also be proceeded with.

The wheels now receive attention : the axle boxes are taken down from the horns and bedded on the journals until a good bearing is obtained on the semi-circumference, after which the bearing is eased back on either side from the bottom upwards for $1\frac{1}{2}''$, the easement being 0.005″ at the centre line, decreasing to 0.002″. The connecting rod big ends are next fitted to the crank pins, and a good bearing secured.

Next come the eccentric sheaves. If the engine is of an entirely new type, the sheaves are set (cottered up but not keyed to the shaft) to information supplied from the Drawing Office. After valve setting, when the requirements are met, a template (Fig. 9) is made, and all future engines of the same class are set to it as follows :—

For the right hand engine the wheels are set so that the crank hangs vertically downwards. The fore gear sheave is placed on the shaft next to the crank web or the wheel, and moved round until its centre line coincides with the niche (Fig. 9) on template, care being taken that the top edge of the template is perfectly horizontal, which can be observed by means of a spirit level.

A scriber drawn through the key way marks the shaft ; also a check mark is placed on the side of the sheave and journal, so that the sheave can be brought back to the same place while the key is being fitted in. The back gear sheave is similarly marked off to the opposite niche on the template. The sheaves are now removed and the scriber lines

centre-punched. Key ways are sunk with a flat-nosed drill and chipped out to take the key, which is then driven in tightly. The separate halves of the sheave are now placed on the shaft, and the key is filed until the marks on the sheave and shaft coincide. The sheave is then cottered up, and the set bolt (which has a hardened end formed as a circular knife edge) is screwed down and locked with a nut. This bolt forms an additional security and aids the key. The left hand engine is then set in the same way by turning the crank down vertically, after which the eccentric straps can be fitted round the sheaves. All oil holes and grooves in the axle boxes are cleaned out, the journals well oiled, the axle box keeps put up with the pads in place, also the axle box spring hangers, and then the wheels are ready to be placed under the engine.

Wheeling an engine is done by means of an overhead crane. The wheels, having been placed in their proper order on the traverser, are

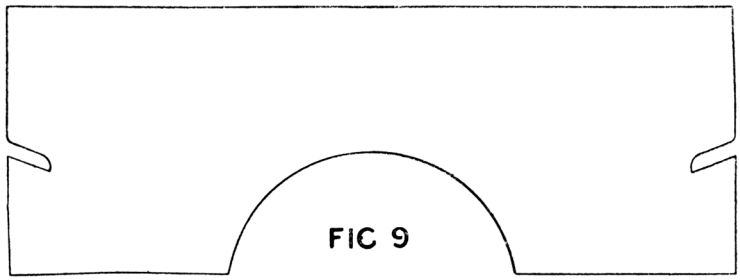


FIG 9

brought up in line with the pit on which the engine is being built. The overhead crane, which has two crabs, is brought directly over the engine, one crab taking the leading end and the other the trailing end. The motors are set in motion and the engine is lifted off the stands to such a height as will allow the largest pair of wheels to be rolled under. The wheels are now brought into position underneath their respective horns, the ties of which have been removed, and the bogie under the centre pin. A man is stationed at each axle box, whose duty is to see that it will enter the horns properly, and he tilts the box to right or left as required.

The crane lowers out very slowly and stops when the boxes are about to enter. As soon as it is seen that everything is in position the engine is lowered down on to packing, placed on the top of each axle box, of such thickness as to keep the engine at running height.

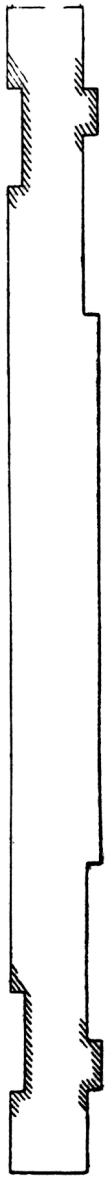


FIG 10

It is during the latter operation that the full advantage of a crane with two crabs is realised, as the whole of the wheeling is then done in one operation, whereas, with a single crab an engine has to be wheeled in two stages : first one end is lifted, whilst the other end rests on packing, and then the engine is lowered down and the opposite end lifted.

The piston rings can now be tried in the cylinders ; and if too large, the ends are filed until they are separated by $\frac{1}{16}''$ when fitting all round the cylinder walls. Then they are passed over the piston head and drop into grooves prepared for them. The cylinders must now be thoroughly cleared of dirt, rust, &c, which may have been left in. This is usually done by means of compressed air, and by drawing a wire through the ports with a tuft of waste on the end. The pistons may now be put in and the cover joints made as soon as the blast pipe flange and the steam pipe joints in the smokebox have been covered over with pieces of steel plate to prevent foreign substances dropping down into the cylinders. The metallic packing glands are now passed over the piston rod, and the cross-head is coupled up by driving in the cotter. The whole is then pushed forward until the piston strikes the front cover, and a mark is scribed on the slide bar : usually in line with the edge of the crosshead slipper. The whole is now moved back until the piston strikes the back cover, and a second mark is scribed on the bar, from the same edge of the slipper. These lines are very important both for checking the connecting rod and piston length and the clearances, and are made permanent by lightly punching ; the distance between them, of course, representing the stroke of the engine plus the total clearance. The latter should be at least $\frac{1}{2}''$, which would give $\frac{1}{4}''$ between the piston and the cover at either end of the stroke.

The valve guide bracket, if one is used, can now be set by means of a line through the valves : if hanger

links are used the suspension brackets can be set and bolted up. The small end of the connecting rod having been fitted to the gudgeon pin, the rod may be coupled up after the bearing surfaces have been well oiled : the eccentric straps and rods can also be coupled up. The reversing shaft is placed in mid gear, and the handle in a corresponding position, in order to ascertain the length of the bridle rod, which can then be welded up. The rod is afterwards ground and polished, and coupled up in position, and all valve gear connections made. The valves and cylinder ports are now checked over to a standard gauge (Fig. 10) for width across the face and exhaust cavity. The valves are put in place and coupled up ; but the front covers are left off to enable the valves to be set, a small bracket being placed across the opening to act as a guide.

The engine is levelled all round to running height (by packing on the

FIG 11

FIG 12

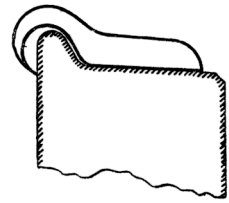


FIG 13

axle boxes ; weight being put only on the driving wheels by the springs) and is first of all moved along a level road in order to mark the centres. This is done as follows :—

Turn the driving wheel round until the crosshead is nearly at the end of its stroke. Put a centre punch mark on the slide block, and with a small trammel (Fig. 11) mark the bar. Before moving the engine, put a centre punch mark on some stationary part of the engine, such as a spring hanger bracket : place one end of a small trammel (Fig. 12) into this mark, and with the other scribe a line on the tyre, and at a known distance from the edge of the tyre, obtained by using a gauge (Fig. 13), put a centre punch mark. Now cause the wheel to be revolved in the same direction until the crosshead has reached the end of its stroke and is returning. When, by means of the trammel on the slide block, the first mark is again reached, stop, and mark the face of the tyre as before.

Bisect the distance between the two marks on the tyre and centre punch it, (marking it R.F. or R.B. as the case may be), removing the two marks on either side. If the wheels are caused to revolve until the trammel off the spring hanger bracket coincides with the centre mark, the dead centre is obtained. The other three centres are found in the same way, and all four should be equidistant. Whilst at the dead centres, mark the bar as was done to obtain the bumping mark : then the distances between these marks and the bumping marks will give the clearances in each case. This gives an excellent check on the accuracy of the detail work, for if the clearance at the back is not the same as that at the front, the piston, connecting rod, or crosshead is at fault ; and a careful examination must be made to determine which it is. Assuming that the clearances are all right, the valves may be set ; the points aimed at being to obtain the desired leads and cut-offs required by the designer. Taking the case of the piston valve with internal admission, the lead, cut-off and port opening cannot be obtained directly, obviously, but as the valve and ports have been checked by a standard gauge, as mentioned before, they may be obtained indirectly by means of a brass angle bracket (Fig. 14) fixed to the steam chest studs, the top face of which is directly beneath the spindle and is polished so as to be free from marks ; it extends a sufficient length so as to cover the extreme travel of the valve spindle plus the length of the trammel to be used.

When the valve is in mid position, the exhaust edge of the steam port and valve will be line and line if there is no exhaust lap. The engine is therefore moved along carefully until the valve reaches mid -position, this being obtained by means of an exceedingly fine feeler. An " L " shaped trammel, one end of which is placed on the spindle, is used to scribe a fine line on the face of the bracket with its other end. On either side of this line two others are marked, each at a distance equal to the steam lap. If the engine is moved until the trammel off the valve spindle coincides with either of the outside lines, the cut off point is obtained, and so all the valve movements may be followed from outside. Two very important points to obtain are the lead at 25% and 75% cut off. To obtain the lead, place the engine with one crank on a dead centre, and the valve gear notched up as required. Then the distance between a trammel mark at this position and cut off mark, gives

the lead ; to alter the lead the sheave must be moved round a little on the shaft.

To obtain the valve travel the engine is moved until the spindle is nearing the end of its travel, when marks are made with the trammel, and these are continued until the spindle is returning. Obviously, the extreme mark represents the valve's furthest movement in that direction. If the distance from this mark to the cut-off, compared with the corresponding mark at the other end, shows any inequality, the eccentric rod is drawn or jumped as required. The back gear is tried over in a similar manner.

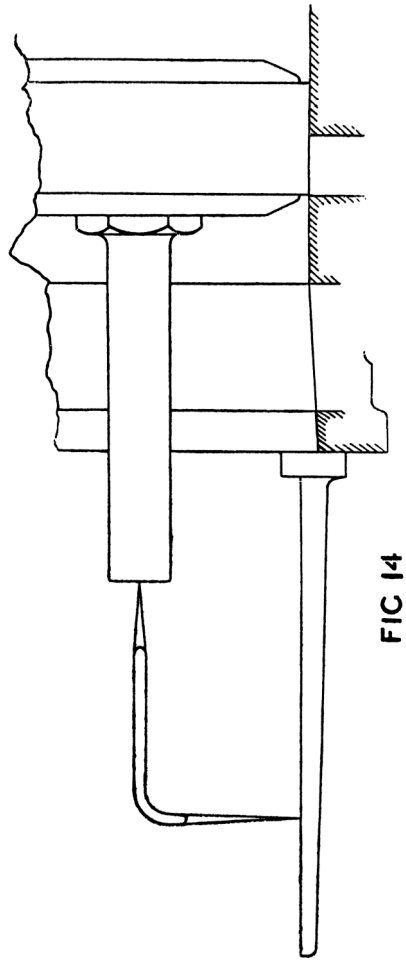


FIG 14

It may be noted that the sheaves are moved to *alter* the lead ; but to *equalise* the lead on the front and back strokes the rods must be jumped or drawn. If the travel requires equalising it is done through the rods.

A large number of engines are fitted with flat slide valves underneath the cylinders, and as the bogie is just below them, special arrangements are made so that the general work of the shop shall not be hampered. As soon as the valves are in the steam chest, and before the bogie goes under, the cut-off points are marked on a bracket of a similar type to that already mentioned for piston valves, except that it is somewhat shorter and is fastened to the studs of the dummy gland in front.

The cut-off can be taken directly (as these valves have external

admission) by the use of a feeler, and the trammel on the end of the spindle marks the bracket for both cut-offs as before. Check marks are put on the bracket from the cylinders, and the bracket taken down and placed, together with the trammel, in a pigeon hole marked with the engine number until required for use. Meanwhile the other work about the engine progresses, and the bogie may be put under, as the bottom steam chest covers will not be taken off again. When valve setting commences the bracket is put back and set to the check marks, proceeding as before mentioned for piston valves.

In the Walschaert gear valve openings are corrected by drawing or jumping the eccentric rod ; and if a four cylinder engine, the outside valve is adjusted by means of a special nut provided for that purpose.

The brake shaft can be placed in position and the caps bolted up, also the vacuum cylinder brackets and the cylinder, with its trunnion brackets. If the cylinder swings freely it can be coupled up to the brake shaft, and the whole may be allowed to drop to the bottom position, which will be " brakes off. " The hangers are next put up, with the brake blocks in place, and, with the cross girders, are wedged up against the tyres, so that the length can be taken for the pull rods. These are welded up and ground all over before fixing up in position.

The spring gear now receives attention. The springs, equalisers and rollers are put up, and the spring hangers passed through the brackets on the frames so as to come in line with the eye end of the spring. Pins are put in, and the nuts underneath pulled up until the engine just lifts off the packing. Further adjustment is left until the engine is on the weigh table. If the engine has a pony truck, the cross beam and longitudinal equaliser are fixed in position before the springs are pulled up. Care must be taken to see that the beams, &c., do not foul anything, and that sufficient clearance is allowed for any movement.

The cylinder cock and sand gears can now be fitted up, the positions on the engine being obtained from the respective drawings.

The two chief parts of the engine requiring pipe work are injectors and the vacuum brake. A drawing is supplied showing the positions of the injectors and the vacuum cylinder, reservoir, retaining valve, &c. on the engine. This drawing also shows the pipes leading to the same, the pipe flanges and their standard numbers, together with a tabulated list of all flanges required for one engine. A standard pipe flange drawing

gives dimensions and details to correspond to the numbers on the pipe arrangement.

The various brackets and clips required for securing injectors, cocks, etc., appear on another drawing, and are labelled, such as " under ash pan, " etc. The injectors, cocks, reservoirs, etc., are bolted up, and then templates, formed of wire, are bent in position on the engine the shape of which the pipes may be made. Four sets of pipes are required for a re-starting injector, viz. :—

(1) Feed water from the tank valve.

(2) Live steam from the fountain.

(3) The delivery pipe to the clack box, on the boiler.

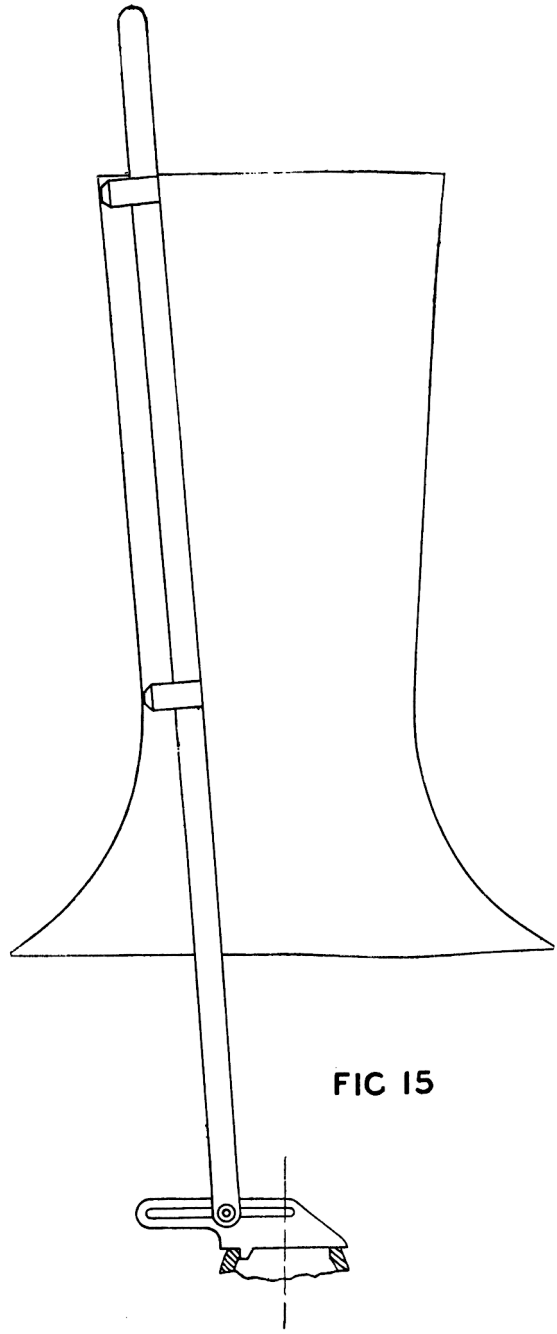
(4) A waste water overflow.

An exhaust injector has in addition a large pipe conveying the exhaust steam from the cylinders, and another supplementary steam pipe from the fountain. With some types the exhaust injector is in two parts, and an extra overflow is necessary, together with a connecting pipe which joins up the two portions. The pipes, with flanges brazed on, are faced and bolted up with asbestos joints for steam, and rubber for cold water and vacuum, after which they are securely clipped to the frames, ashpan, etc.

The cab side and weather board are cut out to the drawing, fitted together, and then riveted ; the windows are put in and the roof fixed on. The ashpan damper rods, cylinder cock and sand gear handles are fitted up, and a wooden footboard is laid down.

The smokebox contains details which affect the efficient working of the engine to a large extent, viz., blast pipe and superheater. The blast pipe is set by means of a gauge (Fig. 15), as it has to be perfectly in line with the chimney. The blast pipe is fixed to the correct height, and the chimney placed on the smokebox with temporary bolts. The gauge, the bottom of which rests on the blast pipe, is set so that the two fingers just touch the top and bottom of the chimney respectively. Then when the gauge is moved round inside the chimney the two fingers should touch everywhere. This type of gauge is suitable for any shape of chimney.

The main steam pipes from the regulator or superheater are fitted in the cones until a good steam-tight bearing is obtained, after which the joint is made with a mixture of red and white lead.



FIC 15

The superheater is supplied complete with the boiler, but the spark plates, dampers and gear for operating them have to be fitted on the engine. The damper is controlled by a small cylinder placed on the outside of the smokebox, and coupled to the damper through a shaft. As the tubes would be burned if the damper remained open when steam was shut off, and the superheater rendered useless if the damper remained shut with steam on, everything must be made to work freely, consistent with good workmanship.

The remaining pipe work can now be fitted up, and such work as hand rails and smokebox doors can be adjusted, also the trimmings placed in the oil syphons, etc.

The springs, which were only pulled up sufficiently to keep the engine level during valve setting, are now pulled up still further by means of the spring hanger nuts, which has the effect of lifting the engine above running height. When water is in the boiler (and also the tanks full in the case of a tank engine) the engine drops to its running height again.

The painters have meanwhile been cleaning the engine, stopping up, and rubbing down with pumice and water. Then a coat of priming or lead colour is put on and rubbed down, followed, when dry, by coats of green, which is in turn varnished.

The engine is now ready to go on the weigh table, and is pulled on to the traverser, and taken by it outside the shop. Here steam is raised and the tender coupled up.

On arriving at the weigh table the engine is run over nuts placed on the rails to make sure that the boxes move freely in the horns, and to shake the engine down to its bearings. It is then placed on an automatic table, which shows at a glance the weight on all the separate wheels. If one wheel of a pair carries more weight than the other, the spring of the former is slackened out a little, and that of the latter pulled up.

Should one pair of coupled wheels be heavier than the others, they are relieved of some weight, and the springs of the others are pulled up until the engine is properly balanced. In cases where spring gear is equalised, the beams distribute the weight proportionately amongst the wheels, and the only effect of screwing up the spring nuts is to raise the engine. The remedy in this case is to move the roller into another

bearing, and as the fulcrum of the beam is altered the weights will be redistributed.

Whilst weighing is in progress the engine is tried round with a staff off the rail to obtain the true running height, and the water scoop is examined to see that it clears the load gauge when up, and is the proper distance below rail level when down. The engine passes beneath a standard load gauge to see that everything clears, and is finally examined as to other clearances, etc., and all nuts securely checked and the necessary split pins put in and opened.

The first engine of a new type is photographed, being specially painted a suitable colour for this, and is also weighed empty as well as full ; that is to say, the coal and water are removed and the engine placed over the table and weighed as before. If a tank engine, and water is placed in the tanks after the latter weighing and another weighing taken, the capacity of the tanks can be calculated, as the tables in use are so sensitive that a movement can be seen on the needle if a man boards the engine during weighing.

A trial run is now performed, any defects being reported by a special inspector who rides with all engines ; and these being remedied, the engine is handed over to the running department, who work the engine at first on stopping trains, sending it back to the weigh table after the first trip to see if the springs are keeping right, and further adjustment is made if necessary.

Any slight defects which may develop are put right by the erectors, and the engine is then sent into general traffic.