Chapter XXIX.—ERECTING ENGINES AND MACHINERY.

IN engines having suspended guide bars, it is not uncommon to set those bars by the working parts of the engine, instead of by lines. This is an advantage when the parts of the engines are not taken down, and, if care is taken, will make a true and smooth working job; but otherwise, it is likely to introduce errors in the lining of the engine, which throw it out of proper line, and cause a great deal of friction.

The proper method of setting the bars depends upon the condition of the engine as to wear. Suppose, for example, that a new piston head has been put in, then, if the gland is new also, or is a good fit to both the piston rod and the bar of the stuffing box, the bars may be set as follows:—

Place the piston at the back end of the cylinder, and put the cross head and guide blocks in proper place on the rod. Put up the bottom guide bars so that they just touch the cross-head guides. Now, in adjusting these bottom bars there are two essential points: first, that the plane of their upper surfaces shall stand parallel with the axial line of the main shaft, and secondly, to place the upper surface parallel with the axial line of the cylinder (it being of course assumed that the cylinder and crank shaft are in proper line). The first of these essential points will be attained when a spirit-level, placed truly along the bore of the

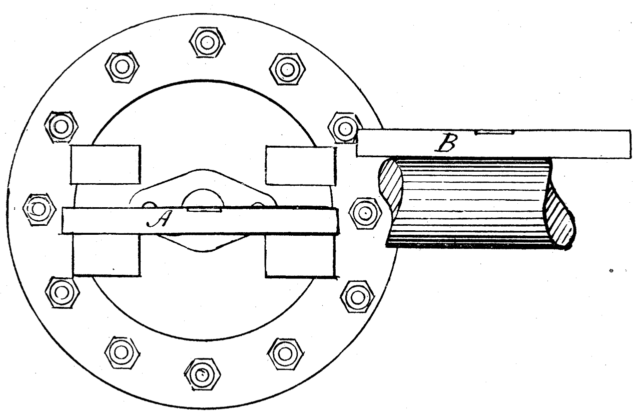


Fig. 2518.

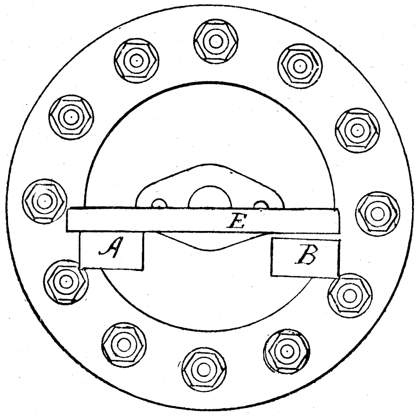
cylinder, shows the bubble to stand in the same position in the tube, as it does when placed upon and along the bar. The second will be attained when a spirit-level, placed across the bars, as in Fig. 2518, at A, shows the bubble to stand the same as it does when the level is placed on a parallel part of the shaft, as in the figure at B. When the bars are thus temporarily set, the liners, or pieces of iron, may be fitted to the proper thickness, so that the gland will pass in and out of the stuffing box easily by hand, no matter in what position the piston may be in the cylinder.

To get the thickness of these liners, take wedges made of iron, wood, or lead, and insert the thin end between the faces of the bars and those of the supports, forcing the wedges in sufficiently to leave a mark upon them. By chalking the faces of the wedges they will exhibit the marks more plainly. The wedges should be inserted at each end and on both sides of the bar, for one bar at a time, the liners being got out a trifle too thick so as to allow some for fitting.

If the liners require to be very thin and are difficult to hold in the vice without springing, take a piece of soft wood faced true, and grip it in the vice, and fasten the liner on it by means of brads driven in around the edge of the liner.

When the four liners are ready place them in position between the bars and their seatings. Bolt the bars firmly in position, wipe them clean and test them lengthwise with the spirit-level to ascertain if they are parallel with the cylinder bore, and place the level across the bars at each end to test parallelism with the engine shaft, as in Fig. 2518, and, having noted where further adjustment is necessary, put marking upon the bars and move the cross head back and forth to ascertain how much the respective liners require reducing. If the gland is a fit upon the piston rod and in the stuffing box, moving the gland in and out of the stuffing box will be an admirable test of the guide-bar adjustment.

The straight-edge should also be applied to test if the surfaces of the bars lead true one to the other; thus, in Fig. 2519, A and B are the bars and E the straight-edge, which by being pressed



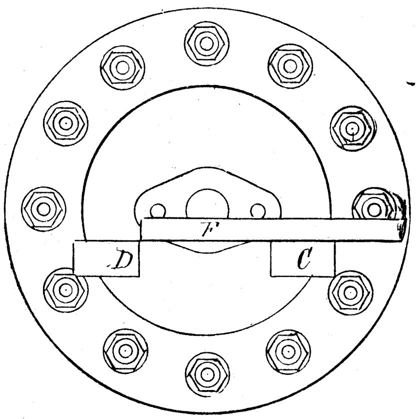


Fig. 2519.

firmly to the surface of A discloses that the surface of A is not in line with B, because if it were so the straight-edge would meet the face of B as in Fig. 2519, where the straight-edge F pressed to the surface of C leads true to the surface of the bar D. All four of the bars require testing in this manner. If the seatings for the bars or the liners are not made flat and of equal thickness, or if from any other cause the bars do not bed properly upon the liners, then bolting up the bars will spring them as shown in Fig. 2520, in which, at A, is shown a bar sprung in the bolting up, because the liners fit at the ends B C only; while at E is shown a bar sprung or bent because the liners fit at the ends D D only. In either case the cross head would be forced to travel in a curve, bending the piston rod, and inducing much friction. The way to test the bars in this respect is, after the above operations, and before loosening the bolts, place a long straight-edge lengthwise along each bar and move it laterally at one end. If it swings from the centre the bar is rounding, while if it shuffles across first at one end and then at the other the bar is hollow in its length and we must find at which end of the bar this spring exists.

To do this, slightly slacken the bolt or bolts at one end and again apply the straight-edge, if the spring is removed the error lies in the bedding of the liner at that end. If not removed, retighten the bolts at that end and slacken those or that at the other end, and again apply the straight-edge, and thus may it be determined how much of the spring is due to each of the liners, and this must be remembered and allowed for in filing the liner to its final adjustment. Before putting the liners in a second time it is better to give them a light coat of marking to show where they bear. At each trial of the bars the spirit-level and straight-edge should be applied and the cross head should be moved back and forth to show by the bearing marks how the cross-head guides fit to the bars. These marks are a great deal finer test than any spirit-level adjustment, hence the last part of the fitting should be performed with strict reference to the bearing marks upon both the bars and the cross-head guides as well as upon the liner, the cross-head

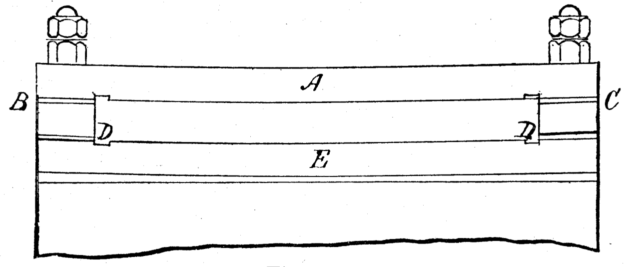


Fig. 2520.

flanges being adjusted and fitted at the same time as the face fitting.

To set the top bars place the cross head in the middle of its stroke, and place them upon the cross-head guides. Then, with the wedges applied as before, ascertain the required thickness of the respective liners one at a time, leaving them, as previously, a trifle too thick, and testing them while fitting by marking placed upon their faces. The top bars may be entirely adjusted from the contact marks left by the cross-head guides when moved along the bars, thus dispensing with the use of the straight-edge and spirit-level.

As the bolts supporting the bottom bars often require to be loosened to get the top bars off, pieces of wood may be placed beneath the bottom bars to retain them in position when the bolts are loosened. These pieces must be removed during the testing, for if left so as to wedge the bars they may spring them, and thus

to the gland would produce the result shown in Fig. 2521, in which the dotted line A A is a line or cord stretched axially true with the cylinder bore, and coincident with the centre of the pillow block at B. The gland being a loose fit permits the piston rod to fall below its proper level, and the surface of the bars, if set by the gland only, without using the spirit-level, would be set true to the full line C C, and therefore out of true line. If the bars are set by spirit-level true to the length of the cylinder bore, the gland becomes useless as a guide to set the bars by. It is a not uncommon practice, when the gland has play, to insert in the stuffing-box bore, at the bottom, a piece of tin or sheet brass, equal in thickness to one-half the amount to which the gland is too small, or to insert a similar piece beneath the piston head if it is

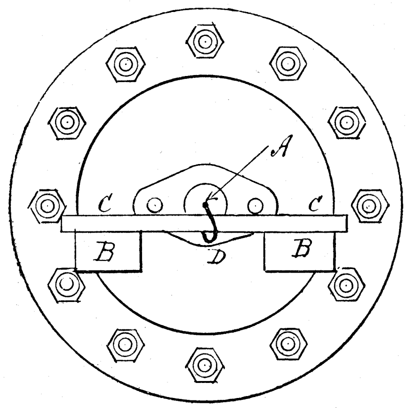


Fig. 2522.

too small. As a rule, however, there will be at least as much play between the piston rod and the gland bore as between the gland and the stuffing-box bore; hence, if there is any play, it is better to discard the use of the gland altogether.

The proper method of setting guide bars by a stretched line is as follows:—

The cord or line is set true to the cylinder bore, and coincident with the centre of the pillow block, as at A A in Fig. 2521, and the two bottom bars are put up in line horizontally with the axial line of the crank shaft, and at a distance below the stretched line equal to one-half the height of the guides for the cross head, as in Fig. 2522, in which A represents the stretched line, B, B the bottom bars, C C a straight-edge, and D a piece of wire whose length from point to point is equal to one-half the height or thickness of the

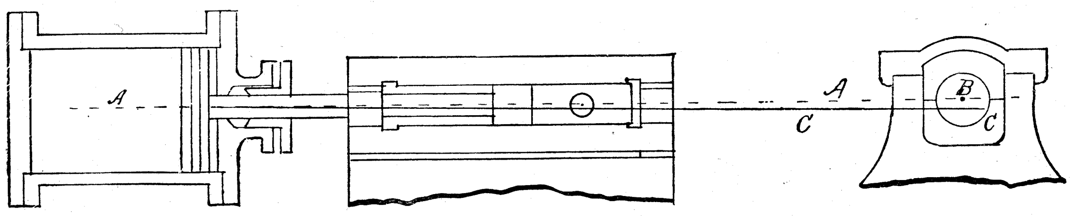


Fig. 2521.

mislead in the adjustment. After the top bars are adjusted the whole bearing surfaces should be oiled, and the cross head pulled back and forth by hand without the use of a lever, providing the size of the piston does not exceed about eighteen inches diameter. The bars when set true should be clamped to their seatings and the holes reamed out to receive the proper bolts, and, finally, mark each bolt, bar, and liner to its place.

When the bars, tested with the straight-edge and spirit-level as described, show true, if the gland will pass freely in and out of the stuffing box with the cross head at any part of its stroke, the guide bars are set.

In this operation let it be noted that the close fit of the piston to the cylinder bore and of the gland to the stuffing box is alone depended upon as a guide whereby to so set the guide bars that the axial line of the piston rod and its plane of motion shall be in line with the centre of the crank shaft.

Suppose, however, that the piston head is a new one, and the gland is worn a loose fit to the stuffing box, then setting the bar

guide blocks. The width apart of the bars is set to suit the width apart of the flanges of the guide blocks on the cross head, by means of a square. The square is applied in the following manner: On a straight-edge mark two lines A and D, Fig. 2523, a distance apart equal to the distance between the flange edges of the cross-head guides. Midway between A and D mark the line C; place the straight-edge across the bars as shown, and when the edge of a square, placed on the straight-edge, coincides with C and the stretched line, and the marks A and D coincide with the edges of the bars, the latter are set true, and will come right for distance apart, and distance from the centre line, supposing the flange edges of the cross-head guides to be equidistant from the centre of the length of the cross-head journal. If, however, such is not the case, the width from A to C and from C to D must be made to suit, C representing the centre of the length of the cross head journal, D the flange on one guide and A the flange on the other guide. Here it may also be remarked that, if the thicknesses of the cross-head guides vary, or if they are not central to the axial line of the cross-head journal, the bars must be set for distance from A in Fig. 2523, to suit the error, because in that figure the straight-edge is supposed to stand parallel to the axial line of the shaft, as it is also in Fig. 2522, the aim in both cases being to so set the bars that the cross-head journal shall stand parallel with the crank shaft.

It is the liability of variation in the thickness of the guide blocks, and of their not being central to the cross-head journal, that constitutes the disadvantage of setting the bars by lines, it being obvious that the bars must be either set to suit any errors in the

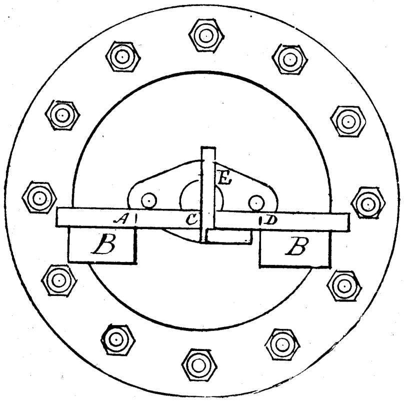


Fig. 2523.

guides, or those errors must be eliminated before setting the bars. The top bars must be set parallel to the bottom ones, at a distance from the bottom ones equal to the thickness of the guide blocks, and parallel to one another. It is preferable to set the top ones with the cross head and guides in place, observing all the precautions as to springing them given in the case of the bottom bars.

The bars thus set will be in line with the crank axle, but unless the piston accurately fits the cylinder bore, they will not long

the parts are not in line, the heating may also be remedied by loosening the fit of the parts; but this will often induce a pound or knock, hence the true remedy is to properly align the parts.

The location of a pound may be discovered by placing a piece of metal wire between the teeth, and resting the other end of the wire upon each end of the cylinder, guide bars, and bearings of the main shaft, repeating the operation in each place, and the sense of feeling will distinctly indicate the location of the knock, by imparting a more severe shock to the teeth when the vicinity of the knock is approached.

The most prominent location of the causes of a pound are, first, in the crank pin, from causes to be hereafter explained, and from its wearing oval at the cross-head journal; and second, at the ends of the cylinders, or the ends of the guide bars, because of a ridge forming there as the wear proceeds.

A crank pin cannot wear oval if the brasses are kept adjusted to fit it, because in that case the brass bore must wear it round; but if there is any play it wears oval, because the pressure of contact between the journal and the brass bores is least when the pin is at and near the points of dead centre, and the most when it is at and near half stroke.

The cross-head pin wears oval because the pressure between the pin and its bearing is in a line with the connecting rod, and there is but little wear on the pin in a direction at right angles to the rod.

Ridges form at the ends of the cylinder bore and at the ends of the guides for the following reasons:—

Referring to the cylinder, the location of the piston stroke in the cylinder bore alters as the connecting-rod keys pass through the rod, because that alters the length of the connecting rod, and therefore the path of the cross-head guides on the guide bars, and also that of the piston in the cylinder.

As the piston rod is shortened there is less wear at the extreme end of the cylinder bore farthest from the crank, and the same remark applies to the guide bars.

If the piston head travels past the end of the cylinder bore and

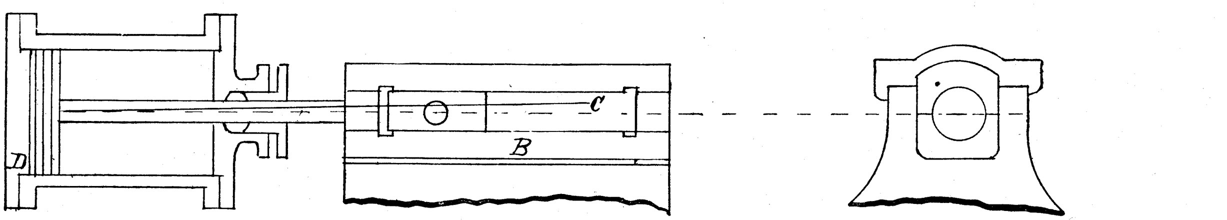


Fig. 2524.

remain in line with the line of motion of the piston rod. For example, Fig. 2524 shows a piston head too small for the cylinder bore, the guides fitting the bars properly, and the gland and stuffing box fitting the piston rod; the piston will be suspended in the cylinder, its overhanging weight being supported by the guides B, the gland, and packing ring. This would cause friction and rapid wear of the gland bore and guide surfaces in a direc-

into the counterbore at each end, a distance equal to the amount of taper on the connecting-rod keys, or equal to the amount the connecting-rod length will alter while those keys are passed through the rod (to take up the journal and brass wear), the piston head will (if the rod is kept to its original length within that amount) always travel to the end of the cylinder bore, and no ridge should form on account of the length of the rod altering;

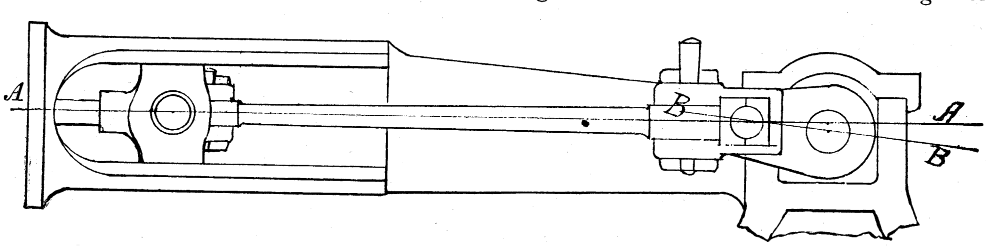


Fig. 2525.

tion parallel to the line C, which would gradually let the piston fall to the bottom of the cylinder bore, touching at the end of D first. In some engines provision is made to adjust the piston to take up its wear, which is, it will be seen, a great advantage.

THE HEATING AND POUNDING, OR KNOCKING, OF ENGINES.—The heating of any part of an engine occurs from one of two causes, viz., either the fit of the parts is too close, inducing undue friction, or the parts are not in line.

When the former is the cause the remedy is to ease the fit. If

but even then a slight ridge may form because the wear is naturally less at the ends. Thus in the middle of the cylinder length the whole thickness of the piston head, piston rings, and of the follower passes over the bore, while at the ends only the flange of the piston head at one end and the follower at the other passes over the metal of the bore; hence the friction and wear are less.

The ordinary cause of pounding and heating is a want of truth in the alignment of the crank pin, or in that of the cylinder, main shaft, or guide bars.

The method to be employed to line an engine, or to discover if it is out of line, depends upon the design of the engine and its condition; thus an engine having a Corliss frame has the slides to receive the cross head made at a true right angle to the end face which meets the cylinder end; equidistant from the centre of the gland hole or axis of the piston rod, and the end of the frame fitting either the bore of the piston or the turned flange of the cylinder cover; hence the guide bars must be true if the frame is got up true, the fit of the frame end to the cylinder end insuring truth in the guide or cross-head slides, providing that the centre line of the frame, during the turning and planing operations, leads from the centre of the cylinder end of the frame to the centre of the crank-shaft brass; or, in other words, the planing and boring of the frame must be true with a line running from the centre of the cylinder end of frame to the centre of location for the crank shaft. This will not only cause the outside of the frame casting

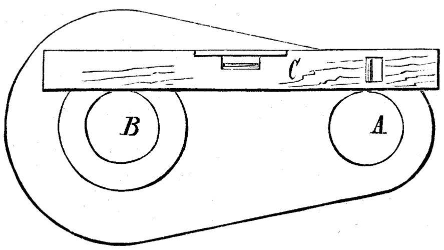


Fig. 2526.

to stand at its proper level when the cylinder bore stands horizontally level; but it will insure that the crank-shaft bearing brasses both be of equal and of a proper thickness through the crown.

The engine being properly lined at first will not be liable to get out of line, excepting so far as affected by the wear of the crank-shaft bearing, which will cause the crank shaft to drop, as shown in Fig. 2525, where A A represents the true centre line of the cylinder and guide bars, which, when the crank is in the position shown in the cut, should be coincident with the centre line of the connecting rod and the crank, but the crank brass having worn below the centre line of the connecting rod and crank, the crank will get out of line as denoted by the line B B.

As a result, a portion of the piston movement and pressure which should be exerted on the crank after leaving the dead centre, will be exerted on it before it reaches the dead centre, thus causing a back pressure, involving a loss of power. Furthermore, the crank centre line must nevertheless stand true with the axial line of the cylinder, when the crank is on the dead centre.

If, instead of having a Corliss frame and fixed guide bars, the engine has a flat bed and adjustable guide bars, as shown in Fig. 2527, the operation is as follows:—

In setting up a new engine it is obvious that if the flanges of the cylinder are planed parallel with its bore and at the proper distance from its axial line, and the pillow block is made of the proper height, a line stretched axially true with the cylinder bore will pass through the centre of bore of pillow-block brasses, or be equal in height from the engine bed; but the length of the cylinder being only about one-fifth of the distance from the cylinder to the centre of pillow block, any error in the planing of the cylinder flange true to the cylinder bore becomes magnified five times at the pillow block; hence it is necessary to stretch a line through the cylinder bore and set the cylinder so that the line, being axially true with its bore, will pass the pillow block at the centre of the bore of its brasses. This is sometimes done by inserting thin pieces of sheet tin, metal, or even paper beneath the cylinder flanges and the bed, and in the requisite positions. The method of stretching the line is shown in Fig. 2527. F is a device for holding the line at that end. It consists of a frame in the form of a cross, with adjusting screws at the end of each arm, and a small hole at its centre to receive the line. The other end of the line A must be secured, under as much tension as the line will safely bear, to a piece of wood clamped to the engine frame at R. The adjustment of the line is made by measuring its distance from the walls of the bore of the cylinder at one end and of the bore of the gland hole at the other end, using a pair of inside calipers or a wire gauge. The latter should be bent in its length to admit of adjusting the same by straightening to increase, or still further bending to diminish, its length to suit the requirements.

The wire, when applied, should only just meet or touch the line and not bear the least hard, or it will spring the line, causing an error of adjustment that will be serious when multiplied by the length of the line to the pillow block as compared with the length of the cylinder bore.

If the pillow block is planed on its bottom face and has its brasses fitted, the latter may be marked off for boring from the line A, Fig. 2527, when stretched to set the cylinder, thus avoiding a second adjustment of the line A A.

Suppose now that it is required to line the brasses in the pillow blocks true to be bored (the pillow blocks being bolted in position). The distance of the face P, of the brass from the stretched line A, in Fig. 2527, must equal the distance from the centre of

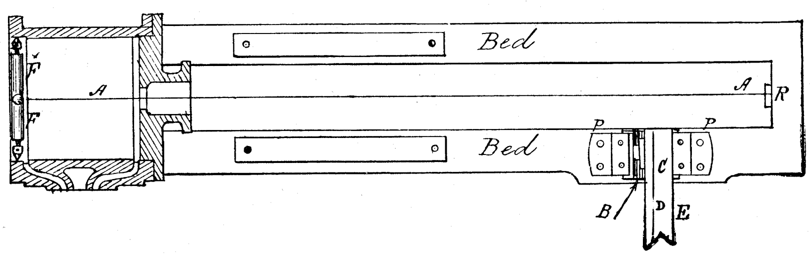


Fig. 2527.

relative position of the eccentric to the valve gear will be altered, impairing the proper set of the valves; hence it follows that the wear of the crank bearing in this direction should be taken up (by raising the lower brass) before it becomes excessive. To find how much the bottom brass requires raising, or whether it requires raising or not, find the centre of the crank shaft, and from this centre strike the circle B, in Fig. 2526, whose diameter must equal that of the crank pin A, and place the edge of a spirit-level coincident with the perimeters of the crank pin and circle, as shown in the cut. When the bubble of the spirit-level stands in the same position as it does when the level is placed upon the bore of the cylinder or along the piston rod, the crank will be in line with the cylinder bore.

As a rule, the cylinder bore of a horizontal engine stands horizontally true, and the crank centre line should also stand so when the crank is on its dead centre, but if such is not the case the the length of the crank-pin journal, to the face of the large crank hub, and this distance may be shown by a line marked on the edge of the brass flange.

Place a straight-edge C, Fig. 2527, having a line D parallel with its edge E, so that this line will be in the centre of the width of the pillow-block jaws, and at a right angle to the line A. The line D will then represent the axial line of the crank shaft, and may be used as the centre from which to mark the lines on the brasses used to set them by for boring. To test if A and D are at a right angle, or to set D to A, a large square should be used. If the side face P P of the pillow block stands parallel to A, as it should do when it is true, it will serve to chuck the pillow block by, thus boring the brasses in their places in the pillow block, with the centre line of the bore at a right angle to P. If otherwise, two flat places should be filed on the brasses, as shown in Fig. 2528, in which C is the straight-edge, and A the stretched line as before, H and I representing the flat places whose distance from A, as shown at J J, may be made to represent the thickness of the crank from its large hub face to the centre of length of crank-pin journal; hence the depth of the flat places will show how much to take off the face of the brass to leave it of the proper thickness.

A straight-edge placed across these flat places, or true to the lines H I, must stand at a right angle to the line D, so that by setting the brasses by the flat places they will be bored to stand at a right angle to A. To set the brasses the other way a circle is struck from D, as a centre, upon the faces of the brasses as in the end view, Fig. 2528, in which the straight-edge C is shown wedged in the bore of the brasses, which is the most convenient way when it can be done.

The line D is carried down on the end face of the straight-edge, and the latter is used as a support for the compass points while striking the circle M, which is defined more clearly by indenting it with fine centre-punch marks. The height of the centre for bore of brasses may be carried from the centre line of the cylinder A A to the end of the straight-edge C, by placing another straight-edge across the engine bed and measuring from the end of C to A.

Suppose now that the brasses are bored, and the position of the pillow block is to be set, and the process is the same, the line D being marked true from the bore of the brasses, and the pillow blocks adjusted until D is at a right angle to line A A.

line to enable connection at the other end without springing or bending the rod.

Furthermore, it often happens that the frame work of an engine does not form a base for the whole of the parts, thus in a large stationary engine, the end of the main shaft or crank shaft farthest from the crank (generally called the *outboard* bearing) is generally supported by a bearing having an independent foundation, and as this foundation does not exist until the engine comes to be permanently fixed for operation, its alignment must be performed when setting the engine. In an old engine this foundation may settle, or the wear itself may throw the engine out of line, so that the lining of an engine becomes periodically a necessity.

As a general rule a want of alignment induced by wear or incurred from repairs to the parts principally affects the main shaft, the cross head remaining more nearly true; and, with the exception of the crank pin, the same holds good with reference to a new engine.

Now while an error of alignment may exist in any direction, it is true, nevertheless, that an error in any direction will be discoverable if the parts be tested at four equidistant parts of the stroke or revolution, as, for instance, on the two dead centres of the crank and at the highest and lowest points of the path of rotation of the crank pin; hence attention may be confined to those four points.

Suppose then an engine already put together requires to be tested for being in line, and we have to test—

1st. The alignment of the main or crank shaft vertically.

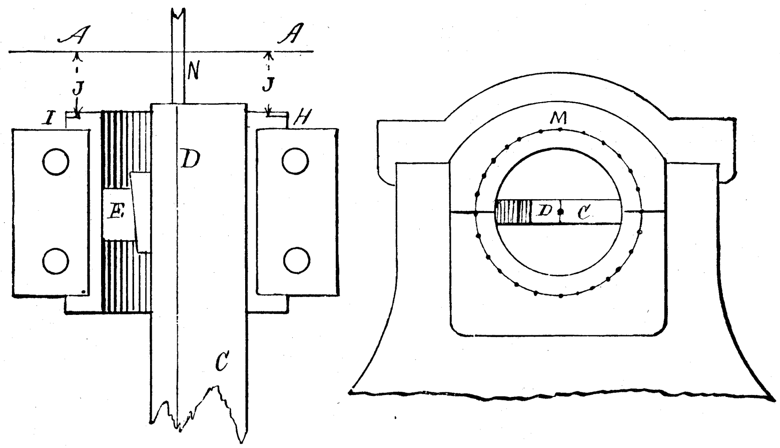


Fig. 2528.

Though in a new engine every part may be made as true as possible in the details of manufacture, yet when the parts come to be put together errors of alignment will generally be found to exist. These errors may be too minute for discovery in the separate piece, and yet form important defects in the finished engine.

In rough practice these defects are left to remove themselves by abrasion and wear, the process being to allow the parts to be somewhat loose (wherever possible) in their adjustment, and adjust them closer as the abrasion proceeds.

This is termed letting the parts *wear down to a bearing*. But the very process of wearing *down to a bearing* attests that the parts have not been properly fitted to a bearing, whereas to attain the best possible results the parts should be fitted to a bearing, because in wearing down to a bearing, undue abrasion, and to some extent or in some degree, roughness of the wearing surfaces, must ensue, because the strain intended to be distributed over the whole *intended* bearing area is limited to the *actual* bearing area. It is necessary, therefore, that, in putting an engine together, each part be properly fitted to its place, and that it be subsequently adjusted in its fit and position with relation to the other parts to which it is connected.

The fitting of the single piece is a test of its individual or disconnected truth; the subsequent or second adjustment is a test of its truth with relation to the others. Thus a pair of brasses may fit a journal perfectly, but that is no assurance that the brasses are so bored as to bring the rod holding them in proper

2nd. The alignment of the main shaft horizontally.

3rd. The axial truth of the crank pin with the main or crank shaft.

4th. The adjustment of the crank shaft for vertical height, with relation to the cross-head journal.

Referring to this last, it may be necessary to remark that the axial line of the main shaft may be parallel when viewed either vertically or horizontally with the cross-head journal, and yet if a line be passed through the centre of the cylinder bore, and prolonged past the crank centre, the latter may fall above or below that line, but it will generally be below, because from the weight of the crank shaft its bottom bearings wear the most; and, further, to whatever extent those bearings wear after being in proper line, the crank shaft will fall too low.

We may now subdivide the errors of alignment of a crank shaft thus:—

1st. Its axial line, when viewed vertically, may form an acute angle to the axial line of the cross-head journal.

2nd. It may form an obtuse angle with the cross-head journal when so viewed.

3rd. It may, when viewed from the crank-pin end of the engine on about a horizontal position, be too high or too low at the crank-pin end only.

4th. It may be too high or too low at the outboard end only.

5th. It may be too high or too low at both ends, although parallel to the cross-head journals.

It will be found on consideration that with the exception of the last-named case, the connecting rod forms the best test whereby to discover an error in any of these directions, because it magnifies the error and makes it more plainly discernible. It will further be found upon careful observation, that although a combination of these errors may exist, the connecting rod will serve to discover each error separately, as well as the collective error, because, although in some respects two distinct errors may have the same general result, yet the result will be different if taken in detail, and it follows, therefore, that the testing must be taken or made in detail first.

To test the parallelism of the axial line of the crank shaft with that of the cross-head journal, when viewed vertically: In Fig. 2529, let A A represent a line true axially with the bore of the cylinder, and B B a line at a right angle to A A, and passing through the centre of the pillow block or bearing spaces. If the engine were in line, B B would be coincident with the axial line of 2530, in which A A is a line coincident with the axial line of the cylinder bore, and B B the axial line of the crank shaft, from C to D is the plane of revolution of the crank pin, while G represents the crank centre. The points at C and F denote points central to the length and diameter of the crank-pin journal. Now, the centre line of the connecting rod for one dead centre is represented by E D, and for the other by F C, and it will be seen that the point at E is farther from A than is the point at F. It will be observed that the point D falls *outside*, while the point C falls *inside* of A A, and yet the centre line of the connecting rod stands, in both cases, at the same angle to the centre line A A of the engine, and in both cases throwing the end of the connecting rod, represented by the points at E F, *outside* the line A A.

If the connecting rod does not, when connected to the engine, as in Fig. 2529, fall true into the cross-head bearing, the error is the same *in amount* and comes on the outside of the cross-head

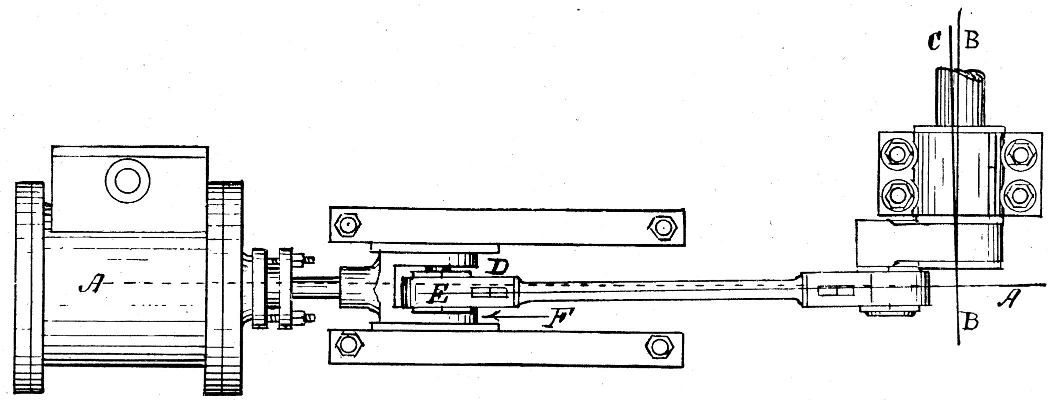


Fig. 2529.

the crank. Suppose, however, that line B C represents the actual centre line of the crank, not then being at right angles to A, the end E of the connecting rod, if connected to the crank pin as shown, and made a good working fit so that there is no play of the pin in the brasses, will not come fair laterally with the bearing in the cross head. The amount of the error is the amount it is out of true in the length of the crank-pin journal, multiplied by the product of the length of the connecting rod (from centre to centre of the bores of the brasses) divided by the length of the crank-pin journal. It is apparent, however, that if the crank shaft be set to have its axial line at B B instead of at B C, the error at E D will be corrected, and thus we may employ the connecting rod to set the crank shaft in line.

It is, however, not sufficient to try the crank on one dead centre

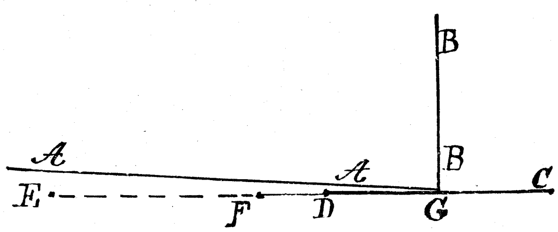


Fig. 2530.

only (as will be seen presently), hence we place it on the other, and move the cross head to the other end of its stroke, and again try the end E of the connecting rod with the cross-head journal, and if it falls to one side, and *on the same side as before, but to a less amount*, it demonstrates that the axial line of the crank forms with the line A A an acute angle. If, however, instead of falling too much laterally towards the side F of the cross head, it fell too much towards D, but more so when tried with the crank on the dead centre nearest to the cylinder than when tried with the crank on the other dead centre, then it is proof that the axial line of the crank shaft forms with A A an obtuse angle.

The reason that the error will be more plainly shown with the crank on one dead centre than when on the other is shown in Fig.

journal with the crank placed on each respective dead centre, it is proof that either the flange of the crank-shaft brass (which is between the crank face and the frame) is too thick, or the inside flange of the connecting-rod on the crank pin is too thick, or else the crank is too thick, measured from the crank-pin journal to its inside hub face, the error being in the new crank or new brass, if one has been put in.

It may here be remarked that if the bore of the crank-pin brasses of the connecting rod is not at right angles to the centre line of the rod itself, the end E, Fig. 2529, might fall either inside or outside, laterally, of the cross-head bearing, but in this case the error will show more at one end of the stroke than at the other, for reasons which are explained with reference to Fig. 2530;

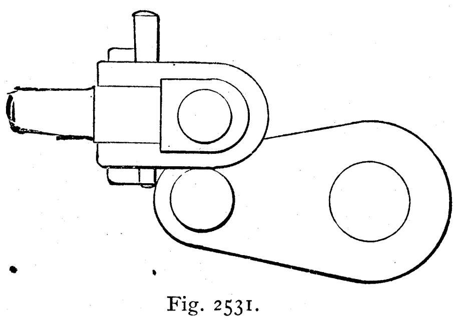


Fig. 2531.

hence it follows that the connecting-rod brasses should be properly fitted to their journals, and made to lead true before using the rod to line the engine by. In some cases it is more convenient to connect the rod at the cross-head end, and try the other end with the crank-pin journal, as shown in Fig. 2531. In this case, however, the connecting rod will (whenever the axial line of the crank shaft is out of square, forming an acute angle with the centre line A A, as in Figs. 2529 and 2530), fall laterally inside the crank-pin journal when on one dead centre, as in Fig. 2531, and outside when on the other dead centre, as in Fig. 2532, the respective amounts of error being in this case equal for the two positions. The reason for this is that the plane of revolution of the crank pin falls outside of the centre line in one case, and inside for the other, as shown in Fig. 2530 at D C.

If the axis of the crank axle formed an obtuse angle to the engine centre line A A in Fig. 2529, the connecting-rod end tried with the crank pin, as shown in Fig. 2531, would fall outside of

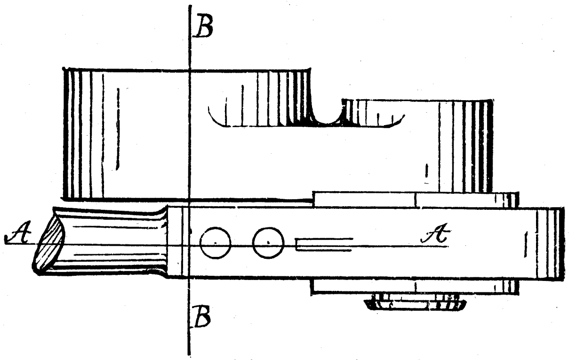


Fig. 2532.

the crank-pin journal when the latter was on the dead centre nearest to the cylinder, as shown in Fig. 2534, and inside of the crank-pin journal when on the other dead centre, as in Fig. 2535.

Now, suppose either of the errors to exist, and the alignment

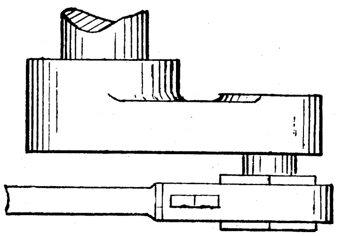


Fig. 2533.

be neglected, then if the brasses at each end be keyed up to fit their respective journals, then the body of the rod must be bent into a bow shape, and the strain of forcing or springing it into this shape will fall upon the journals, which will heat and pound in consequence.

It is now to be explained how to test if the axial line of the crank shaft is at a right angle to that of the cross-head journal, when viewed from the crank-shaft end and horizontally.

From a want of parallelism in this direction, heating of the crank pin and cross-head journals is *sure*, and a pound or thump is, to some extent, liable to occur, and the cause, if the error is slight, is difficult to discover, save by using the connecting rod to test it with.

When a thump occurs at the end of the stroke (when the crank is on a dead centre), it may arise from a ridge at the cylinder, or at the guide-bar end, or from the connecting-rod brasses being

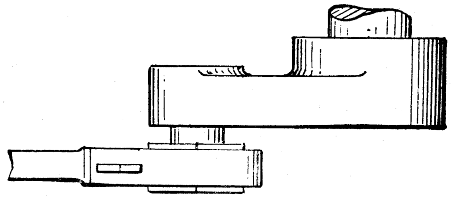


Fig. 2534.

insufficiently keyed up; but when it occurs while the crank is at half stroke these causes are eliminated, and the cause must be looked for in either a crank pin not parallel to the crank shaft, or, as in the case now under consideration, because of one or the other of the crank-shaft journals being too low.

Assuming the crank pin and crank shaft to be axially true, one

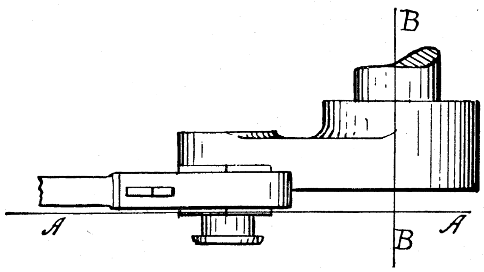


Fig. 2535.

with the other, we may proceed to show separately the cause of the heating and that of the pounding, if the crank journal is too low at either end.

In Fig. 2536, let A represent the cross-head journal, and B B a line parallel to it. Let B C represent the axial line of the crank shaft (being out of parallel because the crank end is too high or the other end too low). Let F F represent the centre line of the crank pin when at the top, and G G when at the bottom of its path of rotation, and it will be observed that the vertical distance between the crank pin and the axial line of the cross-head journal

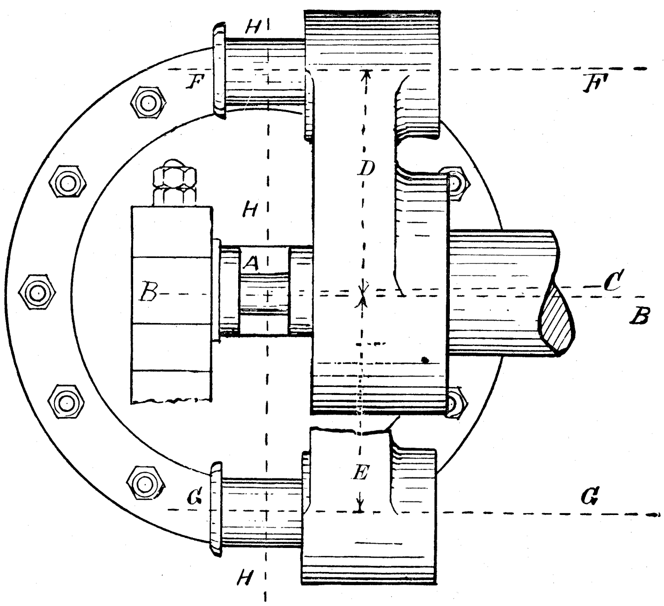


Fig. 2536.

is less on one side than on the other; thus in the figure distance D is less than E. We have in this case measured these distances on a plane at a right angle to the cross-head journal, but it will make no difference if we measure them on a plane with the path of rotation of the crank pin, as will be seen in Fig. 2537, in which the distance from the centre of the crank pin at two opposite points in its path is represented by dots shown at E F, and from E to H measures less than from F to H, H representing the centre of the cross-head journal.

In Fig. 2537, let A represent the axial line of the cross-head

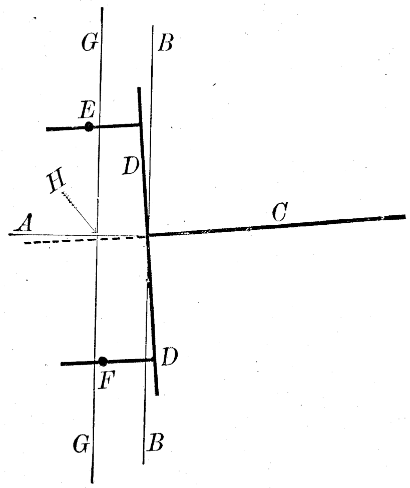


Fig. 2537.

journal, B a vertical line at a right angle to A; C representing the crank shaft extended by a dotted line, so as to enable comparison with A; D the crank, E and F the centre of the crank-pin journal, and G G a line at a right angle to cross-head journal A.

Now G, being at a right angle to A, represents what should be the plane of rotation of the crank pin, whereas C, being out of parallel with A, causes the path of rotation to be in the path from

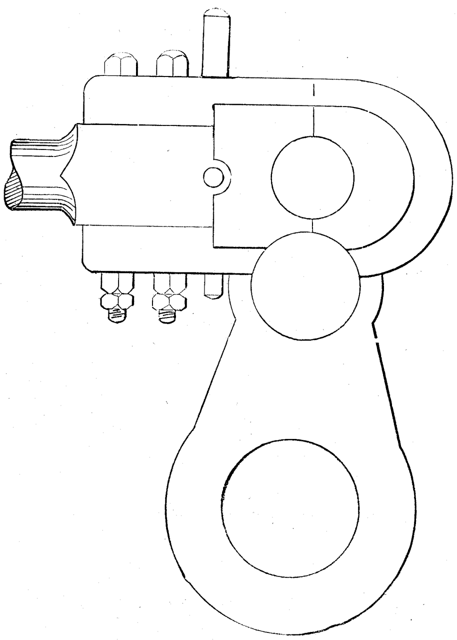


Fig. 2538.

E to F, or as D compared to B; supposing then that the bores of the connecting-rod brasses to be axially parallel one to the other, and keyed up properly, and when at E one bore of those brasses will stand parallel to E while the other is parallel to A, or when at the bottom of the crank rotation, one bore will be parallel to F and the other parallel to A. Thus the rod will be twisted, and the strain due to this twist will cause the bearings to heat. That this twisting is continuous throughout the whole revolution may be seen by the want of parallelism of the dotted line (representing the crank pin when on the dead centre) with A (representing the cross-head journal).

It is now to be observed that if the plane of the crank rotation were at a right angle to the axis of the cross head, as it should be, the path of the centre of the crank-pin journal would be in the plane of G G, whereas it falls outside as at E, and inside as at F, while at H it is coincident; hence it appears that starting from a dead centre H, the rod bends, passing at that end outward to E (when the crank has made a quarter revolution), where it attains its maximum bend, thence diminishing until finally ceasing, when the crank reaches the other dead centre. As soon, however, as it passes the last dead centre a bend in the opposite direction takes place, attaining its maximum at F, and ceasing at H. This bending also causes undue friction and the consequent

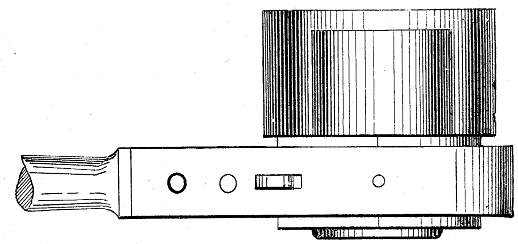


Fig. 2539.

heating of the journals; furthermore, if there be any *end* play between the brasses and the journals, there will be a pound, as the brasses jump from one end of the journal to the other at different parts of the stroke. It is obvious that if the crank end of the crank shaft was too high instead of too low, as in our example, then the effects would be the same, but E would fall on the inside instead of the outside of G, while F would fall outside instead of inside.

To discover if the crank shaft is out of parallel in the direction here referred to, connect the connecting rod to the cross-head journal, setting the brasses up to a close working fit. At the other end of the connecting rod put the strap keys and brasses in their places, but not on the crank-pin journal. Place the crank in its highest position, and lower the end of the rod down to the crank-pin journal, as shown in Fig. 2538, and if the crank shaft is parallel (in the respect here referred to) to the cross-head

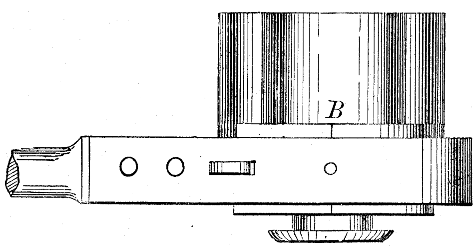


Fig. 2540.

journal, the brass flanges will just meet the faces of the crank-pin journal, as shown in Fig. 2539. If, however, the crank end of the crank shaft is too low, as in our example, the flanges of the brasses will fall to one side of the crank-pin journal, and that side will be toward B, Fig. 2540, when the crank pin is at the top, and toward C, Fig. 2541, when it is at the bottom of its path of rotation.

The effects will be precisely the same, and in the same direction with relation to the various parts of the crank's revolution, if the crank-pin end of the shaft was of correct height; but the other end was too high, hence, in correcting the error, it is desirable to place the engine on the dead centre, so as to determine which end of the shaft to operate on – that is to say, whether to raise the crank-pin end or lower the other end. But suppose the error to be that the crank-pin end of the shaft was too high instead of too low, then, the testing being continued as before, the effects will be of the same general character, but altered with relation to the specific parts of the revolution. Thus, when the crank is at the bottom, the rod would fall towards A, Fig. 2542, and when at the top, it would fall in the opposite direction—that is, towards D, Fig. 2542.

We now come to one of the most common errors in the alignment of the parts of an engine, and to the one that it is the most difficult to locate or discover, namely, a want of parallelism between the axial line of the crank pin and that of the crank shaft.

This generally arises from improper methods in the chucking of the crank to bore it, or from errors induced in fastening the crank to its shaft. The results are precisely alike in both cases, supposing, of course, the errors to exist in the same direction in the two cases.

The error in chucking usually consists in planing one surface of

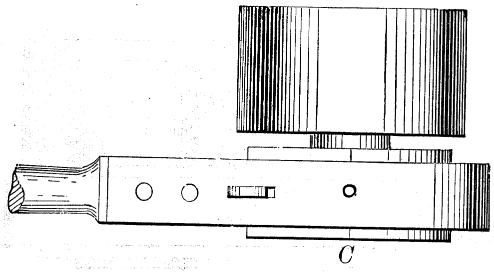


Fig. 2541.

the crank, and bolting the planed surface against the chuck to bore both crank holes. In this case the crank holes will be out of true to twice the amount the lathe face plate may be out of true, and to whatever amount the crank may alter its form from having its surface metal removed.

To avoid these errors the large bore and its hub face should be turned at one chucking, and this hub face should be bolted to the face plate for the second chucking, the small end swinging free, except in so far as the ends of the plates may touch against it to steady it.

The error in putting the crank on may occur from the key springing the crank out of true, and if the crank is shrunk on from too great an allowance for shrinkage or improper heating for the shrinkage or contraction, as it is sometimes termed. Referring to the error in keying, it is more liable to occur when the crank bore and its seat upon the shaft are made taper, than when made parallel, because it is a difficult matter to insure accuracy in the fit of the

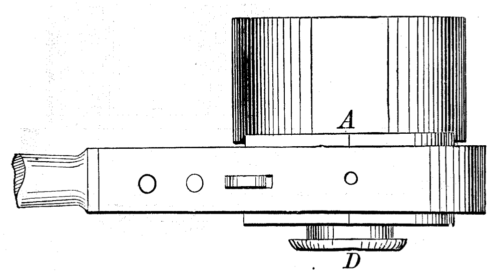


Fig. 2542.

taper, and the key pressure will spring the crank over on the side at which it is the easiest fit. In Fig. 2543 let A represent the end of the crank shaft; B the key, and C the crank shown partly in section: suppose the crank bore (whether made taper or parallel) has a slightly easier fit on the side D than on the side E, and the pressure of the key (supposing it to fit properly top and bottom) would spring the crank over in the direction shown in the figure, the axial line of the crank pin standing at the angle denoted by the line F, instead of parallel to the axial line of the shaft. Suppose the crank to be put on by hydraulic pressure, and the key to fit on the sides and not on the top and bottom, then its fit to its seat on the shaft would depend on the truth and smoothness of its bore and seat on the shaft, the amount allowed for the forcing fit and the amount of the error. If the latter amount was so small that the crank would fit at both ends, but simply fit tighter at E E than at D, the crank would remain true, but might possibly get loose in time. This would be especially liable to occur if the tool marks on the bore and seat were so deep that the contact was mainly at the tops of those marks or ridges which would be apt to compress. But if the surfaces were cylindrically true and smooth, and the amount allowed for forcing was sufficient as stated to give the bore and seat contact at D, with a key fitting sideways, the crank would probably remain tight and true.

Were the bore and its seat parallel the crank would remain true,

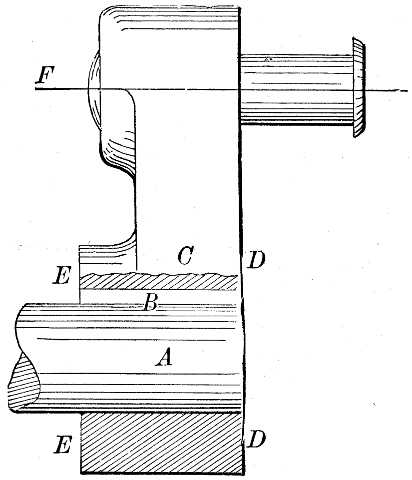


Fig. 2543.

no matter whether the key fitted on the sides or at the top and bottom, providing the key fitting top and bottom were bedded fairly from end to end.

When the surfaces are not smooth, but contain tool marks or ridges, an unequal pressure of the key at one end, as compared to the other, sets the crank over, as shown in the figure, because the key pressure compresses the ridges and lets the crank move over.

Supposing the strain of the key, or keys, to be depended upon to hold the crank, they must fit top and bottom, and their accurate fit becomes of the first importance; because not only is it necessary that they fit equally at each end, but they must also fit equally across the width of the key at each end. For example, in Fig. 2544 is a key binding most at the opposite corners, as denoted by the

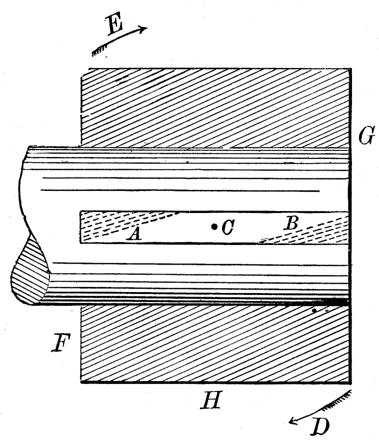


Fig. 2544.

dotted surfaces A B, and the result will be that the key pressure would tend to twist the crank in the direction of D E, having C as a centre of motion, providing that the error was equal at A and B; but in proportion as the error was greatest and the fit tightest at A, or at B, would the centre of motion be moved nearer to either point.

Supposing now that the crank is to be shrunk, or contracted on, then the points of consideration are (supposing the crank to fit properly to its seat, whether the same be either parallel or taper) that the hub of the crank opposite to the throw is the weakest and is likely to give most in the process of contraction, so that if one part (as F) of the crank be made hotter than another (as G) it will give way more, and this will twist the crank. This is specially liable to occur if an excessive amount of difference in the bore and seat diameters has been allowed for contraction.

It may not happen that a crank pin is out of truth in a direction in which the error will show plainest when the crank is on its dead centres, or at half-stroke; but if a crank pin, tested in those four positions, fails to show any error when tested by the connecting rod, it will be true enough for all practical purposes, and true enough to avoid heating and pounding, both of which evils accompany an untrue crank pin. Suppose, now, that a crank pin stands out of true in the direction shown in Fig. 2545, in which A A represents

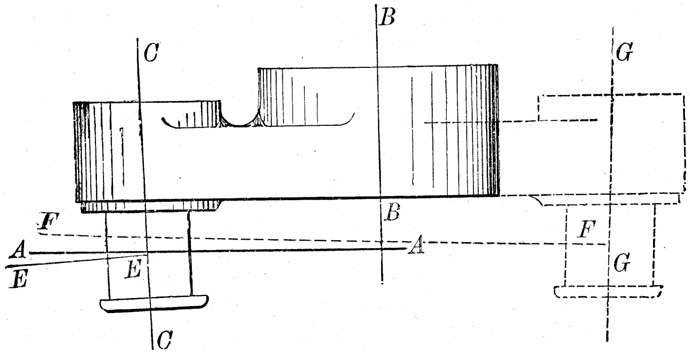


Fig 2545.

the axial line of the cylinder bore prolonged, and B B the axial line of the crank shaft (the two being parallel or in proper line). Let E E represent the centre line of the connecting rod when the crank is on one dead centre, the axial line of the crank pin being at C C. Then the brasses being keyed up to fit the crank pin, the centre or axial line of the connecting rod would stand as denoted by E E. But the brasses at the other end of the rod being keyed up to fit the cross-head journal, and their lines being at a right angle to the line A A, we have that the rod is at that end endeavored to be held parallel to A A; hence, keying up the connecting-rod brasses on the crank pin would tend to bind the rod, one end standing parallel to A A, and the other parallel to E E.

This would place great strain on the outer radial face of the cross-head journal, as well as on the cylindrical body of the journal.

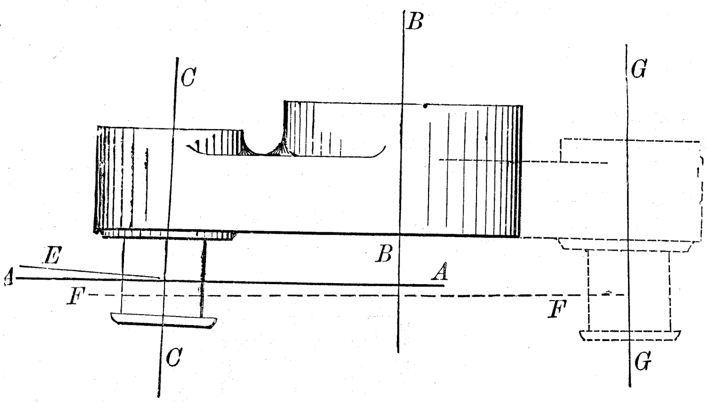


Fig. 2546.

When, however, the crank pin arrives at the opposite dead centre, as denoted by the dotted lines in Fig. 2545 (G G representing its axial line, and F F the centre line of the connecting rod at a right angle to G G), the want of truth in the pin throws the cross-head end of the connecting rod against the inside face of the cross-head journal. Hence, twice in each revolution is the connecting rod bent, and twice does it jam from side to side of the cross-head journal.

It may now be pointed out that if we take either dead centre singly, and connecting the rod at the crank-pin end, try it at the cross-head end, and it will be a difficult matter to determine whether any want of truth at the latter end is caused by the crank pin being out of axial truth, or whether it is the crank shaft itself that is out of line. But there is this difference between the two cases. When the error is due to want of alignment in the crank shaft, the connecting rod will show the error *on the same side* of the cross head, no matter on which dead centre the crank pin stands; but when it is due to the crank pin, the rod will fall inside the cross head on one dead centre, and outside when tried on the other dead centre, as is shown by the respective lines E and F, in Fig. 2545; E being at a right angle to C, and F at a right angle to G.

Again, it has been shown that when the shaft was out of line, a point on the crank-pin journal passed outside of the cylinder centre line at one dead centre and inside at the other; but when the pin is axially out of parallel, the path of a point on its journal will remain in the true plane, as is shown in Fig. 2546, the point being taken at the intersection of E and C C. A A represents the path of rotation of the same, which is parallel to the true face B of the crank.

From the angle of the axial line of the pin being in opposite directions, when on opposite dead centres to the axial line of the crank shaft, the bore of the brasses cannot wear to suit the error, which, therefore, only diminishes by the wear of the crank pin. Suppose the error to be $\frac{1}{64}$ inch in a crank-pin journal 3 inches long, and that the connecting rod is 6 feet long, the error at the cross-head end of the rod will amount to $\frac{3}{8}$ inch.

In Fig. 2546 the error is shown to exist in an opposite direction, throwing the rod to the other side of the cross-head journal. But, in this case, the crank, when on the dead centre nearest to the engine cylinder, throws the connecting-rod end against the inside face of the cross-head journal, as denoted by the line E, which is on the opposite side of A A to what it is in Fig. 2545. Again, when

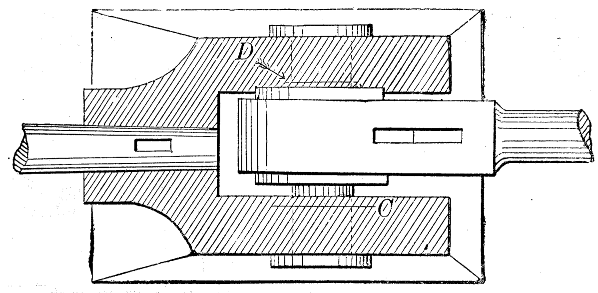


Fig. 2547.

on the other dead centre, the line F F, in Fig. 2546, falls *outside*, while F F, in Fig. 2545, falls *inside* of A A, and it is by this difference that we are enabled to know in which direction the crank pin is out of true. To find the amount to which it is out of true in the length of its journal, place the crank on one dead centre, and with the connecting-rod brasses keyed up firmly home on the crank pin, and the other end of the connecting rod entirely disconnected from the cross head, mark on the latter a line coincident with the side face of the rod end, as at D, Fig. 2547. Then, with the crank pin placed on the other dead centre, mark another line on the cross head, coincident with the other side face of the rod, at C, Fig. 2547. Now, suppose that the line D shows the rod to fall $\frac{3}{8}$ too much on that side, and line C shows it to fall (when on the other dead centre) $\frac{3}{8}$ too much on the other side of the journal, and that the length of the rod is 6 feet, while that of the crank-pin journal is 3 inches, then the latter, divided into the former, gives 24, and this sum divided into the $\frac{3}{8}$, the rod end falling out of true at C and D, Fig. 2547, gives us $\frac{1}{64}$-inch as the amount the crank pin stands out of true in its length; hence, to correct the error, we may file on the crank pin a flat place at each end, as shown in Fig. 2548 by the lines C D, and then file on the top and the bottom of the crank pin a flat place B, $\frac{1}{128}$-inch deep, and of equal depth all along the journal; by then filing the crank pin round and bringing the flat places just up to a circle, we shall have reduced the diameter of the crank pin by $\frac{1}{64}$ inch, and have made it axially true with the cross-head journal. It is important, however, to bear in mind that, in this case, the crank pin is supposed to be out of true in the direction shown in Fig. 2545, and to stand axially true with the cross-head journal, when the crank is placed at half stroke, top and bottom, the crank shaft being in proper line.

If the axial line of the cross-head journal stands truly horizontal, the flat places on the crank pin may be filed horizontally level, with the crank placed on the corresponding and respective dead centres. But as the length of the cross-head journal is so short, it is difficult to gauge, if it does stand axially exactly horizontal,

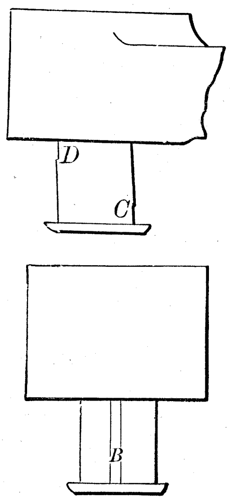


Fig. 2548.

hence it is better to try the rod, or follow the above directions; especially as the cross-head journal and crank shaft may be in line without being axially horizontal.

Suppose now that the axial line of the crank pin stands true with that of the cross-head journal when the crank is on either dead centre, but out of true when at the top and bottom half stroke.

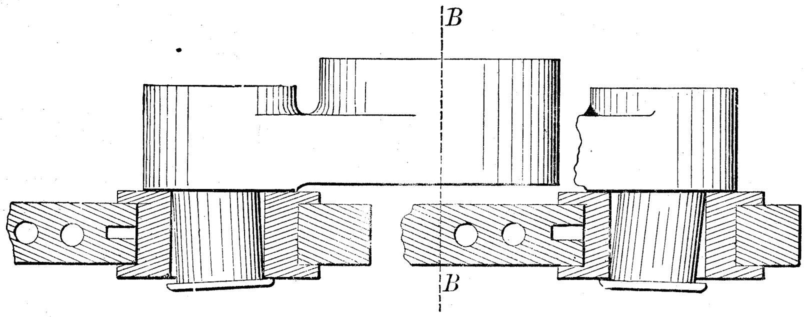


Fig. 2549.

The connecting rod, connected as before, and tried with the cross head, will fall first to one and then to the other side of the cross-head journal, and the direction in which the crank is out of true may be known from the position of the crank pin when the error shows itself.

If the error exists to an extent that is practically measurable, a pound in the journals, as well as their heating, is the inevitable result. In Fig. 2549, for example, the rod end is shown in section, and it will be noted that the error being in the direction there shown, and the crank pin in the respective positions there shown, the brass bore only contacts with the journal at each end, and that the diameter of the bore of the brasses is greater than the diameter of the crank-pin journal to *twice* the amount the crank pin is out of line. Now let us place the crank at the top of its revolution, as in Fig. 2550, and as its axial line then stands parallel to that of the cross-head journal, the brass bore is too large to fit the crank-pin journal and there is lost motion.

From the time the crank pin passes the dead centre this lost motion increases in amount until it becomes sufficiently great to slam the rod over against the side of the cross-head journal, while at the same instant the crank pin pounds in the connecting-rod brasses. At what precise part of each quarter crank revolution this action will occur, depends upon the amount the crank pin is out of line; but the more it is out the nearer to the dead centre it will be, and, conversely, the nearer true it is the nearer the crank will approach its highest and lowest positions before the pound takes place. If it is attempted to key up the brasses so as to spring the rod and let them close along the journal, the brasses will heat in proportion to the amount of error; hence when the crank pin pounds with the brass properly adjusted, and heats while keyed up enough to stop the pound, the crank pin is out of true.

To test the alignment of an engine with stretched lines take out the piston and rod, and take off the connecting rod, then fasten a piece of iron at the open end of the cylinder so that it will hold a stretched line true with the axis of the cylinder bore. Provide at the crank end of the engine bed a fixed piece of wood to hold the other end of the line, and then with a piece of wire as a gauge set this line (tightly stretched) true with the cylinder bore. Then place the crank pin at the top of its path of rotation and drop a plumb line from the centre of its journal length, and this line should, if the crank shaft is horizontally level, just meet the stretched line. If it does not do so place a spirit-level on a parallel part of the crank shaft, and if the shaft is not level it should be made so, and so adjusted that the line from the centre of the length of the crank-pin journal just meets the stretched line from the cylinder bore.

To test if the axial line of the crank shaft is at a right angle to the cylinder bore axis move the crank pin nearly to its dead centre, and measure the distance from the middle of its length to the stretched line. Then move the crank pin over to nearly the opposite dead centre, and (by means of the plumb line) measure the distance of the plumb line from the stretched line. To be correct the plumb line from the crank pin will during this movement just touch the stretched line.

To test if the stretched line is fair with the centre of the crank shaft place a square on the end of that shaft and even with its centre, and the blade should then just meet the stretched line.

The edges of the guide bars may also be tested with the stretched line, and the top and bottom of the guide-bar flanges may be tested to prove if the bars are of the correct height.

To further test the bars place a spirit-level across them and lengthwise on them.

If the piston rod and connecting rod are in place the alignment may be tested as follows: Let the piston rod be as far out of the

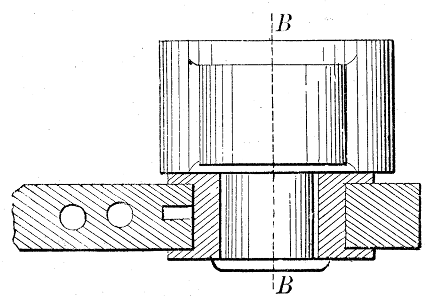


Fig. 2550.

cylinder as possible, and stretch a line to one side of it, just far enough off to clear the guide bars, &c. Set this line as follows: Let it be in line with the rod as sighted by the eye when standing some few feet away from it but horizontally level with the centre of the rod, set it parallel to the rod with a rule or its equivalent.

Then the centre of the crank-pin journal should measure from the stretched line, the distance of the line from the piston rod added to half the diameter of that rod. This test, however, is not very accurate on account of the difficulty in setting the line, and because the piston rod may not have worn equally on each side.

SETTING SLIDE-VALVES.—An engine slide-valve may be so set as to accomplish either one of three objects. First, to give equal lead for each stroke; second, to cause the live steam to be cut off and expansion to begin at an equal point in each stroke; and third, for the exhaust to begin at an equal point in each stroke.

If we set the eccentric so that the exhaust will begin at corresponding points for the two strokes, the valve lead will not be equal, and the exhaust opening will be greater when the piston is at one end of the cylinder than it will be when the piston is at the other end.

If the eccentric be set to cut off the steam at corresponding points for the two strokes, then the lead, the admission, and the exhaust of the steam at one port will differ (with relation to the piston movement) from that at the other. It is generally preferred to set the eccentric so as to give equal lead for the two ports when the piston is at the respective ends of its stroke, which gives an equal amount of exhaust opening when the piston is at the respective ends of its stroke.

The only operations properly belonging to the setting of a slide-valve are those of finding the true dead centres of the crank pin, and setting the eccentric to give the valve the desired amount of lead. It is generally found, however, that the length of the eccentric rod requires a little correction, and as this must be done before the eccentric can be set, the setting operations should be conducted with a view to making the correction as early as possible.

In many of the instructions given by various writers it is directed to first square the valve, which is to attach the parts and move the engine crank, or fly-wheel, through one revolution, to ascertain if the valve moves an equal distance on each side of the centre of the cylinder ports, correcting the length of the eccentric rod until this is the case. This is an error, because on account of the angle of the eccentric rod the valve does not, when set to have equal lead at each end of the stroke, move an equal distance on each side of the cylinder ports, but travels farther over the port nearest than it does over that farthest from the crank.

When the travel of the valve is equal to twice the width of the steam port, added to twice the amount of steam lap, the valve does not fully open the farthest port from the crank. When the valve-travel is more than this amount both ports may open fully, but the error due to the unequal valve-travel from the angularity of the eccentric rod is increased. That the amount of error induced by squaring the valve is appreciable, may be seen from the fact that with $1\frac{1}{4}$ inch steam ports, $\frac{3}{4}$ inch steam lap, and $4\frac{1}{2}$ inches of valve-travel, it amounts to about $\frac{1}{8}$ inch with an eccentric rod 4 feet long. As the eccentric rod has (if a solid one, as in the case of a locomotive) to be operated upon by the blacksmith to alter its length, and requires some accurate setting for alignment after having its length corrected, it is obviously preferable to obtain its exact length at once. This may be done with less work than by the squaring process, which is entirely superfluous.

Assuming, then, that all the parts are properly connected and oiled, the valve is set as follows: Upon the face or edge of the fly-wheel an arc, true with the centre of the wheel, should be drawn, as at A B, in Fig. 2551, marking it on opposite sides of its diameter and opposite to the crank pin P. The engine should then be moved in the opposite direction to that in which it is to run, until the guide block I is very near its full travel. A straight-edge must then be placed to bear against, or be coincident with, the end face of block I, and held firmly while a line is drawn across the edge of the guide bars, as shown at C. There should then be fastened to the floor (which must be firm, and not give under the engineer's weight), a piece of iron W, having a deep centre-punch mark, or its equivalent. A steel tram-rod T, pointed at each end, is then set in the centre-punch mark at W, and with the upper end D a line made across the wheel edge or face. The fly-wheel must then be moved so that the crank passes the dead centre, the guide block moves back and away from the line C, and then approaches it again. When the end of the guide block is again coincident with the line C, the tram should be set as before and a second line, F, marked on the fly-wheel rim, and from these two lines, D and F, the crank may be placed upon its true dead centre as follows:—

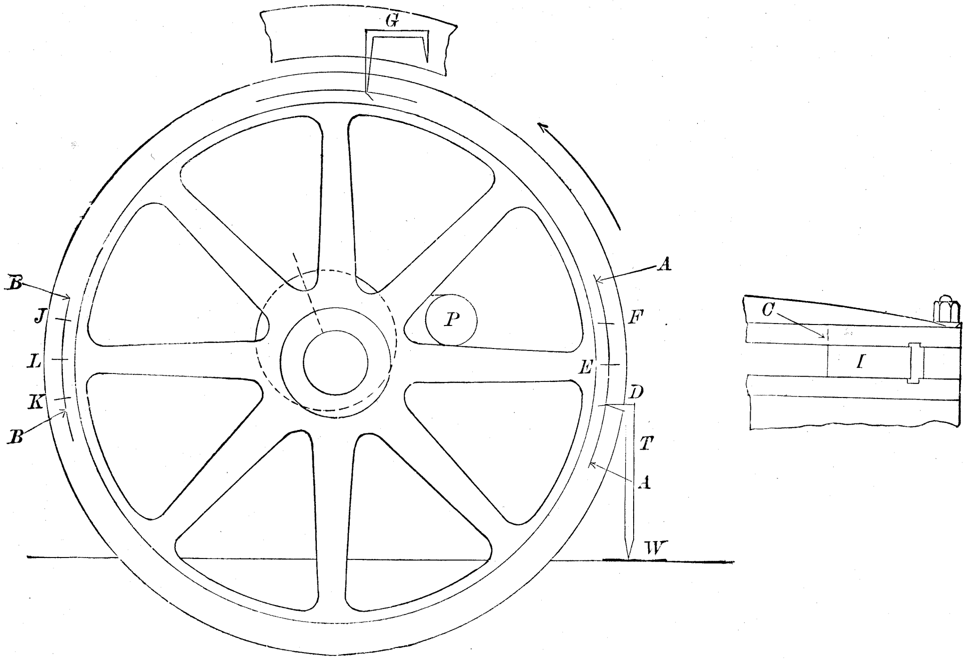


Fig. 2551.

In Fig. 2552 a section of the fly-wheel rim is shown (enlarged for clearness of illustration); from the lines D, F the centre E is found, and marked with a centre-punch dot to define it. It will be obvious, then, that if the fly-wheel be moved until this line and dot come fair with the upper edge of the tram T, the guide block will be at the exact end of its travel, and the crank, therefore, on its dead centre. By a similar operation performed with the guide block at the other end of the guide bars, and with lines on the other side of the wheel rim (as shown at B, J, K), the other centre L may be found. In obtaining these centres, however, a question arises as to the direction in which the wheel should be moved for bringing the guide block up to the lines at C, and for marking the

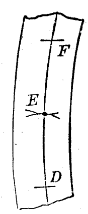


Fig. 2552.

lines D F and J K, or for bringing E or L true with the tram point. If the fly-wheel be moved in the opposite direction to that in which the engine is to run, the cross-head journal and crank pin will bear against the boxes of their brasses in the direction in which they will have contact when the engine is running. Suppose, for example, that the top of the fly-wheel when the engine is in motion moves from the cylinder, then the cross-head and crank-pin journals, driven by the piston, will bear against the half-brass nearest to the cylinder, which, *when the force-producing motion is applied to the fly-wheel instead of to the piston* will be the case when the fly-wheel is moved in the opposite direction. By moving the fly-wheel in an opposite direction to that in which the engine is to run, the lost motion in the journals and bearings is therefore taken up in the proper direction so far as the connecting-rod brasses are concerned, and any lost motion between them and their journals will not impair the set of the valve, as would be the case were the fly-wheel moved in the direction in which it is to run.

But by moving the fly-wheel backwards the play in the eccentric and in all the joints between it and the valve spindle is up in the wrong direction, because the power to move the rods is being applied in the opposite direction to that in which it will be applied when the engine is running, and, therefore, the play motion of the jointed or working parts will cause a lost motion impairing the set of the valve.

Now there are generally more working parts between the eccentric and the valve than between the crank pin and the piston, and hence more liability for lost motion to exist, and it follows that in such case it is better to move the engine in the direction in which it is to run.

It may be remarked, however, that the play may be taken up in the proper direction in both cases, and the engine be brought upon its dead centre, by moving it in the opposite direction to that in which it is to run, and that in setting the eccentrics they be moved on the shaft in the direction in which the engine is to run, as forward for the forward eccentric, and backward for the backward one (assuming the engine to have a link motion, and, therefore, two eccentrics).

It is obvious that any other resting place may be used instead of the floor for the tram; thus in a locomotive the wheel guard may be used, the tram T being used to mark lines on the upper part of the wheel rim, instead of opposite the crank. To set the valve, place the fly-wheel on its dead centre, moving the fly-wheel as directed until one of the points (E or L, say E) comes fair with the point of the tram; then move the eccentric on the shaft until the steam port is open to the required amount of lead, and fasten the eccentric to the main shaft. Next move the fly-wheel around until on the opposite dead centre, and if the lead is the same in amount for both ports the valve is set. Suppose, however, that in this last case the lead is too great; then it shows that the eccentric rod is too long,

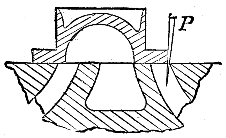


Fig. 2553.

and it must be shortened to an amount equal to half the difference in the lead. Or suppose that the lead when the wheel was tried on the last dead centre L, was less than for the other port; then the eccentric rod must be lengthened to half the amount of the difference. Assuming that the rod was too long by $\frac{1}{32}$ of an inch, then it may very often be shortened by simply heating about six inches of its length to a low red heat, and quenching it in water. If the rod has a foot which bolts on a corresponding foot on the eccentric, then to lengthen it a liner of the requisite thickness may be placed between the two feet.

Suppose there is an equal amount of lead at each end but the amount is not sufficient or is too great: then the eccentric must be moved on the shaft until the proper amount of lead appears at the port. The lead must then be again tried at the other dead centre. In moving the eccentric, however, it must, under all conditions, be moved in the direction in which it will rotate, for reasons already given. The best method of measuring the lead where the lines on a rule cannot be seen is with a lead wedge P, as shown in Fig. 2553; this, if slightly forced in, will mark itself, showing how far it entered.

In some practice the position of the valve is transferred to the valve stem outside of the stuffing box or gland, as shown in Fig. 2554, sectional view. The valve stem being disconnected from the rod or arm that drives it, the valve is moved by hand to have the proper lead, as at A; a centre-punch mark is then made outside the stuffing box and a tram B rested thereon; with the other end of the tram a mark C is made on the valve stem. A similar mark is made on the stem when the crank is on the other dead centre, and the tram and marks, applied as shown, are employed instead of measuring the lead at the ports themselves. This involves extra work, but gives no more correct results. It involves marking lines on the valve stem, which is objectionable. If several trials have to be made there is a confusion of lines on the valve stem, and the

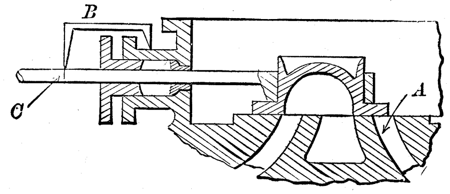


Fig. 2554.

wrong one is apt to be taken. On the other hand it affords a facility for setting the valve without having the steam chest open, which may in some cases be desirable. If this plan be adopted the lines on the valve rod should not be defined by centre-punch marks, for they will cut the packing in the stuffing box.

When the eccentrics are secured to the shaft by a set-screw only, and not by a feather, it is an excellent plan, after they are finally set, to mark their positions on the shaft, so that if they should move they may be set to these marks without moving the engine around.

For this purpose take a chisel with the cutting end ground to the form of a fiddle drill, one cutting edge being at a right angle to the other. The chisel must be held so that while one edge rests upon the axle, the other edge will bear against the radial face of the eccentric. A sharp blow with a hammer upon the chisel head will make a clean indented cut upon the axle and the eccentric, the two cuts exactly meeting in a point where the eccentric bore meets the axle circumference, so that when they coincide the eccentric is in its proper position.

If the eccentrics of a locomotive should slip when the engine is upon the road, and there are no marks whereby to readjust them, it may be done approximately as follows:—Put the reverse lever in the end notch of the forward gear, then place the crank as nearly on a dead centre as the eye will direct, and open both the cylinder cocks, then disconnect the slide-valve spindle from the rocker arm, and move the valve spindle until the opening of the port corresponding to the dead centre on which the crank stands will be shown by steam blowing through the cylinder cock, the throttle valve being opened a trifle. The position of the valve being thus determined, the eccentric must be moved upon the shaft until the valve spindle will connect with the rocker arm without being moved at all. The throttle valve should be very slightly opened, otherwise so much steam will be admitted into the cylinder that it will pass through any leak in the piston and blow through both cylinder cocks before there is time to ascertain which cock first gives exit to the steam.

Instead of finding when the crank pin is on the dead centre by means of the process shown in Fig. 2551, it may be found as in Fig. 2555, which is for a vertical engine. On the face of the crank and from the centre of the crank shaft as a centre, draw a circle B equal in diameter to the diameter of the crank pin. Then take a spirit-level C and apply it to the cylinder bore and note where its bubble stands. Then apply the spirit-level to the perimeter of the crank pin A and circle B, and move the crank until the spirit-level bubble stands in the same position as it occupies when applied to the cylinder bore. If the cylinder bore stands truly vertical the bubble will in both cases stand in the middle of the spirit tube; but in any event, the bubble must stand in the same position when applied to the crank as when applied to the cylinder bore, in which case the crank will be on its dead centre whether the cylinder bore be horizontal, vertical, or at an angle, the dotted line E passing through the centre of the crank and the axis of the cylinder bore.

When an engine has two eccentrics, so as to enable the engine to run in either direction, as in the case of a locomotive, it is necessary to consider which eccentric is to be set for the forward, and which for the backward motion. In American locomotive practice it is usual to let the eccentric nearest to the wheel, and, therefore, the most difficult to get at, be for the backward motion, which is the least used, and therefore the least liable to get loose upon the axle.

The eccentric that connects to the top of the link is usually that

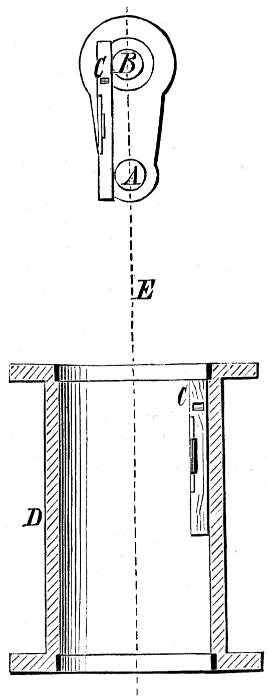


Fig. 2555.

for the forward motion, and hence that which connects with the eccentric farthest from the wheel.

In testing the lengths of the eccentric rods, work may be saved after the engine is first placed on its dead centre by putting the reverse-lever in the forward notch of the link, and adjusting the forward eccentric until the valve has the proper lead. Then set the reverse-lever in the back notch and move the backing eccentric (in both cases moving them in the direction in which they will run), until the proper amount of lead appears. The engine may then be placed on the other dead centre, and the lead both for forward and backward gear measured, so that if there are any errors both the

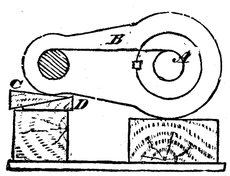


Fig. 2556.

rods may be corrected for length ; but for the final trial the crank pin must be set on its dead centre for each direction of motion separately, so as to take up any lost motion in the connecting-rod brasses.

In the case of large marine engines it is not practicable to move or rotate the engines to set the valves, and the eccentrics are therefore adjusted to their positions on the crank shaft by lines before the crank shaft is put into its place or bearings. First, the throw of the crank is set to stand horizontally true by the following method : From the centre of the crank shaft strike a circle of the diameter of the crank pin, as shown in Fig. 2556, at A, and draw upon the face of the crank a line that shall just meet the two circles as denoted by the line B, using a straight-edge, one end of which rests upon the crank pin, while the other end is coincident with the perimeter of the circle A.

By means of the wedges shown at C D adjust the crank until the line B stands horizontally level, tested by a spirit-level. A straight-edge having straight and parallel edges is set horizontally level,

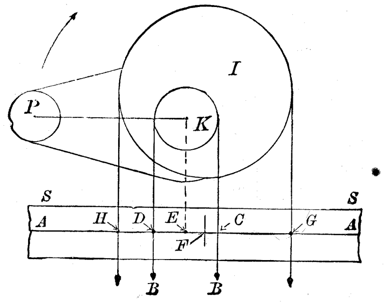


Fig. 2557.

beneath the eccentric, so that its edges will stand parallel with the throw line of the crank. On this straight-edge, and parallel to the edges, is marked the line A A, Fig. 2557. The first process is to mark on A A the centre of the crank shaft K, which is done as follows : Over K is placed the fine line B B, suspending the weights or plumb bobs at B B ; coincident with this line and across A A, are marked two lines C D ; midway between C D is marked E, which therefore stands directly beneath the shaft centre. From E the line

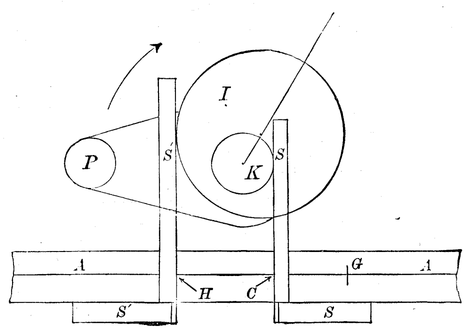


Fig. 2558.

F is drawn distant from E to the amount of lap added to the lead the valve is to have. From F as a centre two lines are drawn across A, their distance apart equalling the full diameter of the eccentric ; the plumb line is then placed over the eccentric, and the latter is rotated on the shaft until the plumb lines come exactly fair with the lines G H.

It is obvious that instead of using plumb lines a square may be

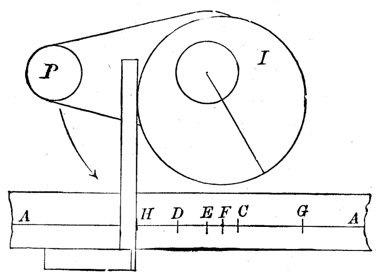


Fig. 2559.

employed to mark the lines C D, and to set the eccentric to the lines G H, the square being applied as at S and S′, in Fig. 2558.

In this example it has been assumed that the direction of crank rotation was to be as denoted by the arrow ; but, suppose the crank rotation required to be in the opposite direction, then the marks on the straight-edge would require to be located precisely the same, but the position of the eccentric throw-line would require to be as in Fig. 2559, the perimeter of the eccentric being set to the lines G H as before. The eccentric rod being supposed to connect direct to the valve spindle, without the intervention of a rock shaft, for if there is no rock shaft the eccentric leads in the direction of rotation, while if the engine has a rock shaft the eccentric follows the crank-

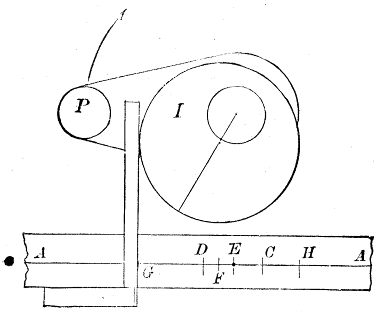


Fig. 2560.

pin in the direction of rotation, and F must be marked on the crank-pin side of E, as in Fig. 2560.

If two eccentrics are used, as in a link motion, the lines for setting one eccentric are equally applicable to both; the lap and lead line F being located on the crank-pin side of E when there is a rock shaft,

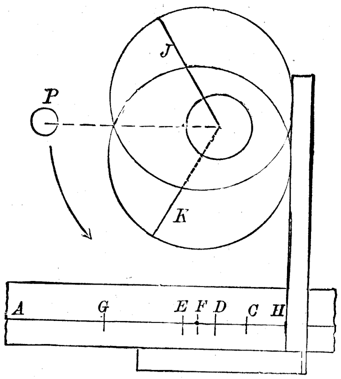


Fig. 2561.

as is supposed to be the case in Fig. 2561; and on the other side of E when there is no rock shaft; and in this case the eccentric that is to operate the valve to make the engine run forward must have its throw-line following the crank pin, as at J, in Fig. 2561; the eccentric K operating the valve for running backward. Conversely, in the

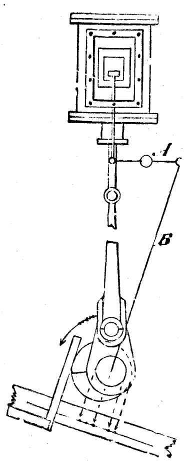


Fig. 2562.

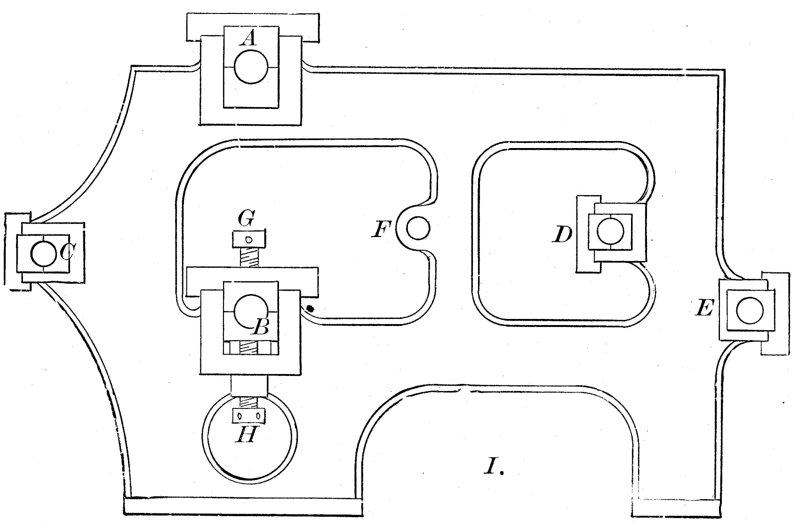


Fig. 2563.

absence of a rock shaft, the throw-line of the forward eccentric leads, while that of the backward eccentric follows the crank pin.

When the line of connection of the eccentric rod is not parallel to the axial line of the cylinder bore, the crank must be placed horizontally level (or if it be a vertical engine, on the dead centre), but instead of the straight-edge being placed parallel to the throw-line of the crank, it must be placed at a right angle to the line of connection of the eccentric rod.

Thus in Fig. 2562 the engine is supposed to be a vertical one, and the crank is, therefore, placed on its dead centre, its throw-line being vertical instead of horizontal as in our previous examples (which were supposed to be for a horizontal engine). It is also supposed to have a rock shaft A; hence the straight-edge is set at a right angle to the line of connection of the eccentric rod which is denoted by B.

It is obvious that to set the crank throw-line vertical the circle B

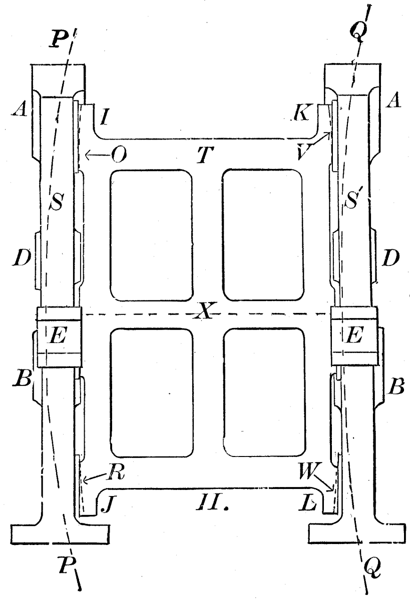


Fig. 2564.

in Fig. 2509 may be used, the spirit-level being resorted to to discover when the crank stands vertical.

An example in the erection or setting of framed work is shown in Fig. 2563, which represents a side elevation of a frame put together in four parts, two side and two end frames. A and B are journal bearings requiring to stand parallel and true one to the other, B being capable for adjustment in distance from A by means of the adjusting screws G, H. The bearings C, D, E, F, are to be parallel one to the other and to A, B. Their proper relative distances apart, and the axes of all the shafts, are to stand at a right angle to the side frames.

Fig. 2564 represents an end view of the frame, the ends T being bolted to the side frames S and S' at I, J, K, and L.

Now it is obvious that the ways for the bearings A, B, C, &c., may be trued out, ready to have the brasses fitted before the framework is put together, and that from their positions they would have to be planed out at separate chuckings; supposing, of course, the frame to be too large to be within the capacity of the machine table. It would be difficult to cut all the surfaces of the bearing ways to stand in the same plane, unless there were some true plane to which all might be made common for parallelism.

Furthermore, unless the surfaces where T is fastened to S and S′ are properly bedded to fit each other, bolting them up would spring and bend the frames out of their normal planes. To meet these requirements, there are given to the side frames a slightly projecting surface where the feet of T meet them, and furthermore, the feet of T themselves project beyond the sides of T as shown. These projecting pieces may therefore be planed to a common plane without planing the sides of the respective frames; and this plane should be as nearly as can be parallel with the body of each frame surface. The surfaces of the bearing ways may then be planed parallel to those of the projections, and the jaw surfaces true to the side surfaces, and all the bearing ways will stand true if the frames be properly set—when put together with the bolts. But unless the bedding surfaces at I, J, K, L, be made to bed and fit properly, the whole truth of the bearing ways and their distances apart across the framework may be altered. Thus, supposing the feet of T at I and J to meet S as denoted by the dotted lines O R, and whether the fault lie with the feet of T or with the projections on S the result will be that the pressure of the bolts holding I J to S will bend S so that its plane will be a curve as denoted by the dotted line P P, and the distances apart of the journal ways B B and D D respectively will be wrong, being too wide on account of the bend outward of S.

But the feet may touch on the opposite corners, the surfaces of S′ or of T being out of true or out of full contact, as denoted by the dotted lines V W on K, L; in this case the frame S′ would be bent to the curve Q Q, and the journal ways would be too close together.

On the other hand, the want of fit between these surfaces may be in the direction of the length of the frame instead of the direction of its height, as has been supposed; or it may be in one direction on one foot and in another direction on another foot. But in whatever direction it does exist, it will inevitably bend and twist the frame.

It must not be taken for granted, that because these surfaces have been planed or milled, that therefore they are true; because frames of this class cannot, if large, be held without springing them to some extent from the pressure of the bolts or other devices necessary to hold them to be cut.

It is not uncommon to plane the surfaces as true as may be, and put the frames together, bolting them up tight, and then applying the straight-edge trammel and rule to test the truth, correcting any error that may be found by inserting pieces of paper, sheet tin or material of requisite thickness on one side of the surfaces, so as to offset the error in their fit and bring the framing true; but this is not the proper way, because it reduces the area of contact, and furthermore renders a new testing and adjustment necessary whenever the frames are taken apart It is better therefore to apply a straight-edge to the surfaces and true them to it, testing them vertically as by placing the straight-edge across K L, and longitudinally across S′, at K and the corresponding projection at the other end of the frame, filing them until they appear true.

The holes through the frame may be drilled before filing these surfaces, so as to reduce the area to be filed. Since the end frames T do not in this example carry any journals or mechanism, the position of T is not so particular as it otherwise would be; hence, the holes in its feet may be marked off and drilled independently of the frame, the holes being drilled a little too small to allow for reaming with the holes in the frame. The framing will then be ready to put together (all machine work upon them being supposed to be done). The feet of all such frames should be planed true, so that the frame, when put together, may stand true and steady when placed upon a level floor or foundation, and in this case the distance and parallelism of the feet surfaces will be true with the ways or bearings, affording much assistance in holding the frame while putting it together. The height of the holes may be measured and marked from the feet surface, thus insuring truth as far as height is concerned. Lines may be drawn or marked on each side frame, at the proper distance from and parallel with the jaws of the ways A, B, thus completing on the side frames the marking of the location of the centres of the holes for bolting the end frames on.

If the frames were of a size to be sufficiently easily handled, the end frames might be put in their places, and the whole framework set true, so as to mark the holes in the end frames from those already drilled in the side frame. But if the use of a crane were necessary to lift them, it would be better to mark the holes on the end frames, and drill them before putting the framework together at all, leaving sufficient to ream out of the holes to bring them fair, notwithstanding any slight error in drilling them. In this case, a line denoted by the dotted line X in Fig. 2564, should be drawn across the frame, and the holes at I and J be made equidistant on each side of it, as well as the proper distance apart. X must be at a right angle to the trued foot surfaces at I J, so as to cause the side frames to stand vertical while their feet are horizontal.

Supposing now the holes to be drilled and the frames are to be bolted together, the whole frame may be held temporarily together by bolts passing through the side frames at each end, or a bolt may be passed through the holes F to steady it. Indeed, if these holes F have been accurately bored, a neatly fitting mandrel passed through them should hold the side frames true. The end frames T having been set to stand at a right angle to the side frames, and with their holes at I J, &c., as near fair as may be with the holes in the side frames, two feet, as I J, may have their holes reamed fair with the holes in the side frames, and tightly fitting bolts be driven in and screwed firmly home. Before reaming the other holes (as K L) of each end frame, the jaws to receive the bearing boxes should be tested for alignment one with the other. Truth, in this respect, being of the utmost consequence for the following reasons:

Suppose the bearing ways on one side frame to stand higher than those on the other, then, the shafts will not stand level in the frame unless (except in the case of the brasses or boxes in B) the lower brasses are made of unequal thickness through the crown, to an amount equal to that of the error. In the case of the brasses in A, C, D, E, the joint faces of all the brasses of one side frame would require to be made thinner beneath the journal than above it on the high frame, and thicker beneath than above on the low frame, This would entail much extra work in planing, marking, and boring the bearing boxes or brasses, and be an inferior job when done.

Again, the bores of all the brasses would not be parallel to the crown or bedding faces, and this error would entail the following extra work: 1. Ascertaining the amount of the error, and allowing for it in marking the brasses; 2. The setting of the ways of the brasses out of true with the ways when clinking them for boring; and, finally, extra fitting or filing the brass bores when fitted with the shafts in place. This extra fitting would be necessary for the following reasons:

When the surfaces of work are to be parallel, they can be measured with calipers. Surfaces to be at a right angle can be tested with a square; those to be in line can be tried with a straight-edge, and in each case the truth or alignment of the surfaces is tested by contact of the testing tool. But in the cases where surfaces at an angle are tested or measured the tools must be set to a line or lines, and the work must be measured or cut to lines, thus: Suppose it were found that the bedding surface of the brass B was a certain amount out of alignment with the corresponding bedding surface on the other side frame, and, by measurement, this amount determined to be $\frac{1}{64}$ inch, then there is a liability to error in measuring this $\frac{1}{64}$. The brasses must be marked (for boring the same $\frac{1}{64}$ out of square, inducing another liability of error in marking that amount); this marking being done by lines, there is a liability to error in setting the work to the lines. From these liabilities to error, it is generally found that work not true in alignment requires, when it comes to be put together, to have each piece fitted to its place and corrected for alignment.

But, suppose the ways are made true and in proper alignment, then the brass bores are simply made of equal thickness at the crown, and on the sides at a right angle to the inside faces of the ways; and truth, in these respects, may be measured by actual contact, with the square or calipers, eliminating the chance of error.

In repairing the machine, or putting in new bearings or brasses;

the measurement and transferring of the error in the ways to the brasses has all to be gone through with again, and the parts fitted for alignment; whereas, if the ways are true, the brasses can be made true, and to go together, with but little, if any, adjustment when tried in their places.

The most accurate method of testing the adjustment of the ways is as follows: Fig. 2565 represents a plan view of the frame; N represents a straight-edge applied to the surfaces of the jaws *a b*. The method of applying this straight-edge is to place one end across a jaw, as *a*, while the other end is elevated above *b*; then, while pressing the end firmly against *a*, lower the other end to the face of *b*; if its edge at that end falls fair with *b*, so as just to touch it, the process may be reversed—one end being pressed to *b*, and the other lowered upon *a*. By this means, it will not only be discovered whether the jaws *a* and *b* stand square across the frame, but also whether the frame on either side is sprung. A square *c* may also be rested against N, and its blade *d* tested with the side face of the way, as shown. The same process of testing should be applied to the other jaw faces *e, f*.

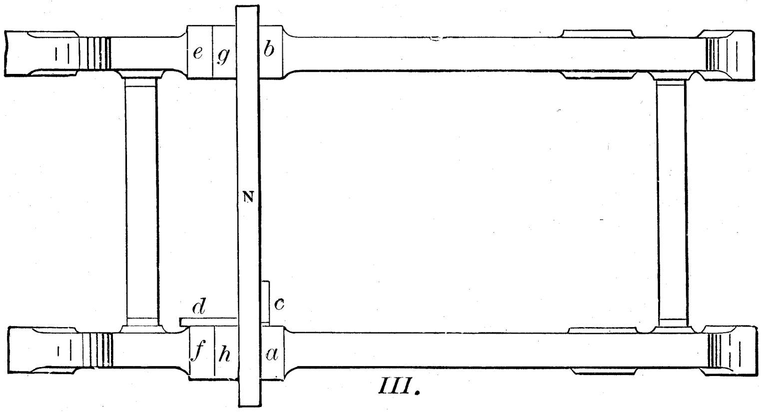


Fig. 2565.

Suppose, however, that the width between the jaws *a, f* was less than that between *e, b*, then the straight-edge, when pressed to *a*, would show a space between its edge and *b*; and also a space between its edge and *e*, when its other end was pressed to *f*; and, when these spaces were equal in amount, the frames would be set true in one direction. To test the truth in the other direction, the straight-edge should be applied after the same manner to the bottom surfaces *g, h*.

It will not answer to rest the straight-edge against the two surfaces and observe their coincidence with its edge, because any error cannot be sufficiently, readily, or accurately tested by this means. Nor will it answer to test by the bearing marks of a straight-edge applied with marking, unless the coat of marking be very fine and the straight-edge be moved without any vertical pressure on it; because, under such pressure, the straight-edge will bend.

The ways for all the bearings should be tested in this manner; so that, if from any error in the machine work, some of them will not come fair, the frames may be set to align those that it is of most importance to align truly; or if there is no choice in this respect, then those carrying the largest bearing should be set true; because, if it be decided to correct the error on the other bearing or bearings, there will be less area to file or operate upon. The setting being complete the holes may be reamed and the remaining bolts put in, the testing being repeated after the frame is finally bolted together. If this final test shows that bolting the frame up has altered the alignment by springing the frame, the bolts in one foot, as say I, Fig. 2564, may be slackened and the test repeated; and, if the frame is then found true, it is the bolting at I that causes the spring, on account of the bedding surfaces not fitting properly. If I is not found to be at fault, it may be bolted up again and J tested by loosening its bolts, and so on, until the location of the error is detected. Furthermore, when the frame is bolted up, the width of the bearings, as from *a* to *b*, should be tested; for in a job of this kind, it will pay to have the framework so true to the drawing that, if the other parts, as the shafts, bearing parts, &c., be also made to the drawings, the parts will go together, thus avoiding the necessity of varying all the other parts from the drawing to accommodate errors in the framework.

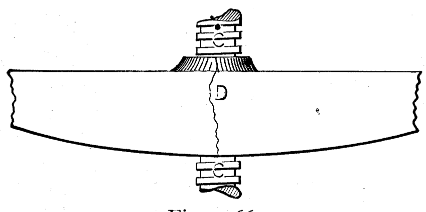


Fig. 2566.

Among the jobs that the erector is often called upon to perform is that of patching or repairing pieces that have cracked or broken. Fig. 2566 represents a case of this kind, the fracture being at D. The principle to be observed in work of this kind is to cause the bolts to force the fractured pieces together, so that the irregularity or crookedness of the crack, as at D in the figure, may serve to lock the pieces together.

Suppose, for example, we were to put on a patch P, Fig. 2567, and there would be but little to prevent the crack from opening under severe strain, and the patch would stretch, permitting the crack to open and finally causing the bolts to break or sheer off. A preferable plan, therefore, is to put two patches on the sides in the following manner:—

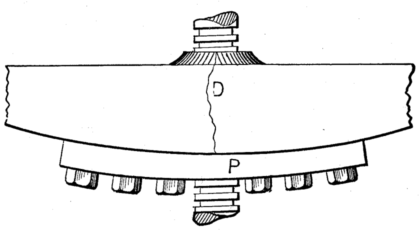


Fig. 2567.

The holes should be drilled through the beam and the plates held against the beam so that their holes may be marked by a scriber passed through the holes in the beam. The holes in the plates should be drilled closer together than those in the beam, so that when driven in they will serve as keys to close the two sides of the crack together, as shown in Fig. 2568, where it is seen that one side of the bolt bears against the holes in the patch and the other against the holes in the beam. To facilitate getting the bolts in place the plates may be heated so as to expand them.

In cases in which it would not be permissible to drill so many holes through the beam on account of weakening it, we may use patch bolts with countersunk heads, as in Fig. 2569. Two only of the bolts pass entirely through, and it is best to let them be taper, as at A in the figure, the head not meeting the patch. The hole in the beam, after being reamed taper, should be filed out on the side B, and that in the patch plates on the other side, as at C and D, so that the bolts will serve as keys. After these two bolts are in place and their nuts firmly screwed home, the holes for the patch bolts may be drilled through the plates and into the beam. When the countersunk head bolts are fitted they should be turned down behind the head, so as to leave a part weaker than the bolt, and then screwed in until the required end breaks off. The taper bolts should be of steel, but those with countersunk heads may be of iron.

ERECTING AN IRON PLANER.—If an iron planer be properly fitted and erected, the table will be quite solid in the **V**-ways in the bed, and will not rock or move even though a heavy vertical cut be taken at the extreme sides of the table, but any error of truth of alignment or fit either in the bed-ways or the table **V**'s will cause the table to lie improperly in the **V**'s and to be apt to rock as it traverses. The author has had planed upon a planer thirty years old, at the Freeland Tool Works, in New York City, a cast-iron surface 12 × 20 inches, the metal weighing about 60 lbs.,

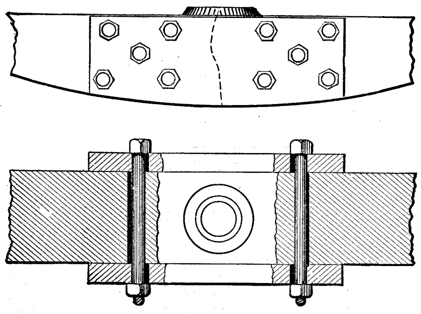


Fig. 2568.

and the surfaces were so truly planed that one would lift the other by reason of a partial vacuum between the two. These planed surfaces were exhibited by the author at the American Institute Exhibition in 1877, and were awarded a medal of superiority.

The manner in which this planer was fitted and erected, and the principles involved in such fitting and erecting, are as follows:

While it is essential that the foot or resting surface of a planer bed (whether it stands on legs or rests direct upon its foundation) be as true as it is practicable to plane it, still it is more essential that the **V**'s or ways be true, and as the casting will be apt to alter its form from having the surface metal removed, it is best to plane the side on which the ways are, the last.

When the bed is placed upon the machine to have its resting surface planed, the casting being uneven, it will be necessary to place packing pieces of suitable thickness beneath the places

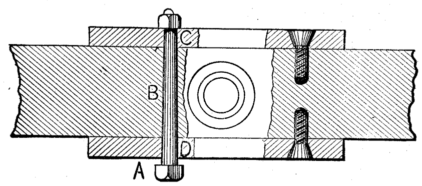


Fig. 2569.

where the clamping plates hold it, so that the pressure of those plates may not spring or bend the casting.

These packing pieces require to fill up solidly (without lifting the bed) the hollow places, and it is a good plan to place among them a piece of strong writing paper for reasons which will appear presently.

In planing the bed all the surfaces should be roughed out before any are finished. Before any finishing cuts are taken all the clamping bolts should be loosened and the pieces of paper tried by pulling them, so that if the casting has altered its form it will be made apparent by some one of the pieces of paper becoming loose.

In this case the packing must be readjusted, clamping both as lightly as will hold the work, and all as equally as possible, when the finishing cuts may be taken.

The best form of template to plane the ways to is that shown in Fig. 2570, in which B is a side and A an end view. A corresponding female template being shown at D to be used in planing the table **V**'s.

The length C of the **V** of the template must not be longer than from 4 to 6 inches, or it will be liable to spring or twist from its own weight. This template is not intended to be used in any sense as a straight-edge to test the truth of the length of the ways, but rather as one to test their width apart, and the correctness of the angles. The top surface A B should be quite true with the **V**'s, being equidistant from them, so that by testing that surface with a spirit-level it may be known whether the ways are level either crosswise or lengthwise.

The **V**'s of the template require to have red marking on them so as to mark the ways when the template is moved, and show that the ways accurately fit to the template, which is highly important.

In planing the table or platen it is essential to bear in mind that the area to be planed on the **V** side is always small in comparison with that to be planed on the other or work-holding side of the table, and as the planing of this latter surface is sure to cause the casting to alter its form, it is necessary to plane it first, so that the alteration of form may occur before and not after the **V**'s have been planed.

In chucking the table to plane its work-holding surface, the packing pieces must be used as described for the bed, and the bolts placed as there described.

Both bed and table being planed they require to be fitted together (no matter how expertly the planing has been done) if a really first-class job is to be made of them. In doing this it is essential that the bed be supported at the same points as it will be when the machine is put to work, for in large or long casting the deflection or bending from its own weight is sufficient to have an important practical effect. The same fact will also apply to

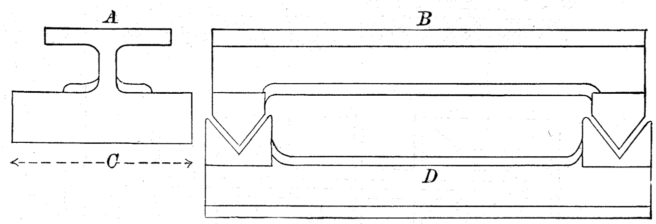


Fig. 2570.

the table and even to the cross slide, even though the latter be heavily ribbed and but, say, 5 feet long.

If, therefore, the bed is to be supported by legs, its guideways or **V**'s should be fitted after the legs are attached. The bed must be carefully levelled so that the ways may stand horizontally true, which may be tested by placing the template A B in Fig. 2570 in place and applying a spirit-level first across and then lengthwise of the upper surface of the template.

If the bed rests upon a foundation at several points in its length it should be rested at those points while being fitted and carefully levelled as before, the template and spirit-level being tried at every two or three feet of the bed length.

To test the width of the **V**'s and their widths apart in the fitting, the template A B, Fig. 2570, must be used in connection with red marking, but to true the lengths of the ways a surface plate about 4 feet long and slightly wider than the width of one side of the ways must be used, and if the template and the surface plate show the ways true they will be of the correct width, of correct angle and true planes. But this does not insure that the two ways are in line one with the other, and for this purpose separate test blocks are necessary, because the template is too narrow in width to give a good test, and cannot be made wider, because in that case its own weight would cause it to spring or deflect to suit any error in the work.

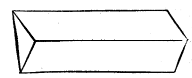


Fig. 2571.

These test blocks are simply two pieces of metal, such as shown in Fig. 2571. The lengths of these blocks should be about 8 inches, and the best way to obtain them true and exactly alike is to make one block and then cut it into two. They possess an advantage not possessed by a template that spans both ways, inasmuch as they may be turned end for end in each way and thus test the accuracy of the angles of each way.

Again, both may be placed in one way, and by various applications in connection with straight-edge, surface plate, and level they will test the truth of the ways, both individually and one with the other in a better manner than by any other method.

Fig. 2572 represents the various positions of the **V** blocks for the testing, A, B, C, D, E, F, G, H, representing the blocks; straight-edges may be placed as at I, at J, and at K, and if the ways are true the straight-edge, lightly coated with marking, should have contact clear across the upper surface of both **V**-blocks, and a spirit-level placed on the straight-edge (in each position of the same) should show them to be level.

The surface P, on which uprights or standards on that side of the plane, rest, being planed with the **V**-ways will be true with them, and the uprights may be erected thereon, their base surfaces being fitted to P until the standards stand truly vertical and parallel in their widths apart. In testing these uprights they should be bolted home as firmly as they will be when finally erected, as they will be liable to alter their set if bolted up more firmly than when tested. These front surfaces should be at a right angle to the length of the bed **V**-ways, and this may be tested by placing a straight-edge across their surfaces and testing it with a square rested against the edge of the planer table.

The method of erecting planers at the Pratt and Whitney Company's shops is as follows:—

To test the **V** s, a plate P, Fig. 2573, is applied as shown, its lugs a, a^1 fitting to corresponding sides of the two **V** s, as B, B. In Fig. 2573 the test is made by inserting thin pieces of tissue paper between a, a^1 and the **V**-sides, the friction with which the paper is held showing the nature of the fit. Thus, if the paper will move easily at one end and is tight at the other end of either of the lugs a, a^1 the fit is shown to be defective. When the fit on these sides is corrected, the plate P is turned around, as in Fig. 2574, and from a similar tissue-paper test, the other sides are corrected. Thus the outside angles of the two **V** s are fitted to the same angle; inside angles are also fitted to the same angle. But it will be observed that it does not follow that the inside angles of the **V** s are of the same degree of angle as are the outside halves or angles, unless the two lugs a, a^1 of the plate P have equal angles. It is on this account that the test is made by tissue paper, rather than by the bearing marks produced by rubbing P along the **V** s, since that might in time wear the angles a, a^1 out of true. The same plate P may be used to true the male **V** s on the work-holding table of the machine, as is shown in Figs. 2575 and 2576, where the table is seen upside down, as is necessary in order to apply the plate. Here, again, the outside angles or halves of the **V** s are fitted from the same **V** (a^1) of the plate, so that the fit of the table will be true to the bed, even though the angle on one side of the **V**-ways were not precisely correct, and there is less liability to error than would be the case were a male and female plate used instead of a single plate. The alignment next in importance is that of the uprights, standards, or side frames of a planing machine, and to enable the correct erection of these, the device A, Fig. 2577, is employed. It consists of a solid plate fitting into the **V**-ways of the planer-bed and having two steps, B and C, which receive the side frames to be erected. The width D is the width apart of the side frames, and the side surfaces of the steps (as G) are vertical to the centre line of the **V**-ways of the bed, so that the side frames may be rested against G on one side, and the corresponding surface on the other step. The surfaces E, F are at a right angle to the **V**-ways of the bed, so that when the side frames are against E, F they will be set square across the machine. The top face of the plate A is planed parallel to the **V** s of the plate, so that in addition to resting each side frame against the surfaces (as F G) a square may be rested on plate A and applied to their trued surfaces, and thus may these side frames be set true and square, both one with the other, and with the ways in the bed, without the use of stretched lines and straight-edges, which secures greater accuracy and saves considerable labor.

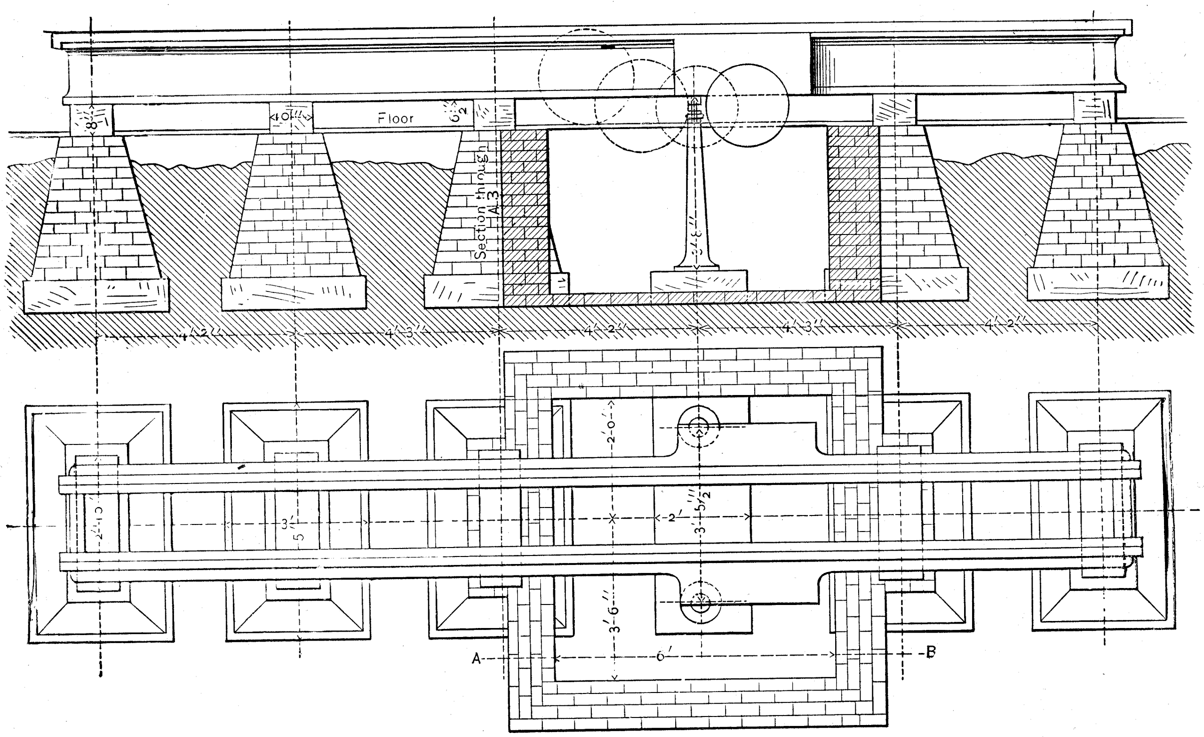


Fig. 2578.

All the smaller parts of the machine may then be erected true to the bed or the side frames, as may be required, and if it be a small planer, in which the bed rests upon feet, all that will be necessary in setting the machine in position to work is to set the surface of the work-table level. But in the case of a large heavy planer a solid foundation must be built for the bed, because it will spring, bend, and deflect from its own weight, and thus the side frames, as well as the bed, may be thrown out of true and alignment. Fig. 2578 is a side and plan view of the foundations for a planer, showing the bed-plate in position upon the same.

The stone blocks forming the base of the foundation require themselves to rest upon a solid base, and not upon a soil or gravel

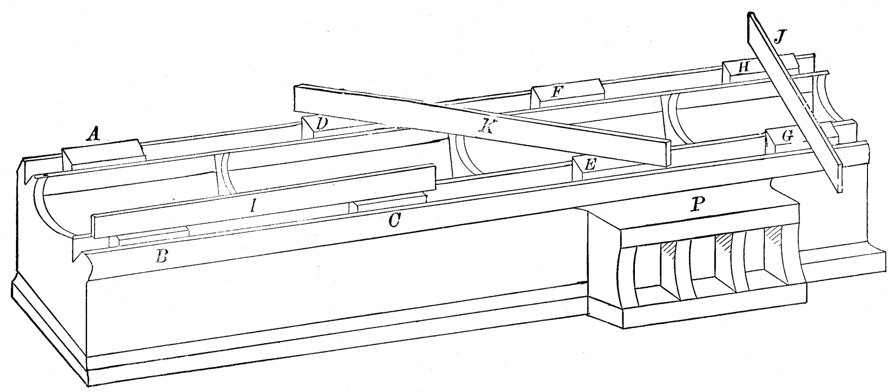


Fig. 2572.

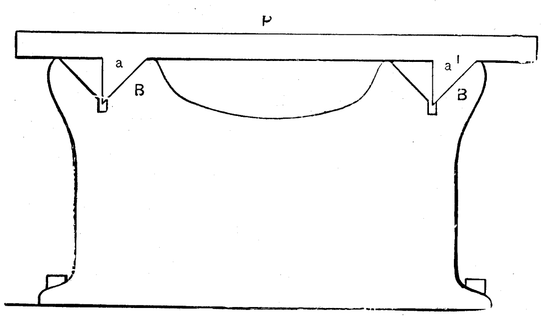


Fig 2573.

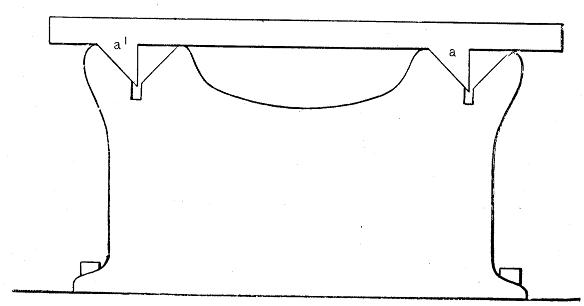


Fig. 2574.

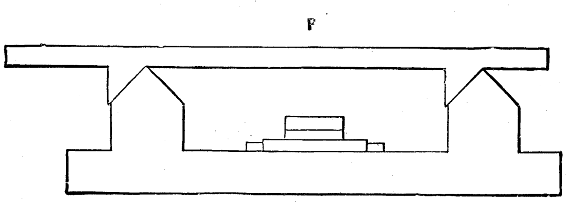


Fig. 2575.

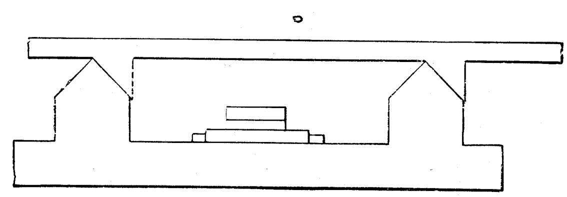


Fig. 2576.

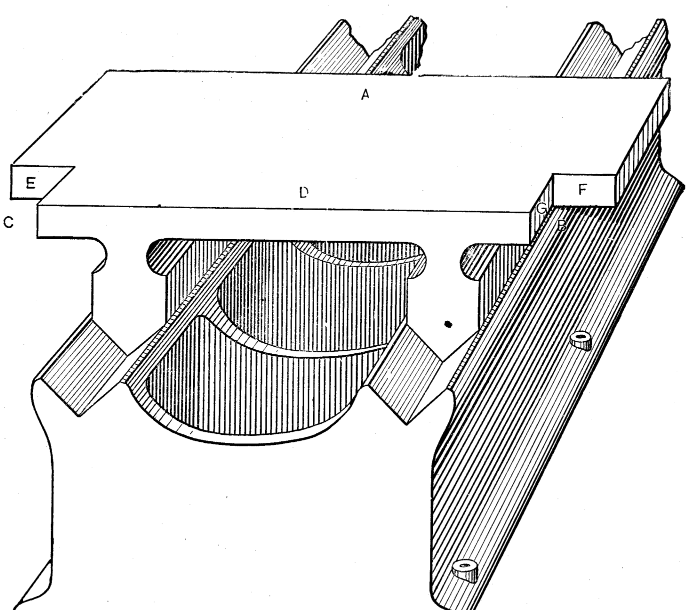


Fig. 2577.

that is liable to sink beneath them. The brickwork above them is best laid in cement, which should be properly set before the planer bed is placed in position. Near the centre of the bed, and directly beneath the cross-slide, is shown a screw jack, to take up any sag of the bed, and cause the **V** s to have a good bearing directly beneath the cutting tool, which is essential to prevent the table from springing from the pressure of the tool cut.

FITTING UP AND ERECTING A LATHE.—The first operation will be to true the bed or shears. If the lathe has raised **V** s on the bed it will be sufficient to true them only, without truing the flat surfaces. The bed should during the fitting be supported at the same points as it will be when in use.

The method of aligning the lathe heads at the Pratt and Whitney Company's workshops is as follows: Fig. 2579 is a side and an end view of a part of a lathe shears A, with the tailstock B thereon. To the bore of the tailstock there is closely fitted an arbor C, accurately turned in the lathe, and having at the end D and at E two short sections of enlarged diameter. A plate F is fitted to the inside **V** s of the shears (upon which **V** s the tailstock sits). This plate carries a stand G, and a second gauge or stand H. Stand G fits at its foot into a **V** provided in F, as shown, the object of which is to so hold G to F that its (G's) face will stand parallel to arbor C. The stand is so adjusted that a piece I may be placed between C and G and just have contact with both, and it is obvious that if this is found to be the case with the tailstock and the stand placed at any position along the bed, the arbor C, and, therefore, the bore of the tailstock, must be true, sideways, to the inside **V** s of the lathe shears. The testing, however, is made at the enlarged sections D and E, G of course being firmly bolted to F. To test the height of the arbor C from the **V** s, and the parallelism in that direction, stand H is provided. It carries a pointer or feeler K, whose end is adjusted to just touch the enlarged sections D and E of C, it being obvious that when the degree of contact is equal at these two sections, with the tailstock and the plate F moved to various positions along the bed, the adjustment or alignment in that direction is also correct. The adjustment and corrections may then be made with the head-stock of the lathe in place of the tailstock, the arbor fitting into the bored boxes of the lathe and extending from it, and having two sections of the same diameter, as sections E in the figure. Now, suppose that in the test thus made the bar C proves to stand true in some locations, but not in others, upon the bed; then it is proof that it is the **V** s that require correction, while the tailstock is in error in all cases in which the error is constant, with the tailblock moved in various positions along the shears.

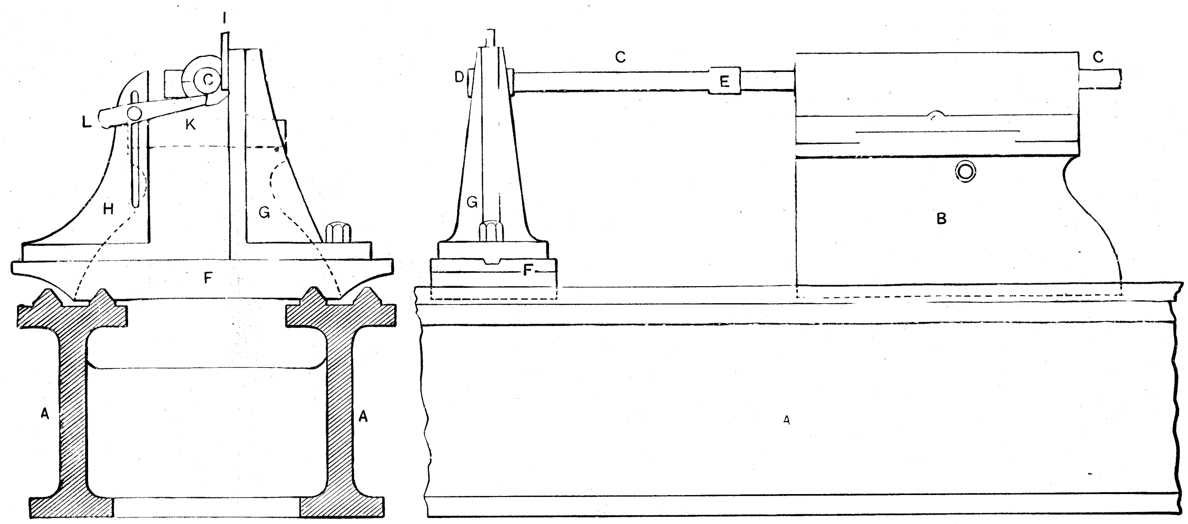


Fig. 2579.

In some practice the heads are bored after being fitted to the ways, and in this case the boring bar may be supported by standards fitting to the lathe bed, running in bearings, and not on centres. There should be three of these bearings, one at one end of the head, and as close to it as convenient, another at the other end, as close as will permit the insertion of the cutters, and the third as far from the second as will permit the insertion on the bar and between them of a pulley to drive the bar, which must be splined to receive a feather in the pulley, so that the bar may be fed through its bearings and through the pulley to the cut. After the live head has been bored the tailstock or back-head may be bored from the other end of the bar, so that the standards will not require to be moved on the bed until the boring is completed. The bar may be fed by hand, or an automatic feed motion may be affixed to one of the standards. The heads being secured to the bed while being bored, there is no liability of error in their alignment, because, even if the holding bolts spring the heads in clamping them to the bed, the holes will be true when the heads are firmly home upon the bed, as they will be when in use, whereas under this condition such will not be the case if the holes for the spindles are bored before the seats are planed and fitted.

The feed screw must be placed quite parallel to the **V** s or guides of the bed, or otherwise the pitches of threads cut in the lathe will be finer than they should be, and the screw will bind in the feed nut, causing undue wear to both.

The method employed to test the truth of lathe shears and heads in the David W. Pond Works, at Worcester, Massachusetts, is as follows:—

The planing, both of the lathe shears and of the heads, being done as accurately as possible, the heads are provided with a mandrel or arbor, to the end of which is secured the device shown in Fig. 2580, in which A is a hollow cylindrical piece having a threaded and split end, so that by means of a nut the bore may be closed to tightly fit the arbor referred to; B, B are two arms, a sliding fit in A, to enable their adjustment for the width of lathe **V** s, and having a flat place on one side, as at C C, to receive the pressure of a locking device D, by means of which B, B may be fastened in their adjusted positions; E, E are cylindrical arms, a sliding fit in B, B, also having flat sides, and capable

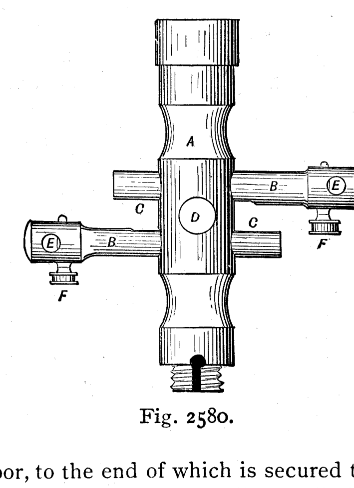


Fig. 2580.

of being secured in their adjusted positions by means of locking devices F, F.

Fig. 2581 is an end view of the device in position on a lathe tail stock, and Fig. 2582 is an enlarged view (being half full size) of the devices at the lower end of arms or rods E, E.

At the lower ends of E, E are provided two pieces G G, which are capable of adjustment to fit the V s H, H of the lathe, as follows :—

The middle pins I are fast in the arms J, but are pivoted in G, the end pins, as K, are pivoted in G, are flat where they pass

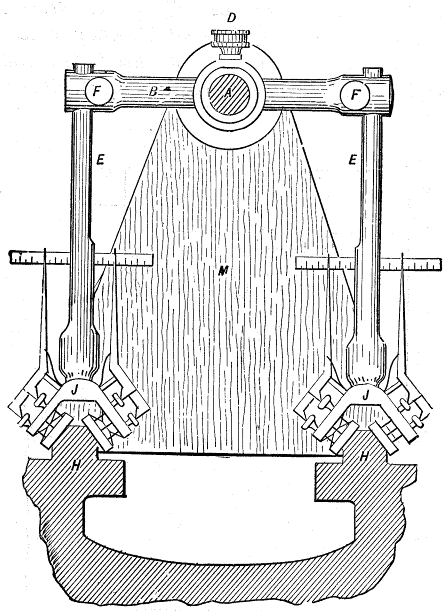


Fig. 2581.

through J, and threaded to receive the nuts, L, of which there are four, two to each piece G. By operating these nuts, G may be adjusted to bed fair on the angles on the lathe Vs H. At M are two fixed pins which afford a fulcrum, at N and O respectively, to four index needle arms. Two of these index arms only are seen in the cut, marked respectively P and Q, which are pivoted at N. Two similar pointer or needle arms are on the other side of M, being behind P and Q, these two being pivoted respectively at O. At the lower end of P is a point resting in the centre of the nut, and similarly the end of Q rests in the centre of the nut on that side. Similarly the two needles not seen have pointed ends resting in the centre of the nuts marked respectively L. Between G and J are two springs placed back to back, which act to hold G away from J. But it will be seen that if either end of G be forced towards J, as by passing over a projection on the V H, then the pin K, will push nut L, and this will raise the end of the pointer or needle to a corresponding degree, and the pointer being pivoted (as at N), its upper end will move and denote on the graduated index R that there is an error in the lathe V, the amount of the error being shown multiplied on account of the leverage of the needle arms from the pivots.

The pieces G being adjusted to bed fairly on the lathe Vs, the heads of the lathe are moved along the lathe shears, and if the Vs are true to angle the upper ends of the needles will remain stationary, a projecting part of a V will, however, cause the needle point to move toward E, while a depression on a V would cause the springs K to move G in, keeping it in contact with the V, while the needle point would move away from E. To maintain the needle arms in contact with the nut heads L, springs S are employed. Variations in the widths apart of the Vs on either side of the shears would obviously be shown in the same manner, the defect being located by the needle movement. The corrections are made from the contact marks of the heads, caused by moving the heads along the Vs and by careful scraping.

Notwithstanding that every care and attention may be taken to make a lathe true in the process of manufacture, yet when the whole of the parts are assembled it is found essential to test the truth of the finished lathe, because, by the multiplication of minute errors the alignment of the lathe, as a whole, may be found to need correction. A special inspector is therefore employed to test finished machines before they leave the works, and in Fig. 2583 is represented the device employed for testing the alignment of the line of centres of lathes.

Upon the face of the face plate and near its perimeter there are turned up two steps, as denoted by B and C. The tail-spindle is provided with a stud S, which fits in the place of the dead centre, and carries what may be termed a double socket, one-half of which (as F) envelops the stud S, while the other half (A) envelops and carries a rod R. These two halves are in reality split sleeves, with set screws to close them and adjust the fit. By means of the screws E, the sleeve F may be made a tight working fit upon S, while, by means of screws G, sleeve A may be made to firmly grip the rod R, which may thus be securely held while still capable of being swung upon stud S. Upon the outer end of the rod R is another sleeve I, which is also split and secured to the rod R by means of screws corresponding to those shown at G. It also

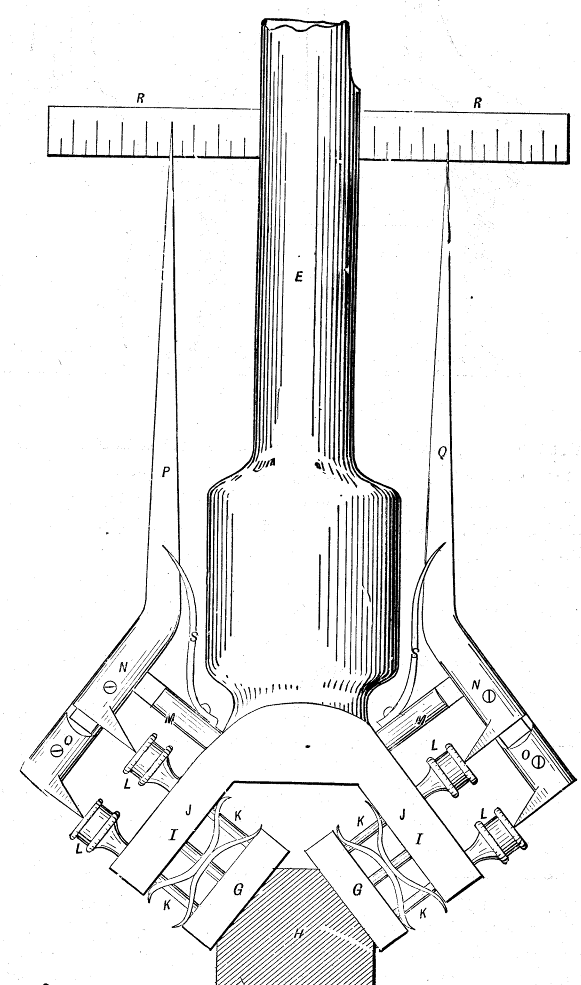


Fig. 2582.

carries a pin, upon which a disk K is pivoted, and a lug through which the adjusting screw V is threaded. Upon K is a lug which has on one side of it the end of a spring T, and it is obvious that by operating V the disk K will be rotated upon its central pin. K carries two lugs, L and M, the latter being threaded and split. These two lugs receive a sleeve N, threaded into M, and a close plain fit in L. The small end of this sleeve is split and is threaded slightly taper, and is provided with the nut P. Through this sleeve passes a needle Q Q, one end of which is bent as shown, and it is obvious that by screwing nut P upon N the sleeve will be closed and will tightly grip the needle Q Q. Now, suppose that the head of N is operated, and it will move endwise through L and

M, carrying with it the needle Q Q, which will remain firmly clasped in the sleeve; or suppose that screw V is operated, and K will revolve, carrying with it the needle Q Q, which will still remain firmly gripped, and it follows that there is thus obtained a simple means of adjusting the needle without releasing it.

The application of the instrument is as follows: To test if the head and tailstocks are of equal height from the bed, the instrument is set and adjusted exactly as shown in the engraving, the needle being adjusted to just touch the diameter of the step at B. The rod R is then swung around so that the needle comes opposite to the same step B at the bottom of the face plate, and if the needle just touches there also the adjustment for tailstock height does not touch it when tried at the bottom of the plate, then the error may be caused in three ways—thus, in the first place, the whole tailstock may be lower than the headstock; in the second place, the front end of the tailstock may be too low; or, in the third place, the back end of the tailstock may be too high. If the first was the cause, the test with the needle point tried with face C would show correct. If the second or third was the cause of the error, the needle point when tried to face C would touch when applied at the top, but would not touch when tried at the bottom of the face plate. Another case may be cited. For example, suppose the needle applied as shown touched at the bottom but not at the top of the step B, then the test with the

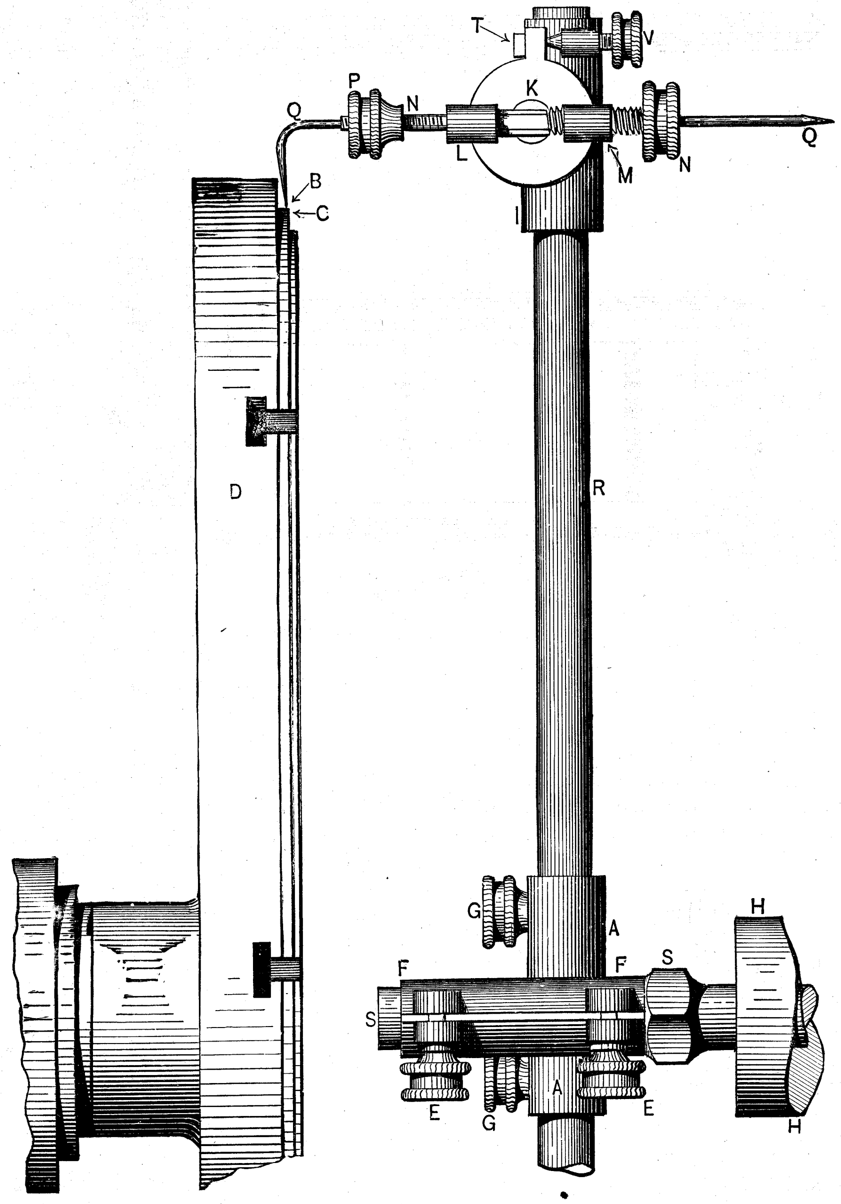


Fig. 2583.

is correct. Similarly for testing if the tailstock is set true sideways the needle may be tried in the same manner and upon the same step, but upon the two opposite sides of the face plate, instead of at the top and bottom. It now remains to test if the tailstock is in line in a horizontal direction with the live spindle, and this is done by reversing the needle end for end in the sleeve N, and setting it to just touch the face C of the turned step on the face plate, and if it just touches at the top and bottom as well as at the two sides the tail-spindle is obviously in line. It may be observed, however, that if an error in any one direction is found, it is necessary to go through the whole series of tests in order to precisely locate the error. Suppose, for example, that the needle, being adjusted as in the engraving to just touch the step at B, needle reversed would show whether the whole tailstock was too high, or whether the front end only was too high, or the back end too low. There is one excellent feature in this device to which attention may be called, which is that the tests are made on as large a diameter of face plate as possible, which shows the errors magnified as much as possible.

The same device is used to test if the cross slide of the carriage or saddle is at a right angle to the lathe shears, the method of its application being as shown in Fig. 2584. The split sleeve A receives in this case a rod R, which is laid in the slideway S of the carriage or saddle, and a long rod H carries the needle-holding devices. The rod R is held fair against the slideway, and the face of the sleeve A is held against the edge of the carriage or saddle. The needle Q is then adjusted to just touch the edge D of the lathe bed. When this adjustment is made the rod H is swung over to the right and the coincidence of the needle point again tried with the edge of the lathe bed, the cross slideway being at a right angle when the needle point touches the edge D of the lathe bed when tried on the left hand, and also on the right hand, of the carriage. The stiffening rod U is brought under tension by a nut operated against a lug on X. To counterbalance the

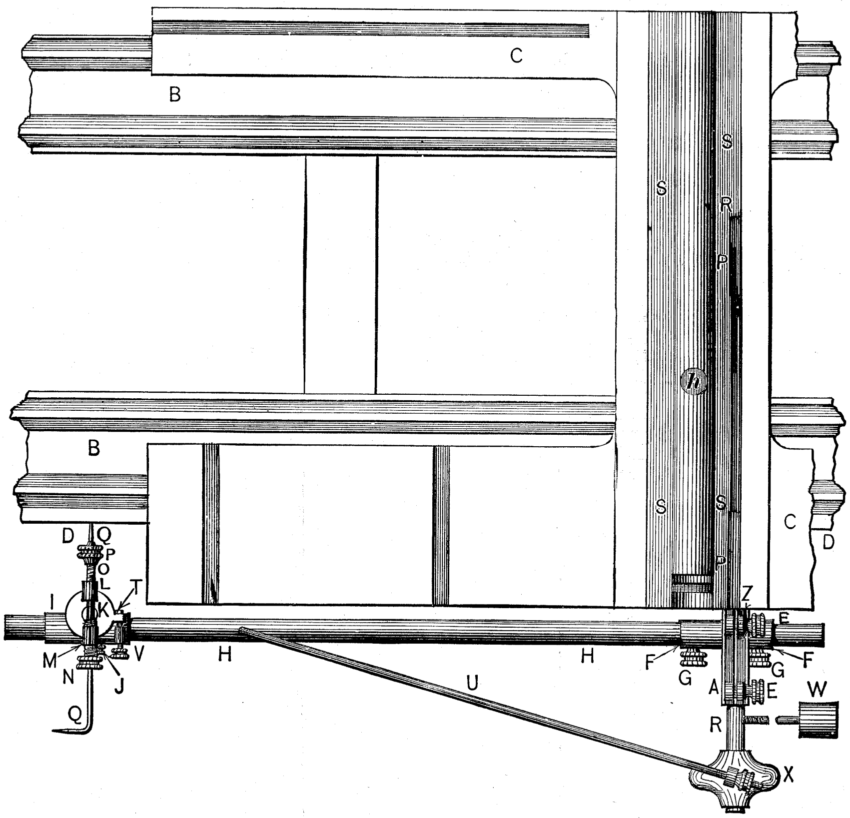


Fig. 2584.

overhanging weight of the rod H and its attachments, a rod carrying a weight W is employed. It is obvious that the truth of the operation depends wholly upon the straightness and parallelism

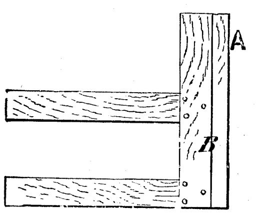


Fig. 2585.

of the enlarged sections P of the rod R, upon keeping the end face of A in contact with the carriage at Z, and upon the correct adjustment of the needle to the edge of the lathe bed.

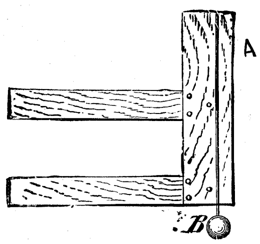


Fig. 2586.

Setting Line Shafting in Line.—The following method of adjusting line shafting or setting it in line, as it is termed, is that generally adopted in the best practice.

First prepare a number of rude wooden frames, such as shown in Fig. 2585. They are called targets, and are pieces of wood nailed together, with the outer edge face A planed true, and having a line marked parallel with the planed edge and about three-quarters of an inch inside of it. Upon this frame we hang a line suspending a weight and forming a plumb-line, and it follows that when the target is so held that the plumb-line falls exactly over and even all the way down with the scribed line, the planed face A, Fig. 2586, will stand vertical. To facilitate this adjustment, we cut a small **V** notch at the top of the scribed line, the bottom of the **V** falling exactly even with the scribed line, so that it will guide the top of the plumb-line even with the scribed line at the top; hence the eye need only be directed to causing the two lines to coincide at the bottom. To insure accuracy, the planed edge A

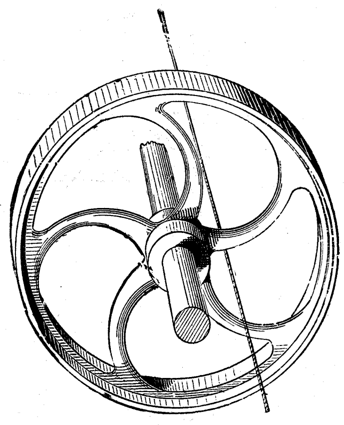


Fig. 2587.

should not be less than a foot in length. Then tightly stretch a strong closely-twisted and fine line of cord beside the line of shafting, as shown in Fig. 2587, placing it say six inches below and four inches on one side of the line of shafting, and equidistant at each end from the axial line of the same, adjusting it at the same time as nearly horizontally level as the eye will direct when standing on the floor at some little distance off and sighting it with the line shaft.

In stretching and adjusting this line, however, we have the following considerations :—It must clear the largest pulley hub on the line of shafting, those pulleys having set-screws being moved to allow it to pass. If the whole line of shafting is parallel in diameter, we set the line equidistant from the shafting at each end. If one end of the shafting is of larger diameter, we set the line farther from the surface of the shafting, at the small end, to an amount equal to one-half of the difference in the two diameters;

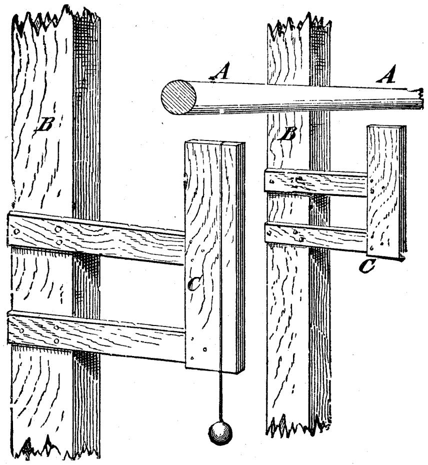


Fig. 2588.

and since the line is sufficiently far from the shafting to clear the largest hub thereon, it makes, so far as stretching the line is concerned, no difference of what diameter the middle sections of shafting may be. The line should, however, be set true as indicated by a spirit-level.

We may now proceed to erect the targets as follows: The planed edge A in Fig. 2585 is brought true with the stretched line, and is adjusted so that the plumb-line B in Fig. 2586 will stand true with the line or mark B. When so adjusted, the target is nailed to the post carrying the shafting hanger. In performing this nailing, two nails may be slightly inserted so as to sustain the target, and the adjustment being made by tapping the target

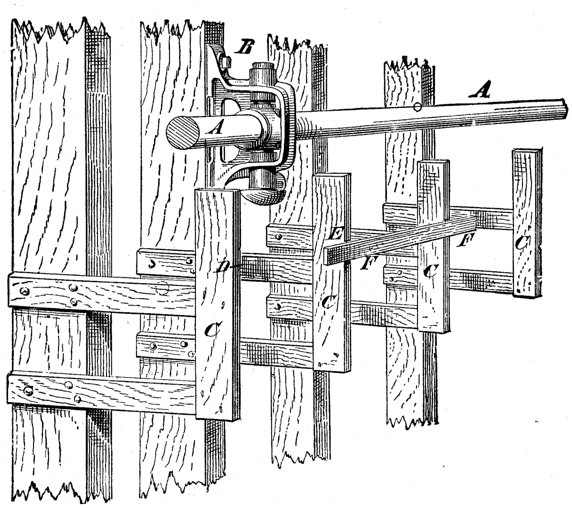


Fig. 2589.

with the hammer, the nails may be driven home, the operator taking care that driving the nails does not alter the adjustment.

In Fig. 2588 A A represents the line of shafting, B,B two of the hanger posts, and C,C two of the adjusted targets.

We have now in the planed edges A of the targets a rigid substitute for the stretched line, forming a guide for the horizontal adjustment, and to provide a guide for the vertical adjustment we take a wooden straight-edge long enough to reach from one post to another. Then beginning at one end of the shafting, we place the flat side of the straight-edge against the planed edge of two targets at a distance of about 15 inches below the top of the shafting; and after levelling the straight-edge with a spirit-level, we mark (even with the edge of the straight-edge) a line on the planed edge of each target, and we then move the straight-edge to the next pair of targets, and place the edge even with the mark already made on the second target. We then level the straight-edge with a spirit-level, and mark a line on the third target, continuing the process until we have marked a straight and horizontally level line across all the targets, the operation being shown in Fig. 2589, in which A represents the line of shafting, B the hangers, and C the targets. D represents the line on the first target, and E the line on second. F is the straight-edge, levelled ready to form a guide whereby the line D may be carried forward, as at E, level and straight, to the third target, and so on across all the targets.

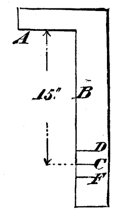


Fig. 2590.

The line thus marked is the standard whereby the shafting is to be adjusted vertically; and for the purpose of this adjustment, we must take a piece of wood, or a square, such as is shown in Fig. 2590, the edges A and B being true and at a right angle to each other. The line D, in Fig. 2589, marked across the targets being 15 inches below the centre line of the shaft at the end from which it was started, we mark upon our piece of wood the line C in Fig. 2590, 15 inches from the edge A (as denoted by the dotted line); and it is evident that we have only to adjust our shaft for vertical height so that, the gauge being applied at each target in the manner shown in Fig. 2591, the shaft will be set exactly true, when the mark C on the piece of wood comes exactly fair with the lines D marked on the targets.

For horizontal adjustment, all we have to do is to place a straight-edge along the planed face of the target, and adjust the shaft equidistant from the straight-edge, as shown in Fig. 2592, in which A is the shaft, B the target, C the straight-edge referred to, and D a gauge or distance piece. If, then, we apply the

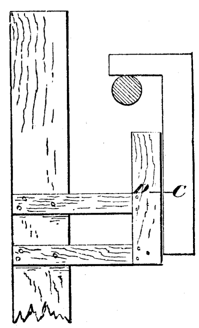


Fig. 2591.

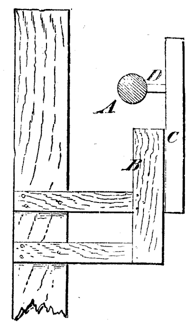


Fig. 2592.

straight-edge and wood gauge to every target, and to the adjustment, the whole line of shafting will be complete.

There are several points, however, during the latter part of the process at which consideration is required. Thus, after the horizontal line, marked on the targets by the straight-edge and used for the vertical adjustment, has been struck on all the targets, the distance from the centre of the shafting to that line should be measured at each end of the shafting, and if it is found to be equal, we may proceed with the adjustment; but if, on the other hand, it is not found to be equal, we must determine whether it will be well to lift one end of the shaft and lower the other, or make the whole adjustment at one end by lifting or lowering it, as the case may be. In coming to this determination we must bear in mind what effect it will have on the various belts, in making them too long or too short; and when a decision is reached, we must mark the line C, in Fig. 2590, on the gauge accordingly, and not at the distance represented in our example by the 15 inches.

The method of adjustment thus pursued possesses the advantage that it shows how much the whole line of shafting is out of true before any adjustment is made, and that without entailing any great trouble in ascertaining it; so that, in making the adjustment, the operator acts intelligently and does not commence at one end utterly ignorant of where the adjustment is going to lead him to when he arrives at the other.

Then, again, it is a very correct method, nor does it make any difference if the shafting has sections of different diameters or not, for in that case we have but to measure the diameter of the shafting, and mark the adjusting line, represented in our example by C, in Fig. 2590, accordingly, and when the adjustment is complete, the centre line of the whole length of the line of shafting will be true and level. This is not necessarily the case, if the diameter of the shafting varies and a spirit-level is used directly upon the shafting itself.

In further explanation, however, it may be well to illustrate the method of applying the gauge shown in Fig. 2590, and the straight-edge C and gauge D shown in Fig. 2592, in cases where there are in the same line sections of shaftings of different diameters. Suppose, then, that the line of shafting in our example has a mid-section of $2\frac{1}{4}$ inches diameter, and is 2 inches at one, and $2\frac{1}{2}$ inches in diameter at the other end: all we have to do is to mark on the gauge, shown in Fig. 2590, two extra lines, denoted in figure by D and F. If the line C was at the proper distance from A for the section of $2\frac{1}{4}$ inches in diameter, then the line D will be at the proper distance for the section of 2 inches, and E at the proper distance for the section of $2\frac{1}{2}$ inches in diameter; the distance between C and D, and also between C and F, being $\frac{1}{8}$ inch, in other words, half the amount of the difference in diameters.

In like manner for the horizontal adjustment, the gauge piece shown at D in Fig. 2592 would require when measuring the $2\frac{1}{4}$ inch section to be $\frac{1}{8}$ inch shorter than for the 2 inch section, while for the $2\frac{1}{2}$ inch section would require to be $\frac{1}{8}$ inch shorter than that used for the $2\frac{1}{4}$ inch section, the difference again being one-half the amount of the variation in the respective diameters. Thus the whole process is simple, easy of accomplishment, and very accurate.

If the line of shafting is suspended from the joists of a ceiling instead of from uprights, the method of procedure is the same, the forms of the targets being varied to suit the conditions. The process only requires that the faced edges of the targets shall all stand plumb and true with the stretched line. It will be noted that it is of no consequence how long the stretched line is, since its sag does not in any manner disturb the correct adjustment, but in cases where it is a very long one it may be necessary to place pins that will prevent it from swaying by reason of air currents or from jarring.

The same system may be employed for setting the shafting hangers, the bores of the boxes being used instead of the shafting itself.