Chapter XXVIII.—ERECTING.

ERECTING.—The term erecting is applied in large work to the operations involved in fitting the parts to their places on the engine or machine, as well as to placing them upon their foundations and putting them together ready to run.

In vice work or fitting, the various parts are put together ready to be erected, each part being complete in itself, but not adjusted with relation to the others. Thus, while a link motion may be complete in itself, the length of its eccentric rods will usually require correcting when placed upon the engine. Furthermore the position of the eccentric is to be adjusted.

The boiler fittings may be complete in themselves, but will still require to be fitted or erected upon or to their places.

Erecting requires the greatest of skill, care, and judgment, in order that the work may be put together properly aligned and any defects of construction corrected in the finished machine.

In erecting a machine, as in building a house—or, indeed, as in everything that man constructs—the work must be begun at the foundation.

In a machine in which the working parts are carried and contained upon framework, such framework becomes the foundation so far as the erector is concerned.

In a stationary steam engine the cylinder and bed plate form the erector's foundation while the engine is in the shop, the mason's foundation being an after consideration.

In a locomotive the boiler is the foundation to which all the other parts are either directly or indirectly affixed.

The erector uses all the measuring tools used by the fitter or vice hand, and in addition many others, as stretched lines, the spirit-level and plumb-level. Either of these tools forms the readiest means of testing whether surfaces that are widely removed and in different positions about a machine are parallel one to the other, it being evident that all surfaces standing vertical will be parallel, or all those standing horizontal will also be parallel, one to the other.

Spirit-levels are often made of wood, which is very objectionable for the erector's use, because the lower or testing surface is apt to catch and hold particles of metal, and furthermore it is very susceptible to abrasion, and wears rapidly. It is preferable, therefore, that it be of iron or steel. The test of a spirit-level is its sensitiveness, and it is found in a properly constructed one that the bubble will move to a perceptible extent if a piece of gold leaf be inserted under one end. In a spirit-level which came into the hands of the author of this work he found the warmth of the finger when placed on its top sufficient to cause the bubble to move nearly the full length of its tube, the body of the level being a block of iron $1\frac{1}{4}$ inches square and 9 inches long. The movement of the bulb was caused by the heat of the finger expanding the top of the spirit-level and causing it to bend. To test the truth of a spirit-level, it should be placed upon a true surface, as a surface plate, and if the bubble comes to rest at the same spot in the length of the spirit tube when the level is tried turned end for end, the level is true. The test should be made several times.

The plumb-rule, though less used by machinists than formerly, is better for machinists' use than the ordinary wooden-bodied spirit-level, since it is more delicate if properly constructed. It should be formed as in Fig. 2450, the sides A A and B B being straight and parallel one to the other; C and D are two plugs of soft yellow brass let in so as to keep the line *l l* clear of the face of the level, so that there shall be no friction between them. At N are notches to secure the line, which should be as fine and as closely spun as possible.

The plumb-level, Fig. 2451, is also preferable to the ordinary spirit-level; its edges A, B must be straight and at a right angle one to the other, C and D representing brass plugs as before. The edge A of the rule or of the level should be laid upon a surface plate, and a fine line drawn on the face of these plugs with a scribing block, the coincidence of the line *l* with these marked lines testing the truth of the work.

Fitting or Making Joints.—The best form of joint to withstand pressure is the ground joint, and next to this, but more expensive, is the scraped joint. The difference between the two is as follows:—

For a ground joint the fitting with files or scrapers is only carried far enough to bring the fit sufficiently near that it may be

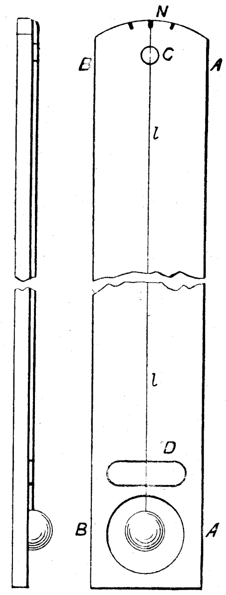

Fig. 2450.

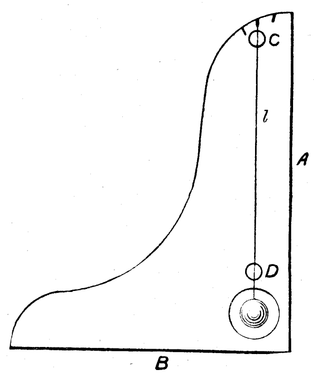

Fig. 2451.

finished by grinding the surfaces by rotating one upon the other with oil and emery interposed between them.

To grind a joint it is obvious that all the bolts or studs must be removed.

In a scraped joint the scraping is carried to such a point of correctness that the fit will be tight without grinding.

Joints in new work are easily ground, because the bolts or studs being new have not become rusted in their places and may therefore be readily removed; furthermore the joint may be ground before the studs are inserted. But in the case of old joints the studs may have become so rusted to their places as to render them liable to break off in the effort to extract them, and in such case it is better in most cases to make a scraped joint, which may be done with the studs left standing in their places.

To make a ground joint, as say a cylinder cover joint, proceed as follows:—

Put a thin coat of red marking upon the joint face of the cover, and after it is coated lightly and smoothly all over, the hand should be passed over the whole surface marked, because any grit left on the surface will cut the faces of the joint when they are rubbed together to fit them, and there is no wiping material that will so effectually clean dust from the surface as the hand will; and furthermore, the sense of touch will instantly detect any grit present. The cover may now be put into its place on the cylinder and rotated back and forth a turn or so to insure that it is properly seated; then we may strike it a light blow in different places with a piece of wood or the end of the handle of the chipping hammer; and if the cover does not fit pretty closely to its seat, a sharp metallic sound will be distinctly heard when the blow is struck over the parts of the face that are much out of true. Hence, by striking the blows all around the flange, we can easily find not only the high and low spots, but can determine, after a little practice, by the degree of the sound, how much the faces are out of true. We next rub the cover back and forth on its seat, so that the marking on the cover will mark the high spots on the cylinder face. If, however, we make the forward reciprocating movement of the cover a longer one than the backward, we shall give to it a gradually rotary as well as a reciprocating movement, and this will tell us if the face of the cover is true or not, for if the marking is removed from the face of the cover in two diametrically opposite places only, it shows that the cover itself is not true; and if the cylinder face also marks on two diametrically opposite places only, it is proof that both the faces are a good deal out of true: but there is no knowing which one is the most out, and so we must file off each an equal amount. If either face marks in more than two places it is evidence that it is pretty nearly true, and it follows that that face does not need much filing. Here it becomes necessary to state why the movement of the cover must, when being tried to its place, be back and forth, as well as rotated by the movement already explained. If we revolve a radial surface of metal upon a similar surface they are extremely liable to cut or abrade each other, and the presence of the least grit will inevitably cause them to cut; and if cutting once begins, the metal gathers upon the cutting part, increasing its size so that the groove cut will get deeper until a complete revolution has been made, and this rule applies to all revolving surfaces, but more particularly to radial or conical ones.

By making the movement a partly reciprocating one we destroy this tendency, and either imbed the grit into the iron or else work it out. To proceed, however. If during our testing the blows induced a secondary and metallic sound as above described, we take a rough file and ease the high spots on both the cover and the cylinder face, filing a good deal off the face that shows diametrically opposite bearing spots only, and but very little off the face that shows three or more bearing spots. In this latter case, indeed, it is better to use a second-cut than a rough file. We next wipe both faces quite clean, apply the marking to the cover as before, and try it to its seat again; rubbing it in the same manner to its seat and testing it for the metallic sound as in the first case. So soon as this sound ceases we may take a second-cut file and fit the faces until they bear in at least four different places, when a smooth file should be used and the fitting and trying continued, until a very light coat of the red marking will show both the cover and the cylinder face to mark in spots not more than an inch apart; and we may then take a flat scraper, ease away the high spots, pressing the scraper firmly to its work and making it cut fine scrapings, using the scaper in strokes of about $\frac{1}{2}$ inch for a large face and $\frac{1}{4}$ inch for a small one. When the two faces show about an even contact all over, the grinding may be performed as follows :—

The two faces must be wiped quite clean, and then with an oil-can we can run a line of oil around both the cylinder and cover faces, and then with the fingers sprinkle on them some dry grain emery, of a grade of about 50 for a cylinder whose diameter is, say, 14 inches or over, and of a grade of about 60 to 65 for smaller diameters; if, however, only coarser grades of emery are at hand it may be ground finer by abrasion on an iron block, using a hammer face to grind it with. The emery and oil being applied, we place the cover in its place upon the cylinder, and give to it the reciprocative rotatory movement already described, continuing the movement until the cover moves so smoothly and noiselessly that it is evident that the emery has done its duty. We then take the cover off and examine the faces.

If there are prominently bright spots upon either face, denoting that the emery has not operated upon them, it will pay to take the scraper again and ease away the dullest and most frosted-looking spots, which denote that they have suffered most during the grinding operation. The difference between the spots that have been the most and those the least affected by the grinding will be very plainly visible if the faces are wiped clean. We must continue the grinding operation with this grade of emery until the marks show the grinding to have been performed pretty evenly all over the faces, and we then apply a coating of oil and emery, as in the previous operations, the latter being in this case of a grade of about 70, moving the cover as before until it revolves so smoothly and noiselessly as to indicate that the emery is no longer doing any duty. Having continued this process, applying fresh emery and oil until the face appears true, we may perform the finishing and testing process, which is of the utmost importance, since it will detect the faintest possible defect in the job. Wiping the faces quite clean, we put the cover in place upon the cylinder again, and move it as before back and forth, and yet slowly advancing; but it must be borne in mind that if the cover makes the least jarring noise during the operation we must at once remove it and wipe it clean again, or the faces will abrade and become destroyed. There is no danger of this, however, if the cover be at once removed when the jarring sound is heard. If it be not heard, we continue the operation until the cover has made four or five revolutions, and then remove it, and we shall find that the emery and oil, which had impregnated the surfaces, have worked out. We again wipe the faces clean and put them together and rub one upon the other as before, bearing in mind that if the faces cling much one to the other, we must wipe them clean again. Usually the finishing process requires performing about three times, and then the faces will have become as bright and clear as a mirror, magnifying the slightest defect in the joint. Joints made in this way will stand any pressure without leaking (unless the pressure be so great as to spring the metal of the cover). It is well, however, when making the joint, to put a little oil or pure tallow on it, and it is from this that it is called in England a grease joint, while in the United States it is termed the ground joint. It is common, however, in England to finish the whole joint by scraping; but this is a much more tedious job, and not so good a one, after all. Here it becomes necessary to remark, that in order to be able to handle the cover readily, it is best to bolt to it a wooden lever overhanging both sides of the cover, and to serve as a handle in moving it. And during the grinding we may place a weight on the cover, which will greatly expedite the process. It would appear that this is a long job, but such is not the case; indeed, a 16-inch cylinder face and cover $\frac{1}{32}$ inch out of true one with the other can be got up in half an hour.

It is to be observed, however, that the cylinder cover that contains the stuffing box for the piston rod often carries one end of the guide bars, and in any event carries the gland whose bore requires to stand in line with the cylinder bore. It must be remembered that if more is filed off the top than off the bottom of the face, or *vice versâ*, the gland bore may be thrown out of parallel with the cylinder bore, and the guide bar seatings will be thrown out of parallel in the same direction.

To facilitate the making of ground and scraped joints it is preferable that the surface of the joint, both on the cylinder and the cover, project from the rest of the flange, from the bolt holes to the bore in the one case, and from the bolt holes to the body in the cover in the other, so that the bearing surface of the joint shall extend from the inside edge of the bolt holes to the cylinder bore only. This provides ample surface to make a joint, while reducing the surface to be operated upon.

TO MAKE A SCRAPED JOINT.—Let us now suppose that the studs are in their places, and it is decided, for fear of breaking them in taking them out, to make a scraped joint, and the process is as follows :—

The testing and marking of the high spots or places must be made by giving to one of the surfaces a light coat of red marking and then bolting up the cover moderately tight, screwing up the nuts at first until they just grip the work all around, and not letting one part of the cover face bear at any time with greater pressure against the cylinder face than there is on the diametrically opposite side of the cover, for the side under most pressure will receive the marking most readily. Especially is this the case when the two faces first meet, because even a low part of the face will show most contact under such circumstances, and then easing such marks away will make the cover a worse fit than it was before. When the cover is bolted home, the marking on the cylinder face may be made to transfer itself on to the high spots of the cylinder cover face more plainly if a piece of wood be placed on the cover and struck lightly with a hammer, moving the wood around and between the studs. If the wood be struck heavily it will cause an almost endless and assuredly a faulty job, because the force of the blow will spring that part of the cover to its seat on the cylinder face, whether it fits in that particular spot to its seat or not, and hence the filing or scraping may be done in places where it is not required, because the marking misleads. If the bolt holes are very close together, as in English practice, lightly striking the cover will prove an assistance; but where they are several inches apart, as in American practice, it is better to omit it, for the bedding marks will show plainly and properly if the marking be evenly distributed by the hand over the cylinder face, and the cover is bolted at each trial tightly to its seat, providing of course that the red marking is free from grit.

In a job of this kind it is difficult to know, when a leak occurs, whether the defect is in the cylinder face or the cover, and it is very desirable to perform the operation with a view to correct the defect rather than bed one face to the incorrectness of the other.

If then the stud holes are equidistant apart and concentric (so as to permit it), the cover may be tried on in one or two positions, and if the bearing marks occur on the cover at each trial in the same places it is the cover that is out; or if this occurs on the cylinder face, it is that face which is out. Since the studs are in their places the cylinder face may be best operated on by a scraper, while for the first part of the operation on the cylinder cover a file may be used. The corner at the junction of the cylindrical part of the cover (where it fits into the cylinder bore) should be scraped well clear, or it will be apt to bind on the edge of the cylinder bore and prevent the cover from screwing fairly home to the cylinder face. The joint should be made to bed well inside of the bolt holes, and coated with oil or grease when finally put together.

JOINTS FOR ROUGH OR UNTRUE SURFACES. — The most permanent form of joint for a rough or untrue surface is, for steam pressure, a gauze, and for water pressure, a pasteboard, or a duck or canvas joint.

A gauze joint is composed of copper wire gauze, having square meshes of about $\frac{1}{32}$ inch square; this gauze is cut out to fit over the joint surfaces, a single, double, or treble thickness being used according to the unevenness of the surfaces. A coating of red-lead putty is first spread over the joint with a piece of smooth surfaced metal; the wire gauze is then put on, and over it another coating of red lead; the cover is then put on, and the nuts screwed lightly home so as to bring the cover to bear against the red lead. Then any nut may be given a quarter or a half-turn, and the diametrically opposite one also given a half-turn, this process being continued until all the nuts have been screwed home a half-turn, when the process may be continued until the nuts are screwed firmly home. This is necessary, because if the nuts on one side are screwed home in advance of those on the other, the red lead on that side may be squeezed out too much and the joint will leak. In joints of this class the surfaces being rough it is not unusual to cut out the gauze wire as follows: Lay the sheet of gauze over the joint and cut it to the size by lightly hammering it over the sharp edges of the joint, which will cause the sharp edges to cut the copper wire. To cut out the holes place the ball piece of a hand hammer on the wire and over a hole and strike the hammer face several light blows, and the corners of the hole will cut the wire through.

The gauze joint will answer equally well for hot water as for steam joints, provided that it be given time to dry and become hard. If the joint can have a week in which to dry the red-lead putty may have about one-sixth of its bulk of white lead mixed with it, being made to a consistency of soft dough so that it will spread easily; and the amount being sufficient to fairly cover the gauze and no more, the soundness of the joint may be known by the lead squeezing out all around the joint edge as the bolts are screwed home. If the joint is to be used in a day or so after being made, the white lead should be omitted. In either case the lead should be mixed stiffly at first; the best lead should be used and it should be well hammered on an iron block, after which it may be thinned with boiled oil, or with a little varnish, which will cause it to harden more quickly.

For water joints requiring to stand high pressure, and to be used as soon as made, a paper, pasteboard, or a duck or canvas joint are best. The joint is made by using, in place of the gauze wire, one or two thicknesses of the pasteboard, duck, or canvas, cut out to the size of the flange, and with the necessary holes to receive the standing bolts and leave the bore of the pipe clear. If the flange of the joint is of copper, brass, or wrought iron, or, if of cast iron, is of sufficient strength to permit it, one disk may be made the full size of the flange, and a second may be made to have an external diameter sufficiently large to fit snugly inside of the bolt holes, which will form sufficient thicknesses if the flange is a fair fit to its seat; if it is not, however, three, or even four, thicknesses may be used, in which case at least one of them should fit inside the diameter of the flange across the bolt holes, as described. The disks being prepared, we spread on the first one a thin coating of red-lead putty, and then lay another canvas disk on, again adding the putty until the whole is completed. We then spread a thin layer of the putty around the hole of the seat and that of the flange, place the disk in position and screw the joint up, tightening down the nuts until they bring the flange to an equal seating all around and not sooner on one side than on another, for in that case the red-lead putty will be squeezed unevenly, and too much on the side screwed up to excess. The nuts should be screwed up very tight; the joint wiped, the protruding canvas cut off, and the joint is complete.

For very rude and rough joints, whether used under pressure or not, we may make, for either water or steam, a joint as follows: Taking four or five strands of hemp, we saturate them with a coating of white lead ground in oil, applying just sufficient to make the fibres of the hemp cling well together. We then plait the strands and coat the whole rope thus formed with red-lead putty, and place the strand around the hole of the joint, taking care that the ends lap evenly, so that the joint shall be of even thickness. It is better, however, to bend a piece of lead or iron wire to suit the size and shape of the hole in the joint, and then wind the hemp and red lead around the wire. And in cases where the flanges of the joint are sufficiently strong to have no danger of their breaking from the pressure due to screwing up the nuts, the piece of lead wire, if given a neat butt joint or neatly lapped, may be employed without any red-lead putty or hemp; this does not, however, make a good permanent joint. In cases where a joint requires to be made thick to accommodate the length of the pipe, pasteboard may be used in the place of canvas, giving to it a thinly-spread coating of red-lead putty on each side, and, if possible, leaving the pasteboard a trifle too thick and springing open the flanges of the joint to get the pasteboard into position without scraping off the red-lead putty.

Where it is required that a joint stand great heat or fire, asbestos board, about $\frac{1}{16}$ inch thick, makes a good and permanent joint. It is coated with red lead mixed thinly with boiled oil, containing as much as it will soak up, leaving a thin layer of the lead upon the surface of the asbestos. The holes for the bolts to pass through in the duck, canvas, pasteboard, or asbestos joint should be cut large enough to well clear the bolts.

For cold water, where it is not subject to great variations of temperature, common sheet lead makes a very good joint; but under excessive changes of temperature the expansion of the pipes will soon cause the sheet lead to squeeze out and the joint to leak.

Joints are frequently made with copper wire rings, made of a diameter to pass around the hole of the joint and lie within the diameter of the bolt holes, and brazed together at the ends; but if the joint be rectangular instead of circular the wire must either lie in a recess, or else a shoulder must be left for the wire to abut against, which will prevent its blowing or becoming forced out by the pressure.

In some practice softened sheet copper about $\frac{1}{32}$ inch thick is used to make joints on surfaces that have been planed. Joints of this kind are used for locomotive steam chests.

Rubber joints are used to make steam, water, and air-tight joints, and are usually made from what is known as combination rubber—that is, sheet rubber having a linen or other web running through it; with one such web it is called single, and with two webs two-ply, and so on. There is in many cases, however, an objection to this form of joint, in that it compresses; and hence in the case of the steam chest, for example, it affects the distance of the slide-spindle hole in the chest from the seat, and throws it somewhat out of line with the eccentric. In long eccentric rods the variation is of course minute; but still it exists, and must exist, since it is impossible to tell exactly how much the rubber will compress in making the joint. Furthermore, if it is required to break such a joint, the rubber will very often cling so tenaciously to the seat in one place and to the chest in the other, that it will tear asunder in breaking the joint. To obviate this as

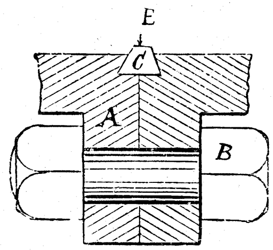

Fig. 2452.

much as possible, however, we may chalk the rubber on one face and slightly oil it on the other, so that the oil will aid the rubber in clinging to one face, while the chalk will assist it in separating from the other face of the joint.

Rubber joints slowly compress after being under pressure a day or so, and also if subjected to heat; hence they should have their bolts screwed up after becoming heated, or after having stood some time. It is advisable also that the rubber be as thin as the truth of the surfaces will admit. If it is necessary to use more than one thickness of rubber, the thickness may be made up of rings, whose diameter will just pass within the bolt holes.

The holes in a rubber gasket should be made larger than the

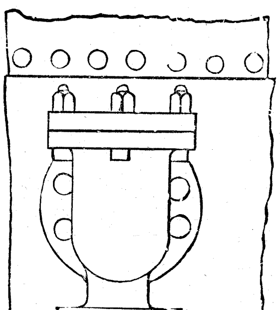

Fig. 2453.

bolt holes, so that there shall be no danger of the bolt, when being inserted, catching the gasket.

If the flanges should not come fair, and it is determined not to set them fair, the rubber should be as thick as the widest part of the opening between them, and shaved off to suit the thin side of the joint, and in this case the bolts must be tightened very uniformly and gradually around the joint to secure a tight one. If there is room to shave the gasket to the amount of taper, and use in addition a ring around the bolt holes, it will make a safer job.

When the gasket requires to be split to pass it around or over a rod, it should be cut through to the canvas on one side, and a short distance off cut through to the canvas on the other side; the rubber may then be stripped carefully back from the canvas and the latter cut through and passed over the rod, when the rubber may be put back and sewed to the canvas again.

Sheet rubber with a gauze wire insertion instead of canvas makes an excellent joint.

In Fig. 2452 is shown a method of making a steam-tight joint largely employed in England, upon the steam chest joint where the cylinders of crank shaft (inside cylinder) engines are bolted together. A is the flange of one cylinder, which is bolted to the other by the bolt B. C is a strip of copper let into a dovetail groove cut one half in one cylinder, and the other half in the other. After the bolts B are all firmly screwed home, hammer blows are delivered upon the top of the copper strip as denoted by the arrow

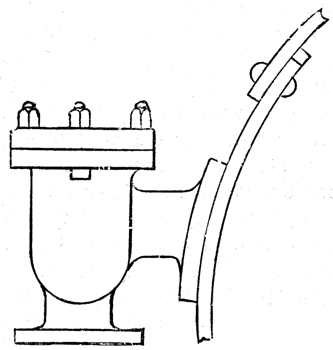

Fig. 2454.

E, expanding the copper so that it completely and closely fills the dovetail groove, and makes a steam-tight groove.

In riveting the copper it is necessary to hammer it evenly all along lightly, and only sufficiently to make it closely fill the groove, otherwise it will spring the joint open, and cause it to leak, notwithstanding the bolts B, which will give under the extreme strain.

Temporary joints are sometimes made by bending a piece of lead wire into a ring or frame, of such a size as to well clear the inside of the bolt holes. The ends are neatly joined, and the lead wire compressing and accommodating itself to the inequalities of the surfaces forms a joint.

JOINTS FOR BOILER FITTINGS.—Let it be assumed that the casting shown in Figs. 2453 and 2454 requires to be fitted to a boiler, both being new. In this case, the holes for the studs or bolts should first be drilled in the flange of the casting, which will reduce its weight and render it easier to handle. The casting should then be held against the boiler in its proper position and location; and, with a fork scriber whose width of points is equal to the widest space between the face of the casting flange and the boiler, pass the fork scriber around the fitting or casting with one point against the boiler shell and the other pressed against the edge of the casting, the result being to mark around the flange of the latter a line exactly following the surface or contour of the boiler, and at a distance from the boiler the nearest that will suffice to properly bed the casting to the boiler surface, or, in other words, the line that will exactly mark the amount of metal requiring to be cut off the flange face to make it bed all over; and that face may, therefore, be cut down to the line. In chipping and filing it, however, the straight-edge may be used to advantage as follows:—

Suppose the casting flange to be gripped in the vice facing the operator, as in Fig. 2455, and that L L represents the scribed line:

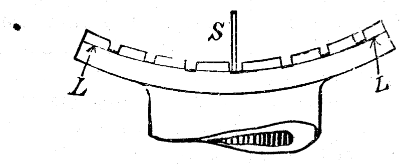

Fig. 2455.

then the cape chisel cuts may be carried clear across th flange, coming exactly down to the line on each side of the flange, while a straight-edge S may be used as shown to show when the cut is carried across level. Then, when the intermediate spaces are cut out with the flat chisel the surface will be of correct shape, and the surface may be rough filed. The casting should be cut clear down to the lines, and if the job has been properly set, marked and faced, no further trying will be necessary previous to marking the bolt or stud holes in the boiler. It is well, however, if the operator is inexperienced in this kind of work, to again set the casting in its proper position to correct the fit. But, with proper care, all the holes in the boiler may be marked without any second fitting of the flange, since the operation properly performed is bound to give correct results. In doing a job of this kind it must be borne in mind that it is very easy to consume more time in trying and altering the job than is required under proper conditions to do the entire job ; hence, in setting the casting, preparatory to marking it with the fork scriber, nothing is near enough that does not carry with it a conviction of perfect reliability ; and if any doubt exists it is better to go through the process again. If the casting flange varies much in shape from its seat, and rocks or is unsteady, wooden wedges may be placed beneath it, or a few pellets of stiffly mixed red lead may be placed on the boiler where there is most room between it and the casting, the boiler surface being coated or painted with red marking, so that the pellets shall adhere to it and not to the flange face. If the casting is too heavy to be steadied by hand, one hole may be drilled in the boiler and a temporary bolt inserted to hold the casting while setting it in position, and marking with the fork scriber.

When the flange is approaching a fit, it must be placed in position on the boiler and the stud holes marked on the boiler with an ordinary scriber, its point being pressed against the boiler while it is pressed against the side of the hole in the casting flange and traversed around it, so as to scribe on the boiler surface circles corresponding to the holes in the flange. From the centres of these circles others of the proper size of the tapping holes may be struck and the tapping holes may then be drilled, and the studs put in. The remainder of the fitting operation consists in applying red marking on the boiler surface, bolting the casting to its place and filing the high spots. The marking

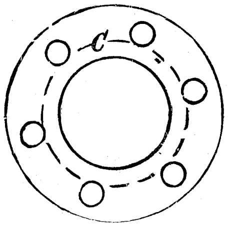

Fig. 2456.

is made to show plainly upon the flange by light hammer blows with a piece of wood interposed between the hammer and the flange face to prevent piercing the latter. These blows, however, should be lightly delivered, or they will cause the marking to be deceptive.

The fit of the flange to the boiler, however, should vary according to the kind of bolt used to hold the fitting to the boiler. If stud bolts are used they are supposed to screw into the boiler steam-tight, hence the flange may be fitted so that it has the closest contact with an annular ring extending from the outside of the bolt holes to the central hole of the flange, as shown in Fig. 2456, in which the area within the dotted circle C encloses the area to be most closely bedded. This is a highly important consideration in flange joints of every description, for, if a joint is made there, that is all that is necessary, and the fit outside of the bolt holes—that is to say from the bolt holes to the perimeter of the flange—has nothing to do with making the joint, unless the studs or bolts leak, and in that case the leak will find egress beneath the nut, unless grummets are used. A grummet is a washer made of twisted hemp, cotton, or other material, and coated with red-lead putty, and is placed beneath the heads of bolts, or under washers placed beneath nuts to stop leaks. It is not necessary to ease the flange from the bolt holes outward much, but to merely make the flange, or fitting, bed clearly and distinctly the most around the main hole, and outwards to the inside of the bolt holes ; for, if there was given too much clearance, the flange would bend from the pressure of the nuts, and would in consequence spring if made of brass, or perhaps break if made of cast iron.

To make the joint, gauze wire, pasteboard, or asbestos board may be used, or if the joint is to have ample time to set, a red-lead joint without the gauze may be used ; but in this case it is an advantage to cut up into pieces about $\frac{3}{8}$ inch long, and thoroughly shred some hemp, and well mix it in the lead, well beating the same with a hammer.

To preserve red-lead putty from becoming hard and dry, as it will do if exposed to the air, it should be kept covered with water.

In some cases joints of flanges to boilers are made by riveting the flanges to the boiler and caulking or closing the edge of the flanges to the boiler shell ; but this possesses the disadvantage

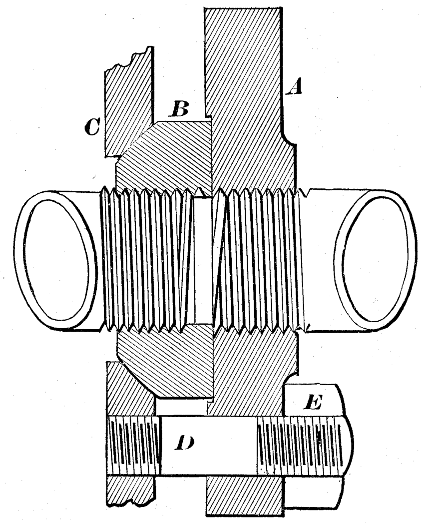

Fig. 2457.

that the rivets must be cut off to remove the fitting from the boiler when necessary, and access to the interior of the boiler is necessary in order to attach the fitting again by rivets.

Fig. 2457 (which is taken from *The American Machinist*), represents a joint for boiler fittings, designed to facilitate the breaking and re-making of the joint. C represents, say, a boiler plate, B a piece having a ball joint seat in C ground steam tight, and A a flange, say, for a feed pipe ; the studs D thread permanently into C, and the joint is bolted up by the stud nuts E. It is obvious

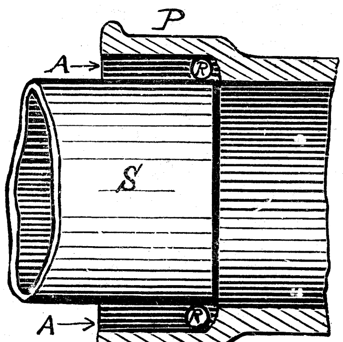

Fig. 2458.

that the ball joint between B and C permits the flange A to set at an angle if necessary.

Rust Joints.—These are joints made by means of filling the space between the flanges, or annular spaces, as the case may be, with cast-iron turnings, and compacting them with a caulking tool. Any interstices through which steam or water, &c., might leak become filled by the subsequent rusting of the iron cuttings, the rust occupying considerably more space than the iron from which it was formed.

Rust joints are employed upon very uneven surfaces, and for pipes for mains to go under ground. In former times this class of joints was much used in engine and boiler work, but of late years it has been to a great extent abandoned. In Fig. 2458 is shown the method of construction for a rust joint for what are known as spigot and socket joints for pipe work. S is the spigot and P the socket. R R is a metal ring, bound over with either dry hemp fibre or tarred twine or rope. The remainder of the space between the pipes at A A being filled with a cement composed of

Sifted cast-iron borings	100 lbs.
Sal-ammoniac	$\frac{1}{2}$ lb.
Sulphur	$\frac{1}{2}$ lb.

but when required to set quickly, 1 lb. sal-ammoniac may be used. These ingredients are thoroughly mixed with water immediately before being used, and just covered with water when used inter-

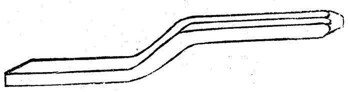

Fig. 2459

mittently. The cement is put into the space A A, in quantities sufficient to fill up about $\frac{3}{4}$ inch in length of the annular space A A, and then caulked by being driven in with the tool shown in Fig. 2459. Cement is then again put in and the caulking repeated, the process being continued until the whole space is filled.

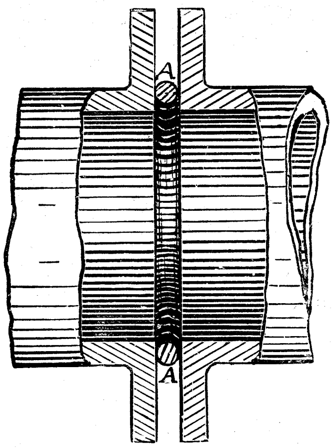

Fig. 2460.

In some cases (as in gas mains) the space A A is filled with melted lead, and when cold caulked with the tool described.

In Fig. 2460 is shown the method of making a rust flange joint; A A being a ring covered with hemp twisted around it, the cast-iron cement being caulked in as before.

The wire rings should be firmly gripped by the bolts to prevent them from moving from the caulking blows, which should be at first delivered lightly.

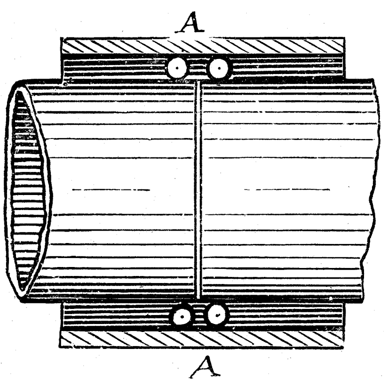

Fig. 2461.

In some cases pipes are joined with rust joints, as in Fig. 2461 in which A A is a sleeve, there being two rings of wire and hemp inserted as shown.

When flanged joints are made with a scraper, or ground joint, or with rubber, duck, or other similar material to make the joint, the length of the pipe, from face to face of the joint, must be made accurate.

Fig. 2462 is a face, and Fig. 2463 (which are from *Mechanics*), a sectional edge view of an expansion joint, being that used by the New York Steam Supply Company for the steam pipes laid under the streets to convey steam to buildings. The object is to provide

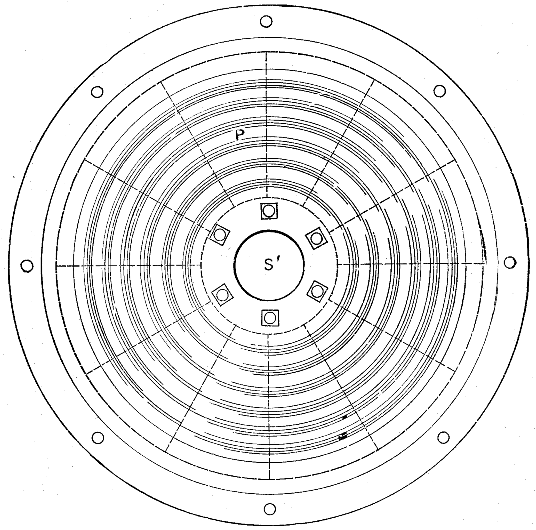

Fig. 2462.

a joint which shall permit and accommodate the expansion and contraction of the pipe under varying temperatures. P P are corrugated copper disks secured to the faces of the pipe ends by flanges, as shown, and gripped at their edges by the flanges of the cast-iron casing, and it is obvious that the ends of the pipe may move longitudinally carrying the corrugated disks with it. The cavity A is filled with steam, and to support the disks P against the pressure segmental blocks B of cast iron are placed behind them, the number of these blocks being as indicated by the dotted

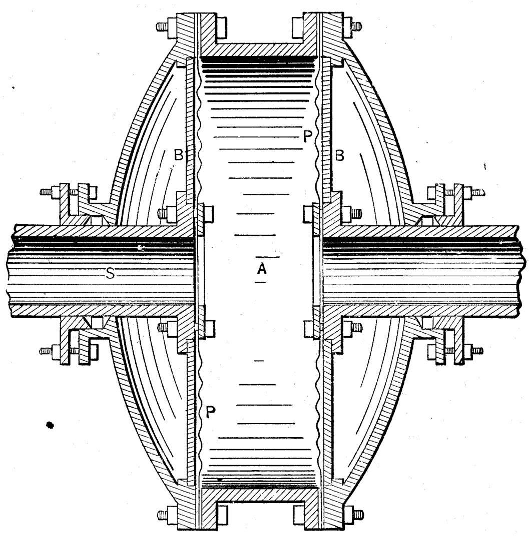

Fig. 2463.

radial lines in the figure. It may be added that this joint has been found to answer its purpose to great perfection.

Pipe cutters, for cutting steam or gas pipe by hand, are usually provided with either a rotary wheel which severs by rolling an indentation, or else are provided with cutting tools. The rolling wheel has the advantage that it makes no cuttings, cuts very readily and is not apt to break; on the other hand it is apt to raise around the severed end of the pipe a slight ridge, which with a worn cutter may be sufficiently great as to require to be filed off before the threading dies will grip the pipe. Cutting tools are apt to break and require frequent grinding; hence, as a rule, the rolling wheel cutter is generally preferred.

Fig. 2464 represents a cutter of this kind, the piece A carrying the cutter B, which is operated in the stock C by means of the threaded handle H.

Fig. 2465 represents a pipe cutter in which are a pair of anti-friction rollers and a severing tool bevelled on one edge only so as

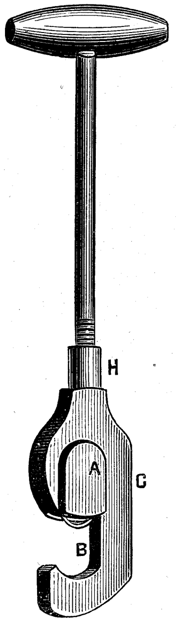

Fig. 2464.

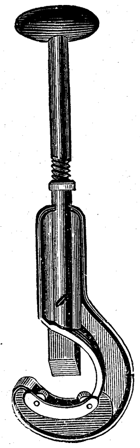

Fig. 2465.

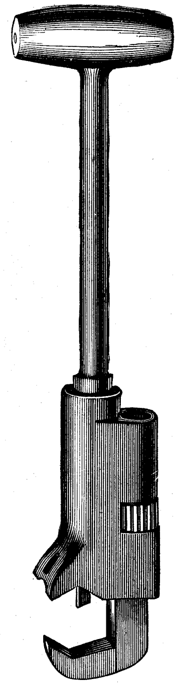

Fig. 2466.

to leave the end of the pipe face cut square, and the piece cut off bevelled on its face; or by turning the cutter round the reverse will be the case, the piece cut off being flat on its end.

The action of this cutter is, as in the case of the wheel cutter, simply that of a wedge, hence no cuttings are formed.

Fig. 2466 represents a pipe cutter in which a cutting tool is employed, being fed to its cut by the handle which is threaded similar to the handle shown in Fig. 2464. The end jaw is operated

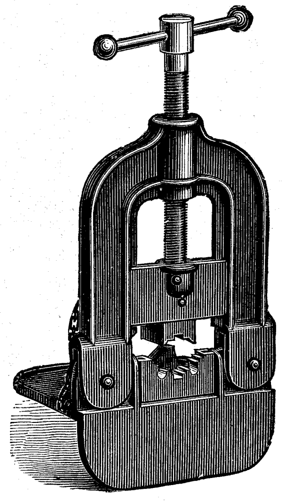

Fig. 2467.

to suit different diameters of pipe by means of the milled nut shown, which receives a threaded stem on the adjustable jaw.

PIPE VICE.—The ordinary bench vice is sometimes provided with an attachment to enable it to grip pipe at three points, and, therefore, hold it sufficiently firmly without squeezing it oval, but it is preferable to use a proper pipe vice, such as shown in Fig. 2467, which consists of a base frame bolted to the work bench and receiving a serrated die to grip the pipe. The upper die is carried to a frame pivoted on both sides to the base, and is operated to grip or release the pipes by means of the handled screw shown.

To change the dies one pivot is removed and the upper frame swung open, as in Fig. 2468.

The proper shape for pipe tongs depends upon the number of

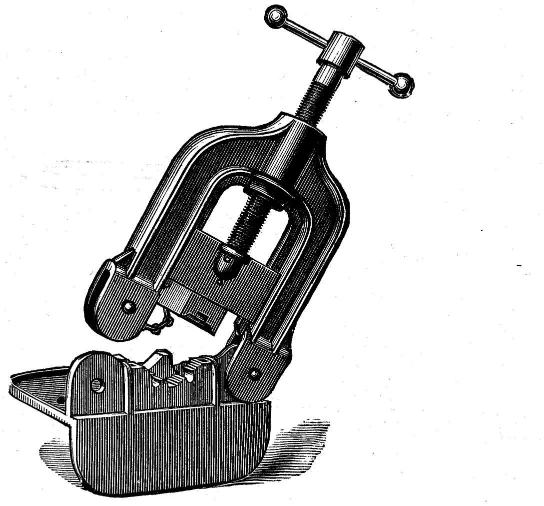

Fig. 2468.

sizes of pipe the tongs are intended for, but in all cases the point at which the gripping point should be is about as shown in Fig. 2469. This enables the edge at A to enter the work and grip it. If this point of contact were nearer to C it would be apt to slip upon the pipe, whereas, were it farther towards B, it would present a less acute angle to the pipe, which would be apt to jam in the tongs.

It is obvious that, if the tongs be moved in the direction of H, the whole power applied to F acts to cause the edge at A to grip the pipe, and that the length from A to G has an important bearing

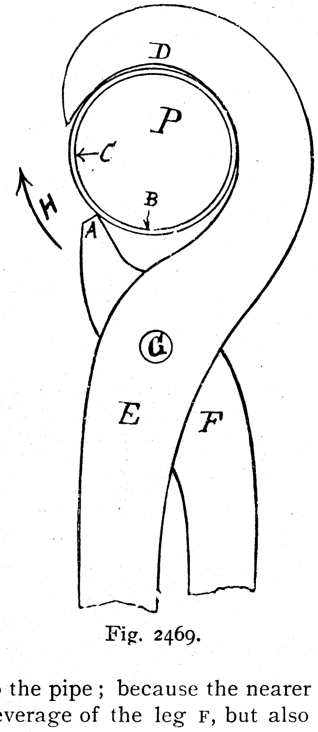

Fig. 2469.

on the grip of A to the pipe; because the nearer A is to G not only the greater the leverage of the leg F, but also the less A, with a given amount of movement of F on its pivot, endeavors to enter the pipe; hence the movement of A in a direction to grip the pipe is less in proportion to the movement of F, and has a corresponding increase of force. It follows then that the nearer the grip of A is to C, the less, and the nearer the grip to B the greater, its grip upon the pipe. But, by making the length of A such as to grip the pipe in about the position shown in the cut, there is latitude enough in the location at which it will grip the pipe to permit of the tongs being used upon pipe of a somewhat greater or less external diameter, increasing the availability of the tongs. Furthermore, if A gripped the pipe at or too near to B, it would be apt to indent it. The crown of the jaw D may be made to fit to the pipe or to be clear of it; for thin pipe, as solid drawn brass pipe, it should fit so that the pressure will not indent the pipe, but for strong iron pipe it is better to let it clear, which will not only afford a firmer grip, but will also better fit the tongs to take in different diameters of pipe. In some cases, as in adjustable pipe tongs, the jaw surface D is, for this purpose, considerably V-shaped, as will be seen presently.

It is obvious that as A grips the pipe automatically, the tongs may be moved through any portion of a rotation that the location may render most desirable. Pipe tongs are designated for size by the diameter of the pipe they are intended for; thus, a pair of inch tongs are suitable for pipe an inch in diameter of bore, the handles or legs of the tongs coming so close together that both can be readily grasped in one hand applied at their extreme ends. If, however, the tongs be applied to pipe of a larger diameter the legs will be wider apart, and one hand will be required to be applied to each leg to force them together. A complete set of

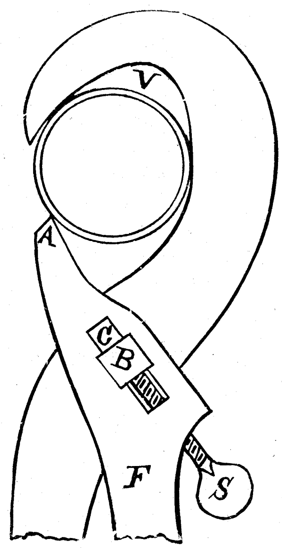

Fig. 2470.

pipe tongs, therefore, includes as many pairs as there are diameters of pipe, unless adjustable tongs be used.

Adjustable tongs are made of various forms; thus a simple plan is shown in Fig. 2470. The gripping surface of the jaw is shaped as at V, so as to admit varying diameters of pipe, the smaller diameters passing farther up the V, the distance of the end A of jaw, or leg F, being regulated to grip the pipe in the proper place by operating the screw S, which is tapped into the jaw F and pivoted in B, the slot C enabling F to move along B. The capacity of tongs of this design is about three diameters of pipe, as 1, $1\frac{1}{4}$, and $1\frac{1}{2}$ inches. There are various other forms of adjustable pipe tongs, but most of them possess the disadvantage that the adjustable jaw hangs loosely, involving some extra trouble in placing them upon the pipe, because one hand must be employed to guide the loose jaw and adjust its position on the pipe. Fig. 2471 represents tongs of this class, the gripping size being varied by moving the jaw A upon B at the various notches. The end of B is serrated to afford a firmer grip upon the pipe. Fig. 2472 represents another adjustable pipe tongs, which is made in two parts, a straight lever A and hooked lever B, the former passing through a slot in the latter. The back of the straight lever is notched and a serrated fulcrum piece C is pivoted in the slotted lever by a pin upon which the lever B receives its support when the tongs are in operation. The fulcrum piece is provided with a spring which retains the serrated edge in proper position to engage the notches in the lever A. By means of the thumb piece D, the piece C can be moved in either direction to increase or diminish the gripping size of the tongs. When the tongs are open the lever A can be moved within the slot and adjusted so that the tongs will fit the pipe. The fulcrum piece C, being pivoted, allows the full length

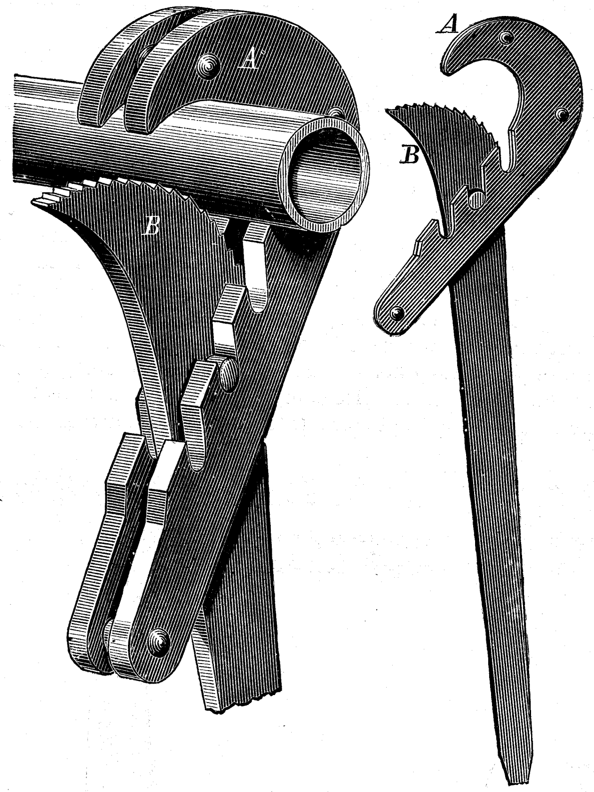

Fig. 2471.

of its serrated edge to come into contact with the corresponding portion of the lever A, so that the parts always have a firm bearing and are subjected to an equal wear.

A common form of pipe tongs of this class is shown in Fig.

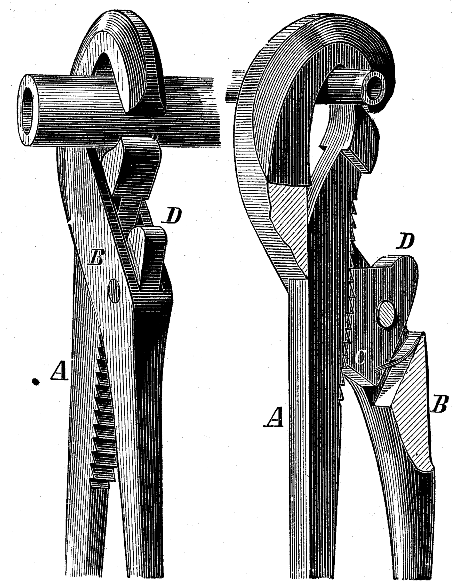

Fig. 2472.

2473, B being pivoted to A by a pin, and changing to various holes in A to suit different diameters of pipe.

ERECTING PIPE WORK.—In erecting pipe work care must be taken to have it align as true as possible, as well as to have the joints tight enough to stand the required pressure without leakage. If the elbows, tees, or other fittings are not threaded true, a pipe whose thread is not true with its axis may be selected or cut purposely to suit the error in the fitting, so as not to leave an unsightly finish to the job.

Suppose, for example, that in Fig. 2474, *e* is a pipe erected parallel to the wall, but that the holes in its elbows are tapped at an acute instead of at a right angle, then by cutting the thread on the end of pipe *d* untrue with its axis, its far end will rotate out of true as denoted by the shaded and by the plain lines, and all that will be necessary is to screw up the pipe sufficiently firm to make the joint, but to leave it in the position shown in the plain lines.

If the pipe tightens sufficiently before it has reached that position it may generally be eased by rotating it back and forth in the elbow with the pipe tongs. If this does not suffice, the pipe must of course be threaded sufficiently further along. To cut a pipe out of true to suit an untrue elbow, a very good plan is to cut the end of the pipe at an angle to its axis, which will cause the dies to cant over when starting the thread, but little practice being required to educate the judgment as to how much to do this to suit any given degree of error.

In erecting pipe it is best to begin at one end and screw each successive piece firmly home to its place before attaching another, so that the lengths of the pieces may be accurate and not vitiated by screwing them up and causing them to enter farther into the fittings. If it is probable that the piping may have to be taken down after erection, it should be put up at first screwed together rather tighter than will be necessary, as the thread fits become eased by being moved one within the other. This is especially the case with brass fittings, upon which it is best in cutting the lengths of pipe to have it of full length, as the threads will conform to each other sufficiently to cause the pipe to enter a thread or so farther if the pipe be rotated back and forth a few times in the fitting.

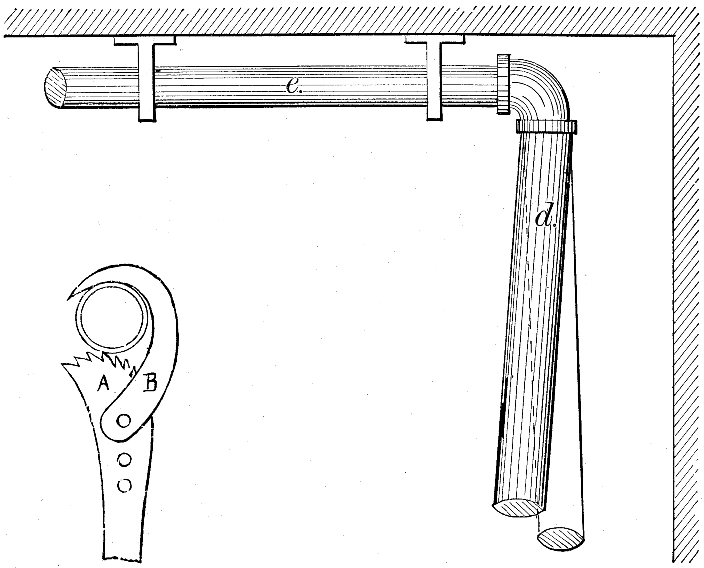

Fig. 2473.

Fig. 2474.

The fit should in all cases be made by tightness of thread fit, and not by the union or elbow face jambing against the end of the thread or the pipe, as joints in which this is the case will usually leak if used under pressure.

The thread of both the pipe and the fitting should be smeared with a thick lead paint. If the pipe is to be used as soon as erected, plain red lead and boiled oil should be used for the paint; but if it may stand a few days it is better to mix white and red lead in about equal quantities, as this, if given time to dry, makes a tighter job. The quantity of this paint should not be more than will thinly cover the threads, otherwise it will squeeze out when the pipes are screwed home, and falling from the end of the pipe within the fitting be apt to be carried by the steam or water to the valves, and getting between them and their seats cause them to leak. The iron cuttings should be carefully cleaned both from the pipe and the fitting for the same reason.

In cases where the piping may require to be used under heavy pressure as soon as erected, it is a good plan to use dry red lead in varnish, thoroughly hammering it to mix it well, and thinning it after it has been so hammered.

In case of emergency a loose pipe may be somewhat improved by wrapping around its thread a piece of lamp wick saturated with this varnish lead, beginning at the end of the pipe and wrapping the thread from end to end.

It is preferable that the stem of the valve stand nearly horizontal, so that any water of condensation may pass freely away with the steam and not collect and lie in the pipe as it does when vertical. If it be quite horizontal the water of condensation will drip through the stuffing box; hence it is better that it stand 10 or 12 degrees from the horizontal.

It is better in all cases to purchase nipples than to make them by hand, because when made in a machine the threads are more true to the axis than those made by hand; especially is this the case in short nipples in which there is not sufficient length to use the guide socket when engaged in threading the nipple with the hand dies.

It is a very good plan in making such short nipples to cut them off the end of a length of pipe that has been threaded by machine, and to screw on the threaded end a coupling. Into this coupling a piece of pipe may be threaded to afford a hold in the vice. If then the nipple is long enough, a guide to suit the size of the nipple may be used in the threading dies, or a guide socket to fit the diameter of the coupling may be used.

A globe valve should be so placed on the pipe that the pressure will, when the valve is closed, fall on the bottom face of the valve, so that the steam may be shut off while the valve stem is being packed.

Cotton lamp wick plaited to fit the packing space, and well oiled, is as good as anything to pack the stem with.

In taking old pipe down a refractory joint may be sometimes loosened by striking it with a hammer while it is under full pipe tongs pressure; or these means failing, the elbow or tee may be heated, which should be done as quickly as possible, so that the fitting may be hotter than the pipe. A very good method of doing this, where it is desired to save the fitting, is to pour red-hot lead over the fitting.

If it is not important to save the fitting, it may be split by a flat chisel, or by cutting a groove along it with a narrow cape chisel; or if the pipe is free the elbow may be rested on an anvil and hammered around its circumference, which will either free it or break it, if of cast iron.

When pipes are to be taken down and re-erected elsewhere they should all be marked to their fittings and places before being taken down, as this will preserve their lengths as near as possible for re-erection. Black japan is an excellent marking for this purpose because it dries quickly.

RE-FITTING THE LEAKY PLUGS AND BARRELS OF COCKS.—When a cock leaks, be it large or small, it should be refitted as follows, which will take less time than it would to ream or bore out the cock or to turn the plug, unless the latter be very much worn indeed, while in either case the plug will last much longer if re-fitted, as hereinafter directed, because less metal will be taken off it in the re-fitting.

After removing the plug from the cock, remove the scale or dirt which will sometimes be found on the larger end, and lightly draw-file, with a smooth file, the plug all over from end to end. If there is a shoulder worn by the cock at the large end of the plug, file the shoulder off even and level. Then carefully clean out the inside of the cock, and apply a very light coat of red marking to the plug, and putting it into the cock press it firmly to its seat, moving it back and forth part of a revolution; then, while it is firmly home to its seat, take hold of the handle end of the plug, and pressing it back and forth at a right angle to its length note if the front or back end moves in the cock; if it moves at the front or large end, it shows that the plug is binding at the small end, while if it moves at the back or small end, it demonstrates that it binds at the front or large end. In either case the amount of movement is a guide as to the quantity of metal to be taken off the plug at the requisite end to make it fit the cock along the whole length of its taper bore.

If the plug shows a good deal of movement when tested as above, it will be economical to take it to a lathe, and, being careful to set the taper as required, take a light cut over it. Supposing, however, there is no lathe at hand, or that it is required to do the job by hand, which is, in a majority of cases, the best method, the end of the cock bearing against the plug must be smooth-filed, first moving the file round the circumference, and then draw-filing; taking care to take most off at that end of the plug, and less and less as the other end of the plug is approached. The plug should then be tried in the cock again, according to the instructions already given, and the filing and testing process continued until the plug fits perfectly in the cock. In trying the plug to the cock, it will not do to revolve the plug continuously in one direction, for that would cut rings in both the cock and the plug, and spoil the job; the proper plan is to move the plug back and forth at the same time that it is being slowly revolved. As soon as the plug fits the cock from end to end, we may test the cock to see if it is oval or out of round. The manner of testing the cock is as follows:—

First give it a very light coat of red marking, just sufficient, in fact, to well dull the surface, and then insert the plug, press it firmly home, and revolve it as above directed, then remove the plug, and where the plug has been bearing against the surface of the cock the latter will appear bright. If, then, the bore of the cock appears to be much oval, which will be the case if the amount of surface appearing bright is small, and on opposite sides of the diameter of the bore, those bright spots may be removed with a half-round scraper.

Having eased off the high spots as much as deemed sufficient, the cock should be carefully cleaned out (for if any metal scrapings remain they will cut grooves in the plug), and the red marking re-applied, after which the plug may be again applied. If the plug has required much scraping, it will pay to take a half-round smooth file that is well rounding lengthwise of its half-round side, so that it will only bear upon the particular teeth required to cut, and selecting the highest spot on the file, by looking down its length, apply that spot to the part of the bore of the cock that has been scraped, draw-filing it sufficient to nearly efface the scraper marks. The process of scraping and draw-filing should be continued until the cock shows that it bears about evenly all over its bore, when both the plug and the cock will be ready for grinding.

Here, however, it may be as well to remark that in the case of large cocks we may save a little time and insure a good fit by pursuing the following course, and for the given reasons. If a barrel bears all around its water-way only for a distance equal to about $\frac{1}{16}$th of the circumference of the bore, and the plug is true, the cock will be tight, the objection being that it has an insufficiency of wearing surface. It will, however, in such case wear better as the wearing proceeds. Plug and barrel being fitted as directed, we may take a smooth file and ease away very lightly all parts of the barrel save and except to within, say, $\frac{3}{8}$ inch around the water or steam-way. The amount taken off must be very small indeed, just sufficient, in fact to ease it from bearing hard against the plug, and the result will be that the grinding will bed the barrel all over to the plug, and insure that the metal around the water or steam-way on the barrel shall be a good fit, and hence that the cock be tight.

The best material to use for the grinding apparatus is the red burnt sand from the core of a brass casting, which should be sifted through fine gauze and riddled on the work from a box made of, say, a piece of $1\frac{1}{2}$ pipe 4 inches long, closed at one end and having fine gauze instead of a lid.

A very good material, however, is Bath brick rubbed to a powder on a piece of clean board. Neither emery nor ground glass is a good material, because they cut too freely and coarsely, which is unnecessary if the plug has been well fitted.

Both the barrel and the plug should be wiped clean and free from filings, &c., before the sand is applied; the inside of the barrel should be wetted in and the plug dipped in water, the sand being sifted a light coat evenly over the barrel and the plug. The plug must then be inserted in the barrel without being revolved at all till it is home to its seat, when it should be pressed firmly home, and operated back and forth while being slowly revolved. It should also be occasionally taken a little way out from the barrel and immediately pressed back to its seat and revolved as before, which will spread the sand evenly over the surfaces and prevent it from cutting rings in either the barrel or the plug. This process of grinding may be repeated, with fresh applications of sand, several times, when the sand may be washed clean from the barrel and the plug, both of them wiped comparatively dry and clean, and the plug be re-inserted in the barrel, and revolved, as before, a few revolutions; then take it out, wipe it dry, re-insert and revolve it again, after which an examination of the barrel and plug will disclose how closely they fit together, the parts that bind the hardest being of the deepest colour. If, after the test made subsequent to the first grinding operation, the plug does not show to be a good even fit, it will pay to ease away the high parts with a smooth file, and repeat afterwards the grinding and testing operation.

To finish the grinding, we proceed as follows: Give the plug a light coat of sand and water, press it firmly to its seat and move it back and forth while revolving it, lift it out a little to its seat at about every fourth movement, and when the sand has ground down and worked out, remove the plug, and smear over it evenly with the fingers, the ground sand that has accumulated on the ends of the plug and barrel, then replace it in the barrel and revolve as before until the plug moves smoothly in the barrel, bearing in mind that if at any time the plug, while being revolved in the barrel, makes a jarring or grating sound, it is cutting or abrading from being too dry. Finally, wipe both the barrel and the plug clean and dry, and revolve as before until the surfaces assume a rich brown, smooth and glossy, showing very plainly the exact nature of the fit. Then apply a little tallow, and the job is complete and perfect.

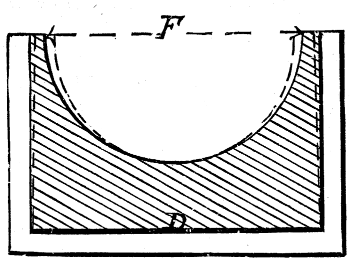

Fig. 2475.

In place of the tallow a soft paste of good beeswax and castor oil is an excellent application, the two being heated in order to thoroughly mix them.

The grinding material must be frequently changed to produce smooth work, because if the grinding cuttings accumulate in it, they will scratch and score the work. Indeed, it is a good plan when convenient, to hold the cock and plug under water while grinding them, and to occasionally lift the plug out, so as to wash out the cuttings.

The surface of a well-ground plug will be in all cases polished, and not have that frosted appearance which exists so long as active grinding is proceeding, and all that is necessary to produce this polish is to well work the plug in its barrel while keeping it quite clean.

FITTING BRASSES TO THEIR JOURNALS.—Brass bores always require fitting to their journals after having been bored, because the finished hole is not a true circle, but too narrow across the joint face, as at F in Fig. 2475, in which the full lines represent the form of the brass before, and the dotted line its form after being bored and released from the pressure of the devices or chuck that held it while it was being bored. This almost always occurs to a greater or less degree, and it arises from local strains induced from the unequal cooling of the casting in the mould, which strains are released as the metal is removed (in the process of boring) from the surface of the bore. It would appear, however, that if the finishing cut taken by the boring cutter be a very fine one it should leave the hole true and round, but the pressure which is placed upon the bearing to hold it against the force of the cut prevents the bearing from assuming its natural form until released from that pressure.

If a bearing be bored to very nearly its finished size and first released altogether from the pressure of the holding chuck, or other device, and then re-chucked, it is probable that the finished bore would be practically quite round and true, but such re-chucking is not the usual practice.

Suppose, however, that the bearing shown in Fig. 2475, be properly fitted to a journal, still improper conditions arise from wear,

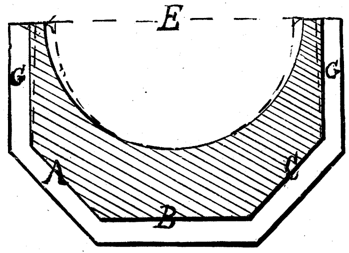

Fig. 2476.

because the area of the surface D becomes from the weight and from vibration condensed, and finally it stretches, causing the bore at F to close upon the journal and bind it with undue friction.

If the shape of the bedding part of the brass, or bearing, be such as shown in Fig. 2476, the surfaces A B and C will condense and stretch, closing the diameter of the bore at E and making the sides G G fit loosely in their places. It is to be observed that a similar condensation of the metal occurs to some extent around

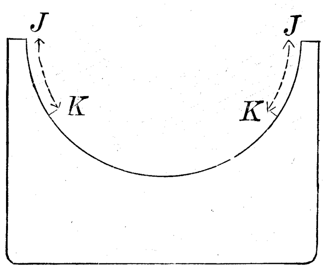

Fig. 2477.

the bore of the bearing; but this surface is being continuously worn away by the journal, and it is, therefore, at all times less stretched and condensed than that on the bedding surface.

There is, therefore, a constant action causing the brass to bind unduly hard at and near its joint face E, Fig. 2476, and thus to cause heating and undue abrasion and wear. To prevent this it is necessary to ease away that part of the brass bore, as is shown in Fig. 2477 from J to K, clear of the journal.

But in the case of bearings receiving thrust, as in engine main

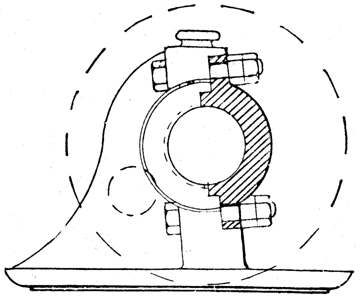

Fig. 2478.

bearings, the line of pressure is in a horizontal direction; and hence the most effective bore area to resist that pressure has been removed. Furthermore, the bearing area of the brass bore has been reduced, thus increasing the pressure per square inch on the remaining area.

The methods employed to avoid this evil are as follows:—In the form shown in Fig. 2478 the joint faces are at an angle instead of being horizontal and parallel to the line of the thrust, or the joint faces may be made to stand at a right angle to the line of journal thrust, so that the crown of the brass will receive the thrust. But the brasses will still close across the joint faces (as already described) as the wear proceeds, and the areas from J to K in Fig. 2477, must still be eased away, requiring frequent attention and giving a reduced bearing area. Furthermore, in proportion as the line of the joint faces of the brasses is at an angle to the line of thrust, the strain on the top or cap brass will fall on the bolts, so that if those joint faces be at a right angle to the line

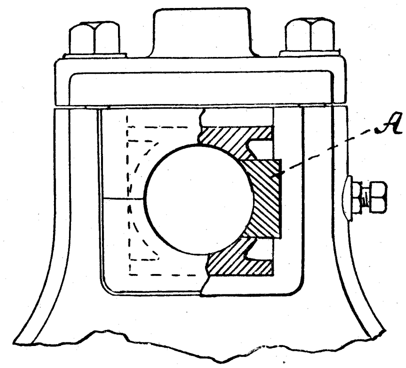

Fig. 2479.

of thrust, the whole strain of that thrust will fall on the bolts that hold the cap and cap brass.

Another plan is to make the bearing in parts, as in Fig. 2479, in which the top and bottom parts of the bearing extend to the joint face on one side, but admit a chock or gib, A in the figure, which may be adjusted by a set-screw as shown. By this means the bearing area may extend all around the bore. In some cases two of such chocks and set-screws, one on each side of the journal, are employed.

In place of the set-screws, whose ends, from receiving the pressure of the thrust, are apt to imbed themselves into the chock and

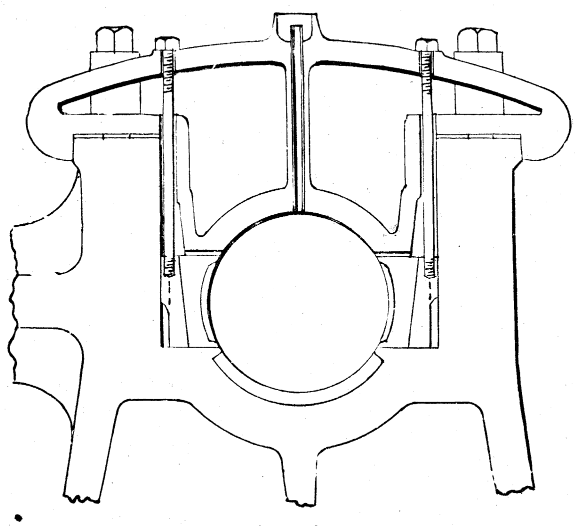

Fig. 2480.

to thus loosen the adjustment, wedges lifted by bolts passing up through the cap, as shown in Fig. 2480, are employed, being preferable to the screws.

In the Porter Allen engine the wedges pass clear through the bearing, as in Fig. 2481, so that they may be pushed up after the manner of a key and their pressure against the side chocks judged independently of the nuts at the top.

In some designs the top and bottom parts of the bearing are free to move in the line of the thrust, and the side chocks or blocks alone are relied on to resist the thrust.

When the brasses are in two halves, they may be fitted so as to have a known degree of bearing pressure upon the journal, and the fit may thus be accurately adjusted, in which case they will wear a long time before requiring re-adjustment. On the other hand when the side chocks are used the wear in the line of the thrust may be taken up as it proceeds. In one case the attending engineer cannot alter the fit of the bearing nor the alignment of the shaft, while in the other he can do both. Thus the facilities that enable him to make these adjustments properly also enable him to make them improperly. But this would be of no consequence, providing it could be determined whether the adjustment were improving the conditions without first making it. With an engine at rest it is easy to determine, by means of the connecting

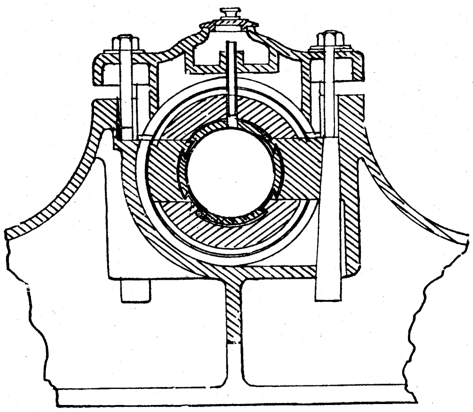

Fig. 2481.

rod, whether the chock adjustment is correct, so far as the adjustment of the shaft is concerned, but it is not easy so to determine the pressure of the chock on the journal; nor when each chock has two adjusting screws is it easy to determine when they both bear alike.

When the bearing is in four pieces, and three of them have two screws each, it is still more difficult to operate all so as to have the bearing equal on the journal. The fit to the journal can only be determined by the results: if too easy, the bearing pounds; if too tight, the bearing heats and wears.

But undue wear may take place without heating, and this is one of the greatest objections to this method of adjustment.

A design of bearing used in American locomotive practice is shown in Fig. 2482. Here the joint faces C, B of the brass is bevelled, fitting into a corresponding bevel in the box, which prevents the brass from closing across the joint face; hence, the bearing on the journal may extend all around the brass bore from the oil cavity A to the edges B C. The brass is, in this case, forced to its place in the axle box under hydraulic pressure, and this pressure springs the box open at H, making it wider; but when the box is put to work the brass compresses somewhat, and its surfaces conform more closely to the bedding surface of the box than when first put in, and this causes the box to close slightly at H.

To prevent this closure from carrying the brass with it and close it across the joint face (as in the case of the brass shown in Fig. 2476) the following plan is adopted. The brasses, after having been turned in the lathe, are filed along the entire surface (on each side) for a distance of about $1\frac{1}{2}$ or 2 inches, so as to clear the bore of the box near the bevels B, C. When the box is put into the hydraulic press, to have the brass forced in, a centre-punch mark J is made, and part of a circle L L is struck; when the brass is home in the box the arc of circle K is made, the distance between K and L showing how much the box has been sprung open by the brass; the amount allowed is about $\frac{1}{32}$ of an inch. If, as the brass is pressed in, it is found that this will be exceeded, it is taken out and eased. When the engine is running and the boxes spring to some extent they do not carry the brass with them, because the sides being eased away gives liberty to the box to come and go slightly; the bevels also tend to keep the brass bore open.

Here, then, the brasses may be fitted to align the axle perfectly, and it is not permitted to the engineer to alter that alignment, while at the same time the fit of the brass to the journal being made correct, the engineer cannot alter it. Under these conditions the whole area of the brass is effective in holding the journal, which increases the durability of the brass by keeping the pressure per square inch on the brass bore at a minimum.

If side chocks are used, however, it is better to set them up by wedges than by screw bolts, because from the tightness of the fit of such screws in the tapped holes, it is difficult to determine, with precision, with what degree of pressure the chocks are forced against the journal. Furthermore, the screws may not fit with an equal degree of tightness; hence, when screwed up with an equal degree of pressure, one end of the same chock may be set tighter to the journal than the other end, and any undue pressure of fit at either end tends to throw the shaft out of line as well as inducing undue wear. But when wedges are used to set up the side chocks the nuts operating those wedges may be an easy fit without fear of their becoming loosened (as set-screws in the line of thrust are apt to do).

On the fast engines of the Pennsylvania Railroad solid bronze boxes, without brasses, are used, and when the boxes require truing from having cut or from having worn oval they close them under a steam hammer, closing the bore across and enabling it to be trued out in the lathe without taking much metal out of the crown of the bore. The wedges and adjusting shoes are thickened when this becomes necessary by reason of the box closure or width.

If a brass bore does not bed fully and equally over the entire intended bearing area the part not fitting will at first perform no duty as bearing area, and the whole strain will be thrown upon a less area than is intended by the construction, causing undue abrasion until the brass bore has what is termed worn down to a bearing. The amount of this wearing down to a bearing may be so small as to be scarcely perceptible to ordinary observation, but if the oil that has passed through the journal be smeared upon stiff white paper, as writing paper, it will be found to contain the particles of abraded metal, which will be plainly distinguishable. Under these conditions the journal will have a dull, though perhaps a smooth appearance, and will not have that mirror-like surface which is characteristic of a properly fitted and smooth working bearing, while under a magnifying glass the journal will show a series of fine rings or wearing marks. It is necessary, therefore, that each brass be properly fitted to its journal so that it shall bed fairly and evenly over all the area of its bore that is intended to bear upon the journal.

The most expeditious method of fitting a new bearing box or brass to its journal is to first file the bore until it fits the journal

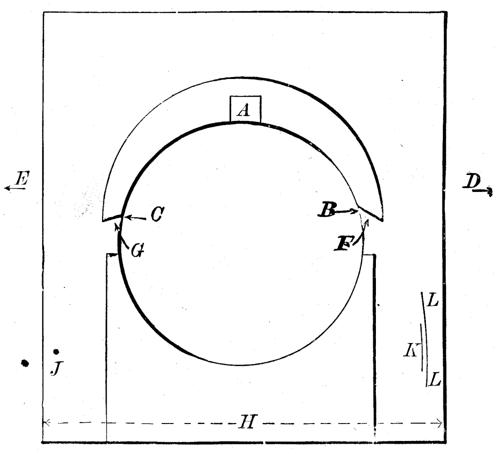

Fig. 2482.

when simply placed thereon by hand, and without going to the trouble to put the brass or the journal in position in the frame which holds them. So soon, however, as the crown of the brass beds to the journal along its whole length, the brass should be placed in its box, or in the frame, and the journal adjusted in its place and rotated so as to leave its bearing marks upon the brass bore, to assist which it may have a faint coat of red marking on its surface. The fitting should be continued both with file and scraper until the whole area of the part intended to bed fits well and is smooth and polished. To produce this result the finishing should be done with a very smooth half-round file, draw-filing so as to leave the marks in a line with the circumference of the bore, and finally with a half round scraper, which will remove the file marks The degree of contact should be such that, when the bearing is bolted up, brass and brass, as it is termed (which means that the joint faces of the brasses are held firmly together), the journal will rotate as freely as when the top brass is removed, while the contact marks on the top brass have been removed by scraping. By this means the fit will be just sufficient to permit the lubricating oil to pass between the journal and the bearing, and the journal will work freely and easily without any play, knock, or pound. If, when the top brass or bearing is bolted home and the shaft is rotated by

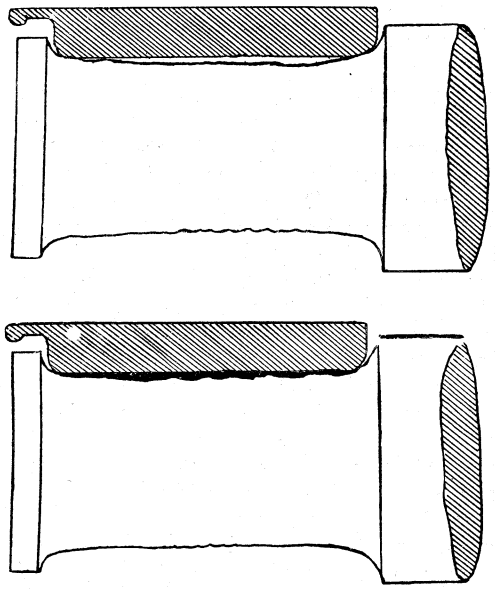

Fig. 2483.

hand, that brass on removal shows contact marks on its bore, although it may rotate comparatively easily it will be so tight a fit that the oil cannot pass, and as a result the wear, instead of producing a glossy surface, will produce a dull one, and undue abrasion will ensue even though no rings appear.

When brasses are held in rods that connect two journals together the fitting of the brass bore must be conducted with a view to have the brasses fit their journals all over the intended bearing area of their bores, which can only be accomplished by trying the brass bores to their journals while in the rod, in the manner to be hereafter described with reference to connecting rods and to lining engines.

When a journal is worn in rings, or so rough as to cause destructive abrasion and undue friction, it may be refitted as follows:—First, with a smooth file draw-file the journal in the direction of its length, taking off all the projecting rings. Then sweep a very smooth file that is somewhat worn (which will cut smoother than a sharp file) around the circumference of the journal so that the file marks will be in the plane of revolution. Then wrap a piece of fine and somewhat worn emery paper around the journal, and wrap around it (say twice around) a piece of coarse string, leaving the two ends about two feet long. Take one end of the string in each hand and pull first one end and then the other, causing the emery paper to revolve around the journal and smooth it.

To refit the bearings, first with a smooth half-round file remove the rings or rough surface, and then fit the surface with the file, so that when in its place the journal is rotated the contact marks show a proper bearing. Then draw-file the bore with a smooth half-round file and finish with a half-round scraper, easing away the high spots until the bore shows proper contact and is smooth. A piece of fine emery paper may then be wrapped around a half-round file and the surface smoothed with the emery paper moved across the bore and not in the direction of the circumference of the same. The emery paper should be well worn for the finishing and of a fine grade number, so as to leave a bright polish and not dull marks.

In some practice the bores of brasses are left rough-filed, the file marks being lengthways of the bearing of bore. If the journal requires smoothing it is draw-filed lengthways of the journal. The philosophy of this is, that the file marks will hold the oil and afford unusually free lubrication while the bearing and journal are wearing down to a bearing.

But where the framework holding the bearings and journals are rigid, these bearings and journals may, with care, be fitted to a polished and equal bearing, leaving a smoother surface than that produced by wearing down to a bearing. But if, as in the case of a locomotive, the framework is subject to torsion, rough surfaces left to adjust themselves are possibly better than those accurately fitted, because the whole framework holding the bearings changes its form when the full load is upon it and after put to work, and the fitting done when there was no load upon the parts is no longer quite correct. The lubrication of the bearing, however, should be very free, and the effort appears at present to be to afford more ample oil ways than hitherto even at some sacrifice of bearing area.

Lead-lined Journal Bearings.—If a journal is worn in grooves or undulations it becomes impracticable to properly fit the brass to it without reducing its diameter to remove the rings, and to obviate the cutting and heating which necessarily follow, as well as to obviate the necessity of fitting the brasses at all, Mr. D. A. Hopkins introduced lead-lined bearings; the lead lining being merely auxiliary to the bearing proper, which is made preferably of hard bronze, and to which the thin layer or facing of lead is firmly attached by a soldering process, so that the two metals are virtually one piece. Into this lead facing the journal, under the pressure of the car, moulds or imbeds itself from the start, and afterwards gradually wears its way through it into the hard metal. The perfect fit thus secured under all conditions of the journal, aided with proper lubrication, not only prevents heating, but secures the full wear of the brasses, and makes them at all times perfect counterparts of the journal surfaces.

Fig. 2483 shows at the top an unfitted bearing without the lead lining, resting upon a worn and badly-cut journal, the only points of contact being near the ends. For obvious reasons such a journal is sure to run hot.

The engraving below shows the application of the lead lining to the same journal, the dark shading between the journal and bearing representing the lead which has been pressed into the worn and hollow surface of the journal, forming a complete bearing and distributing the weight equally upon its surface.

Fig. 2484 represents an end view of an unfitted journal and the same lead lined.

The lead compresses until the brass meets the journal and thus

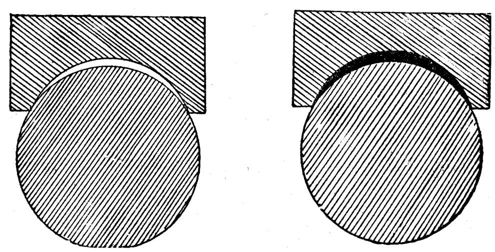

Fig. 2484.

permits between the two contact over the area that does fit or touch; while the lead fills the remaining area of the brass bore, giving it a bearing on the journal, thus relieving the touching points from receiving the whole weight of the load, and preventing the cutting or abrasion that would otherwise occur. As, however, the wear takes place the lead compresses, permitting the journal and brass to come into bearing over its full area, being obviously effective providing the bearing be kept free from grit, which would imbed in the bearing and cause it to unduly wear the journal.

If a brass is too tight a fit upon its journal, heating and abrasion, or "cutting" as it is termed, ensues. But if a brass or box does not fit close to its journal, lost motion and sometimes knocking or pounding ensues. When the joint faces of brasses abut, or come brass and brass as it is termed, they should be a proper fit to the journal when they are keyed, or otherwise set up close together; hence there is no danger of either having a pound in the brass, or of heating and cutting. The objection to this plan is that the brasses must be removed from their boxes and the joint faces filed away to let the brasses together, to take up the wear; hence, in positions in which it is difficult to get the brasses out, the joints should be left open, while in all cases where they can be readily removed they should be made brass and brass.

It is to be observed that brasses that come brass and brass require less adjusting and last longer than those left open,

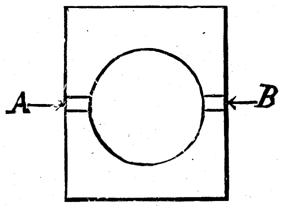

Fig. 2485.

because the latter often suffer from the abrasion due to an improper adjustment.

In brasses that are left open, it is not an uncommon practice to adjust the fit as follows: Between the brass joint faces at each of the four corners a piece of lead wire is inserted; the brasses are keyed as close home as can be upon the journals, which compresses the lead wire; the top brass is then released until the piece of lead wire can be moved freely between the brass joints.

A compromise between the brass and brass and the open joint is sometimes effected by the insertion of slips, as shown in Fig. 2485 at A, B. These slips may be taken out by simply removing the top brass, while their reduction of thickness lets the brasses together to take up the wear. The thickness for these strips may be readily obtained by means of the pieces of lead wire used as already described.

In the case of large brasses which come brass and brass, much of the filing on the joint faces to let them together may be saved

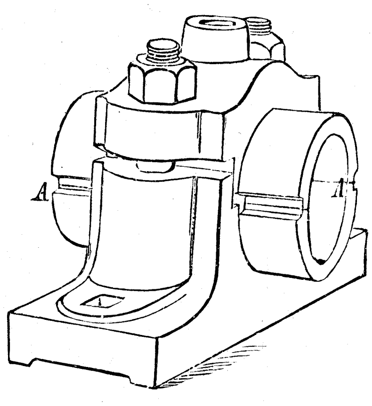

Fig. 2486.

by reducing their thickness and area by cutting away part of the metal, as at A A in Fig. 2486.

To enable the removal of bearings for renewal, or to refit them without taking the shaft out, various forms of construction are employed, of which Fig. 2487, which shows a main bearing, is an example.

Thus, when the cap is removed the side chocks, or gibs as they are sometimes called, can be lifted out by eye-bolts screwed into the holes at *c*; the weight of the shaft can then be sustained while the bottom piece D is removed.

A great deal of trouble in fitting journals and bearings may be avoided if the best conditions are observed in their manufacture. If, for example, the conditions of casting are uniform, and the diameter of the bearing bore and journal bores are constant, that is to say, when a great number of pieces are to be bored, the amount the bearings will close across the joint being definitely determined, the conditions of boring may be made such as to allow for the closure, and the fitting in this respect may be facilitated; but this applies to small bores only, as, say, three inches and less in diameter, because in larger diameters there will be sufficient variation in the amounts of contraction across the joint face to render it necessary to fit to some extent at least the bores to their journals.

In some cases slips of paper are placed between the joint faces of the bearings, or if the joint faces do not meet, slips of brass may be placed between them; or again the conditions of chucking or holding the bearings to bore them may be such as to hold them a certain amount farther apart than they will require to be when on the journal. The bore is then made sufficiently larger than the diameter of the journal that it will be as nearly as possible round after being removed from the boring machine, and will bed down fairly upon the journal without being fitted with a file, which saves considerable labor. But unless the bearings are so held as to be to some extent self-adjusting for alignment, there is liability of the axis of the bore not being quite true with the axis of the journal, the amount being so small as to escape detection

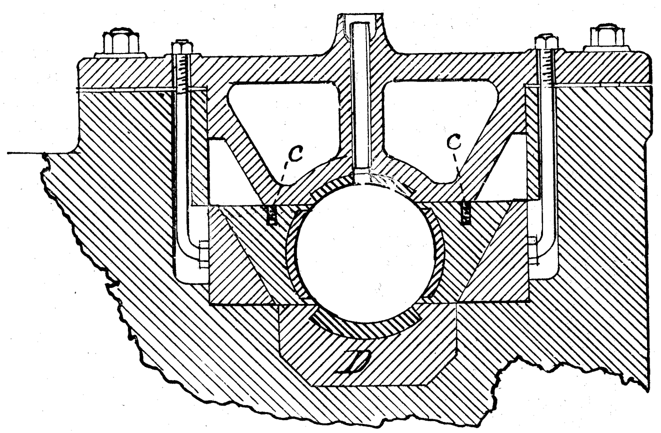

Fig. 2487.

save by trial for fit with the shaft, and the bearings in their respective positions. It is a difficult matter, in the absence of special holding devices, to chuck a bearing, especially if a long one, so true in a boring machine or lathe as to insure that its bore shall stand in absolutely correct alignment with the journal when placed in its position in the framing where it is to operate, and it is for this reason that many bearings are bored while in their frames. In some cases, however, this difficulty is overcome by so constructing the bores and the pieces holding them that the boxes may swivel and adjust themselves, as in the case of the bearings of line shafting.

Examples of the oil cavities for bearings are given as follows:—

For journals of small diameter oil cups screwing into the bearing cups, with feed-regulating devices, are generally used, and the same are used in the case of two half-brasses. But if the journals are of large diameter, as, say, 5 inches or more, oil receptacles are often cast in the caps.

In the absence of side chocks in the bearing all the oiling usually proceeds from the top, save perhaps that an oil groove may be provided in the crown of the bottom brass.

Fig 2488 represents a bearing lubricated from the top and bottom; thus in the cap is an oil cup or cavity from which passes nearly down to the bearing a brass tube containing cotton wick, which slowly feeds the oil to the bearing.

Fig. 2489 represents this tube and wick removed from the bearing. This plan of feeding is largely used on marine engines and on locomotives. When used upon stationary bearings the cotton wick need not fill the tube, but if used on reciprocating parts it should fill so that the oil may not spill over and pass too freely down the tube. In either case, however, it is desirable to twist in the cotton a piece of fine copper wire, and bend the ends over the top of the tube to keep the wick in place in the tube.

The bottom of the bearing, Fig. 2488, is provided with an oil

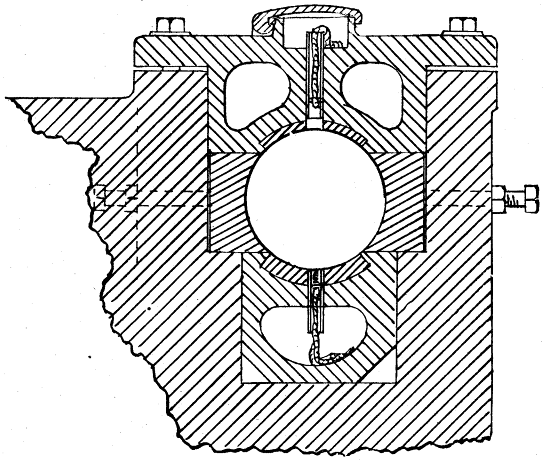

Fig. 2488.

cavity and a similar tube and wick. Usually, however, the oil is fed in at the top only, except in the case of locomotives, because in them all the weight falls on the top brass; hence, the bottom may be utilised as an oil receptacle. In English locomotive practice this receptacle as a rule merely catches the oil that has passed through the bearing box, but sometimes a roller is inserted and forced against the journal by springs so as to rotate, by friction, with the rotating journal.

Fig. 2489.

The bottom of the roller runs in oil so that the roller feeds the journal with oil, but ceases to feed when the journal ceases to rotate, an advantage not possessed by self-feeding oil cups, or by the cotton wick syphons shown in Fig. 2489.

The oil ways or oil grooves are usually provided in small journal brasses as follows:—

It is obvious that if the joint faces of the brasses are left open and oil be supplied to one brass only, a great part of the oil supplied will pass out between the joint faces before reaching the other brass, and one brass will therefore be better lubricated than the other, unless each brass be lubricated independently. Even in this event, however, a great part of the lubricating material will be lost from finding rapid egress through the opening of the brasses. This may be to some extent prevented in brasses whose joint faces lie horizontally by chamfering the edges of the bore so

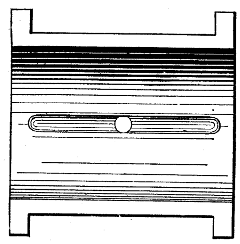

Fig. 2490.

as to form a trough extending nearly to the ends of the brass, as shown in Fig. 2492. Now it is obvious that the oil hole must always be above the journal or bearing bore; hence when the joint faces stand horizontal, the oil hole should come through the crown of the brass, and oil grooves are necessary to convey and distribute the oil along the bore. A single groove, as in Fig. 2490, is sufficient for light duty, but for heavy duty a double groove, such as shown in Fig. 2491, is necessary.

When, however, the joint faces stand vertically and come brass and brass, the oil hole may be filed half in the joint face of each brass, and the edges chamfered off as in Figs. 2492 and 2493, A B representing the chamfers and C the oil hole, the two brasses put together appearing as shown in section in Fig. 2493.

This plan has the advantage that the oil is confined within the journal, except in so far as it may in time work through the ends of the journal bore, while there are two oil grooves provided without reducing the bearing or bedding area of the brass. When

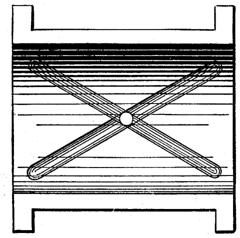

Fig. 2491.

the oil grooves run diagonally, as in Fig. 2491, there is the advantage that the length is greater, and lying nearer to the plane of rotation the oil flows along the grooves easier, being assisted by its frictional contact with the journal, but on the other hand the bearing area of the brass on the journal is so much the more reduced.

Oil holes that are not provided with oil cups should be provided with small wooden plugs, which will serve to keep the dirt and dust out; they should be made of as small diameter as the quantity

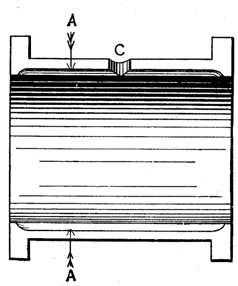

Fig. 2492.

and nature of the lubricant to pass through them will admit of, and should be left plain at the top and not countersunk, because the countersinking simply forms a dish that will collect dust, &c., which the oil applied will carry down into the bearing.

In some cases there is provided an oil dish around the oil hole, and this dish is filled with tallow that will not melt under the normal temperature at which the brass is supposed to operate. But if from defective oil lubrication or other cause the bearing

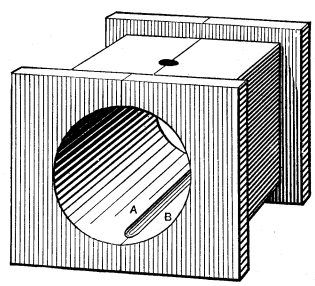

Fig. 2493.

begins to heat, the tallow will melt, and flowing through the oil hole afford the needed lubrication.

It is to be observed that the lubrication of a bearing in which the pressure is moved alternately from one half of the bearing to the other is far easier to attain, and more perfect, than in one in which the direction of the journal pressure is constant, because in the latter case the journal pressure acts to squeeze out and exclude the oil continuously, whereas when the pressure is relieved alternately on each brass, the oil has an opportunity to pass back between the relieved surfaces. Again the lubrication is more perfect when the direction of the journal motion is periodically reversed, as the passage of the oil through the bearing is retarded by the motion, and yet again the abrasion is reduced because, as stated when referring to rotating radial surfaces, the particles of metal abraded add themselves together and form cutting pieces when the motion is continuous in one direction, whereas in a reversing motion the particles are kept separated and flow out more freely with the oil that passes through the journal.

If a shaft having a continuous direction of rotation be given end play so that while rotating it may move endwise, the particles abraded are again kept separated, and the conditions of lubrication are such as to give a minimum of wear, because the formation of fine rings or serration is avoided, the end motion serving to cause the wear to smooth the surfaces.

When a shaft has a collar that is subject to end pressure, the oil way may be carried up the face of the collar as in Fig. 2494 at B. So also where very free lubrication is required, an oil groove may also be cut in the journal itself, as at C in the figure. This plan is adopted by some American engineers upon the crank pins of steam engines, the grooves being cut on diametrally opposite sides of the pin in a line with the throw of the crank.

Referring now to the oil itself, it is generally conceded that a pure sperm or lard oil is equal to any that can be used for general journal lubrication, but the ordinary purchaser has no means of knowing if the oil is pure. The requirements of an oil for lubricating purposes are given in the following paper on testing the value of lubricants, which was read by Mr. W. H. Bailey before

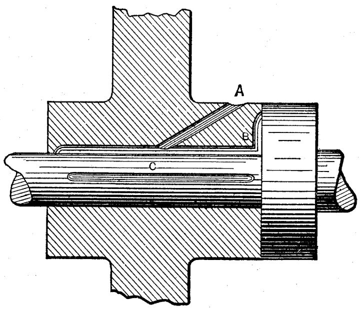

Fig. 2494.

the Manchester (England) Institution of Employers, Foremen and Draughtsmen :—

"A fact in connection with oil and lubrication is probably about as difficult a thing to describe as anything which agitates the minds of engineers and mechanical men. We appear to have very little published information on the subject, except that which describes the labors of Morin, of France, about forty years ago, and that which has been given to us by Professor Rankine more recently in this country. Those investigators who preceded Morin do not appear to have published information of very much value, or which can be used with profit for the discussion of lubricants, for their researches have been more concerning the proportions of bearings, and the value of different materials of construction, rather than the value of different lubricants.

"At the present moment so little is known generally concerning the performance of different oils, that the public are much at the mercy of the vendors of these oils, who can make almost any assertion they like without fear of contradiction.

"The valuable discoveries of our distinguished townsman, Dr. Joule, have enabled us to look upon the cost of friction and the cash value of heat as mere questions of arithmetic. Dr. Joule's investigations have been put into such forcible and elegant English by Professor Tyndall, and other students of the science of force, as to cause us to understand that when friction is produced heat is lost, and that all energy thus wasted passes away in this heat, which may be measured and valued with nearly as much facility as any article of commerce. We may gather from this knowledge, when we apply it to workshop economy, that if a pedestal or bearing becomes so hot through friction as to cause 1 lb. of water to be raised only one degree Fahrenheit in temperature in one minute, that heat has been lost equal to that which would be created by a weight of *one pound falling through a space of 772 feet.* We are told that if we apply this conversely, that heat has been lost which would lift 1 lb. weight 772 feet ; and if we apply these illustrations still further, and imagine forty-two pedestals or bearings losing heat by friction in a similar manner, we may inform ourselves that we are losing nearly 1 horse-power, because they represent 32,424 foot-pounds of force ; and if we know from our books what our coal costs, it will take very little trouble to give us the exact cash value of this friction and destructive action.

"What is friction ? It may be described as the effect produced by two bodies sliding one upon the other, which have upon their opposing surfaces minute asperities, which interlock with each other. The sliding movement which forcibly removes these minute irregularities creates what we call friction. Friction is reduced when these asperities are small, and lubrication is resorted to to prevent that loss of power caused by motion under these conditions. The chief lubricants used are oil and tallow, which have a less coefficient of friction than the parts in contact. It may be well now to state that the term 'coefficient of friction' is an expression which indicates the proportion which resistance to sliding bears to the force which presses the surfaces together. There is little friction when this amounts to only one-twentieth, it is moderate when it is one-tenth, and it is very high when it is a quarter or twenty-five per cent. of the force which presses the surfaces, together, as I before said.

"QUALITIES OF LUBRICANTS.—Good lubricants should have the following qualities : (1) Sufficient body to keep the surfaces free from contact under maximum pressure. (2) The greatest possible fluidity consistent with the foregoing condition. (3) The lowest possible coefficient of friction. (4) The greatest capacity for storing and carrying away heat. (5) A high temperature of decomposition. (6) Power to resist oxidation ; or in other words, the influence of the atmosphere upon them. (7) Freedom from corrosive action on the metals upon which they are used. It will thus be seen that many conditions have to be carefully taken into consideration ; and further, it may be stated that an oil which may be good for heavy bearings may not be desirable for use on light spindles, and for delicate machinery like clocks and watches, where very little power is required to be transmitted beyond that of overcoming their own inertia ; and also that oil which is good for small machinery running at quick speeds is very often useless for heavy pressures and large shafting. For very heavy bearings tallow and other solid lubricants are used, such as mixtures of sulphur and tallow, asbestos, soapstone with asbestos, graphite, caustic soda, beeswax, and other similar mixtures, which find favor among locomotive engineers and those in charge of heavy machinery. The pressure that can be borne by a good lubricant for a useful length of time depends upon the nature of the bearings as well as upon the lubricant itself. The velocity of the rubbing action also must be taken into consideration. The maximum of pressure that solid lubricants will bear without destruction is unknown. For steel surfaces, lubricated with best sperm oil moving slowly, 1,200 lbs. pressure per square inch of bearing surface has been found permissible. Under the pivots of swinging bridges several thousand pounds per square inch have been found to work, and for iron journals 800 lbs. per square inch should not be exceeded.

"Lubricants in the market vary much in cost as well as in quality, and very often it is found that the varying prices bear little or no relation to the value of the article purchased. Probably the best test of value is one with which I was familiar some years ago. It consisted of a small engine very much overworked, which stopped and refused to move or go at the proper speed if the shafting had not been lubricated with good oil.

"TESTING BY DESTRUCTION.—The instrument here illustrated, in Figs. from 2495 to 2501, to which I call attention, consists of a bed-plate, having upon it a piece of shafting upon which friction is created by means of two brass steps, the speed at which it is driven being about 300 revolutions per minute. The friction is brought to bear by levers and weights somewhat after the manner of a friction brake as shown in Figs. 2405 and 2500. In the top step is a thermometer for indicating any increase of temperature caused by the friction. A small index indicates the number of revolutions that the shaft makes for any given temperature which the friction causes the thermometer to indicate. The machines used for testing oil have the friction shaft where the oil is destroyed three inches in diameter. Those for tallow are of larger dimensions. It will be seen that on ascertaining the number of revolutions which may be obtained without generating heat, or with the lowest possible increase of heat, that the value of the oil can be obtained. That oil which allows the greatest heat to accumulate

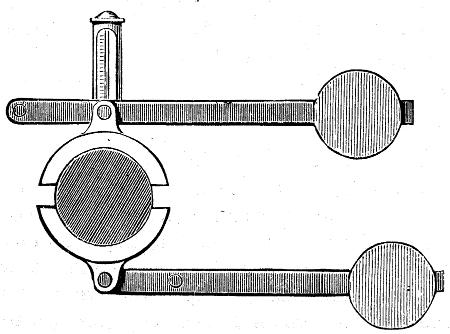

Fig. 2495.

with the fewest revolutions must be a bad lubricant. This tabular method of keeping an account of experiments has been found useful. The machine is stopped when the thermometer indicates 200 degrees, as it is considered that an oil has not much lubricating power left if it permits that heat.

Name of oil.	Price.	Revolutions to 200 degrees F.	Temperature of atmosphere.	No. of revolutions to each degree.

" When testing with this machine a definite quantity of oil should be placed on the friction roller, the top step being removed for that purpose ; the quantity should be about five drops. A glass tube or small tin measure should be used, as drops vary in size according to the temperature of the oil, and also differ with the specific gravity. The inventor of this machine is Mr. Heinrich Stapfer. I believe he may be considered the inventor of the first instrument for testing oils by destroying them by friction under the actual conditions in which oils are used as lubricants. In using this machine I found that, although it was supposed to test lubricants in the way in which they are used in manufactories, a slight difference existed, which prevented accurate results.

" Behavior of Thin Oils.—The first machines were made with the brass steps lipped or recessed, to prevent the oil running away,(see Fig. 2496), which, when thus tested, gave results very much different to those which are accepted by those who are familiar with the use of lubricants. For instance, some thin

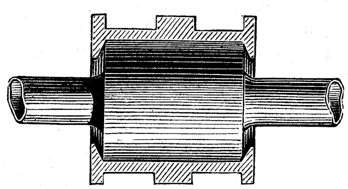

Fig. 2496.

mineral oils were found to be quite as valuable as, and in some cases superior to, sperm ; and this was caused by the lips on the sides, which prevented the oil from running off the bearing when an increased fluidity was caused by friction, and by any slight elevation of temperature. This is a very important quality in lubricating oils, probably next to the capacity to resist oxidation, the most important to be criticised by those who wish to value a lubricant. Although this experiment points out to us that it may be advisable to make the journals of heavy bearings similar to these, if we wish to obtain the best results from cheap thin oils, yet, as oil should be criticised and prepared to be used on bearings with parallel necks, such as are used in works, it was considered proper to alter the tester to that shape to make the conditions similar. This illustration (see Fig. 2497) permits the oil when tested to run away from the bearing if its increased fluidity gives it a tendency to do so. It is this severe test which has enabled sperm oil to rise superior to all rivals, because it has these two apparently opposite attributes—body or thickness, which keep it on its bearing, combined with sufficient fluidity for lubricating purposes. Permit me further to illustrate what I mean in another manner. Suppose we take an oil, good as a lubricant in all other respects, and place it on a bearing, and that 40 per cent. works quickly away because of its extra fluidity when subjected to an increase of frictional temperature, and then compare it with another oil under similar conditions which only wastes, say, 5 per cent. This latter will be 35 per cent. superior as an oil having body, and even if slightly inferior as a lubricant, it may be the

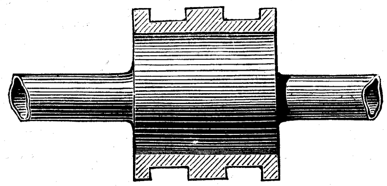

Fig. 2497.

most valuable, because strong in this one great quality of remaining at its duty when placed in position. Still another illustration will inform us that in the one case we obtain, say, 60 gallons of lubricating material out of every 100 purchased, and in the other we obtain 95 gallons.

"The Best Methods of Using Thin Oils.—This will show us that oils which are deficient in body, but which are good in other respects, may be used with good results if doled out in small quantities, as required, by automatic oil-cups like the Lieuvain needle lubricator, Fig. 2498, or any other means. Journals which cannot be fed by means of automatic oil-cups in positions difficult of access should be fed with oil which has a good body. If time permitted, much might be said of the proper shape for bearings of machinery—a subject which would lead to valuable results if discussed by the members of this Society, many of whom must have great experience of those designs which have produced the best results, as well as of those mixtures of metals which are the most durable for light high speed and heavy slow shafting. If any member will take up this subject, or if several members will read short notes, giving their actual experience of different sorts of footsteps, pedestals, and spindles, as well as of the use of different sorts of oil-cups and lubricators, it will be highly advantageous knowledge, which must be of great value to all who use machinery.

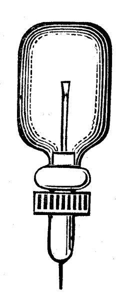

Fig. 2498.

" Fluidity of Oils.—Continuing my remarks on the thinness or fluidity of oils, I wish to call attention to an ingenious arrangement for testing the fluidity when subject to a slight increase of temperature, and also for detecting any tendency which they may have for combining with the oxygen of the atmosphere ; this latter quality being advantageous in oils which are used to mix with paint, but which is a great evil when used for lubricating purposes. A piece of plate-glass placed at an angle is made warm to 200° Fahr. A drop of oil when placed on the upper end of this glass will flow down a few inches and thus indicate its fluidity when subjected to increase of temperature. Fig. 2499 shows a ready method I have designed for testing oil in this way. It consists of a tin box in which is fixed the glass, through which can be seen a thermometer. A graduated scale at the side of the box enables the track of the oil to be measured. The box has a door at the back which enables a copper vessel full of boiling water to be introduced ; the box is lined with felt to prevent rapid radiation, and when the door is closed it will be seen that several experiments may be conducted before the apparatus becomes too cool for use. I think this a cleaner way than using a lamp for the purpose. The copper may also be used by itself for indicating

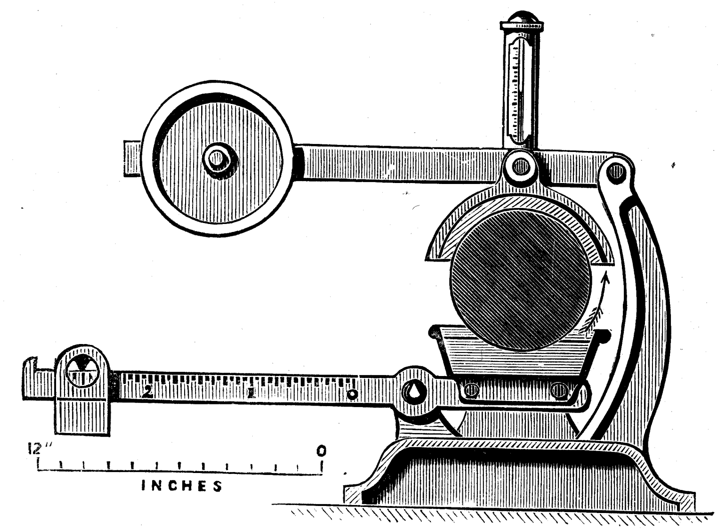

Fig. 2501.

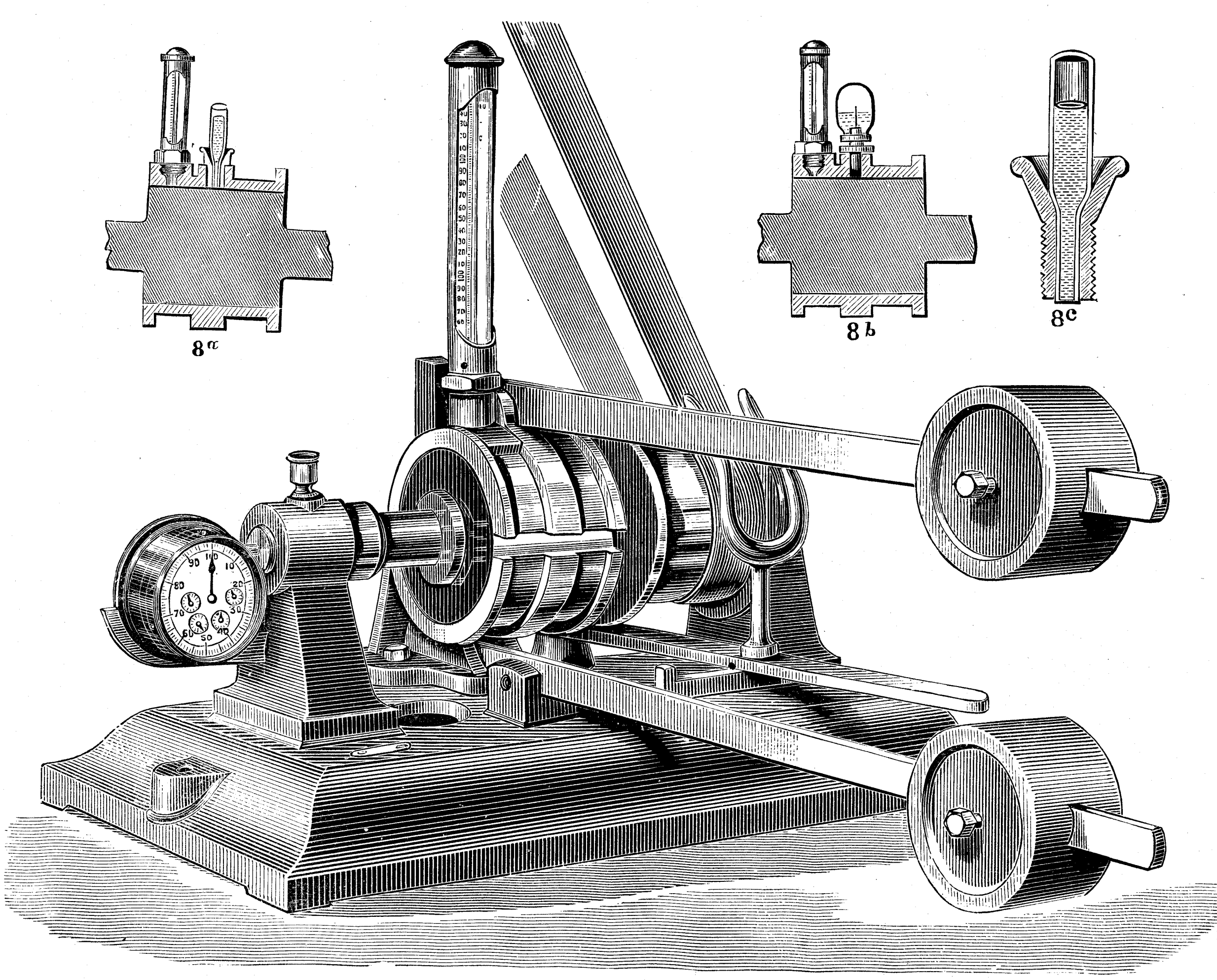

Fig. 2502.

the behavior of oil on copper when slightly warm in making it discolored or otherwise. As I have before stated, there are many oils which are good lubricants, but which become too thin when exposed to slight heat, and I do not hesitate to reiterate the statement, as I wish to have some influence on the future designs of bearing in this district. A correspondent writing to *Engineer* from Queensland says that for six months in the year oil runs off the machinery like water and seems to have no lubricating power; he says that the thermometer registers in the summer 140° in the sun, and 110° in the shade. Great difficulty seems to have been experienced by him in keeping oil on the bearings; his experi-

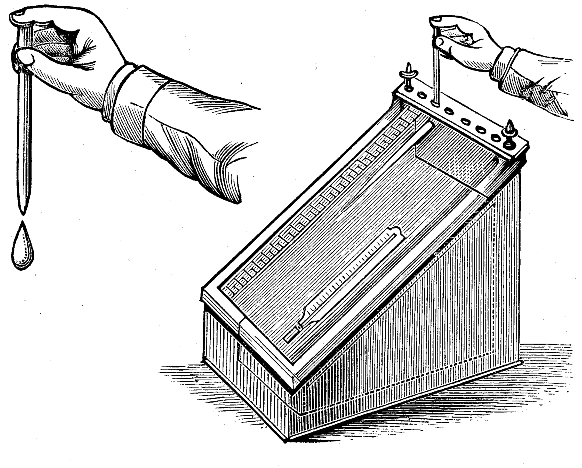

Fig. 2499.

ments on locomotives show that it costs for lubricating a locomotive there about a halfpenny to three farthings a mile, according to the mixture used.

"INFLUENCE OF THE ATMOSPHERE ON OILS.—There are some oils which are excellent lubricants for the first few hours of use, but which have a low capacity for resisting the influence of the oxygen of the atmosphere upon them. The warm glass test may be used for indicating this weakness. If after the test for fluidity the oil be permitted to remain on the glass any exhibition of a resinous or varnish quality may be observed. Another test for this resinous or gummy quality is one which has been suggested to me by Mr. F. R. Wheeldon, of Bilston. He has made many experiments. He found that by permitting oil to remain on a Stapfer friction tester after one test which had been recorded, he tested again on the following day, without adding any fresh oil. This is a severe test, as the thermometer was made to indicate 200° Fahr. each time.

"LONGEVITY OF LUBRICANTS.—Supposing an oil to possess all the qualities which we think a good lubricant should have—that it has fluidity in season, and that it does not combine with the atmosphere and become varnish, that it does not become like water in summer and like mutton suet in winter, and is in most respects satisfactory. We then want to know its powers of endurance, its capacity to resist wear and tear—in other words, its longevity. A good test for longevity or durability of oil when subject to either heavy or light frictional pressure is one suggested by Mr. W. H. Hatcher, a very careful investigator, and chief of the Laboratory of Price's Patent Candle Company, who are extensive oil manufacturers. It consists in taking away the bottom step of the Stapfer tester and placing a small dish containing oil underneath the friction roller (as in Fig. 2500). This oil is carefully weighed before and after several hours' frictional wear and tear. The drawing (Fig. 2501) shows the application of this mode, which I have designed, for testing solid lubricants, such as lard and sulphur and other railway and steamship mixtures. It will be seen that the material is kept to its duty by the weighted lever, and its progress of diminution can be tested in its place by the scale-beam arrangement. When it is used with the pressure on the top step it is advisable to drive it at about 2,000 revolutions per minute; otherwise much time will be occupied in destroying a weighable quantity of oil. The large Stapfer tester (Fig. 2502) was designed a few months ago for this purpose for the Government railways of New South Wales, and it is also used by the Manchester, Sheffield, and Lincolnshire, the Lancashire and Yorkshire, and other railways. I have not been able to get any results of these tests in time for our subject on this occasion, but hope to do so at some future time. The frictional roller is 6 inches in diameter, the pressure amounts to 1 cwt. on each step. As it takes a considerable time to wear away half a pound of solid lubricant, it may be advisable to measure by minutes instead of using the speed index. The speed should be at least 1,500 revolutions per minute. The Stapfer tester should be used in a room of equal temperature, and should not be subject to draughts of cold air, as it will be obvious these will interfere with the indications of the thermometer. A recent alteration in the Stapfer tester permits the quantity of oil used for testing to be measured with greater accuracy than before. A small oil-hole is made in the top step (see Fig. 2502 at *a* and at *c*) in which is placed a glass tube. This only holds a few drops, and can be filled by simply dropping the oil in, holding the finger at the bottom to prevent it running away, and then place it in the hole. If a small needle lubricator be weighed and then filled with oil of a definite weight, and placed in this hole (see Fig. 2502 at *b*), oil may be tested for longevity and for its anti-frictional properties for a longer period than with the small tube. If oil be placed in this at the same time that oil is placed in the lubricators in the works and the oil tester be driven from the same shafting, permitting it to stop and start when the engine stops and starts, the effect of a week's work upon the weight of the oil may be seen; notice should be taken of the difference of the temperature between the thermometer on the instrument and the temperature of the atmosphere of the workshop.

"TESTING FOR SALTS AND ACIDS, ETC.—It will be obvious that however good as a lubricant an oil is, and however valuable its properties may be when examined, if it possesses any corrosive quality which will be injurious to the metals upon which it is placed, it will soon become detrimental to the machinery, and may also cease to be valuable as a lubricant. Mr. William Thomson, analytical chemist, of Manchester, read a paper on this subject at the British Association at Glasgow, and he stated the results of elaborate experiments conducted by him to discover the influence of various oils of commerce upon bright strips of copper. He permitted the copper strips to remain entirely covered by oil. He also conducted similar tests with half of the strip below the surface of the oil, and the other half exposed to the atmosphere, in order to see what influence the oil had, when the surface line touching the metal would, of course, be acted on by the atmosphere. After noticing the effect upon the brightness or dulness of the copper, he carefully tested the oils in order to detect the quantity of metal which had been dissolved. Mr.

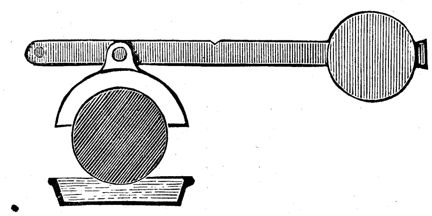

Fig. 2500.

Thomson found the following oils dissolved the largest proportions of copper, leaving the surfaces of the copper slips bright—rape, linseed, sperm, raw cod-liver, Newfoundland cod, and common seal oils; and that the following dissolved much smaller proportions of copper, also leaving the slips bright—seal, whale, cod, shark, and East Indian fish oils; and that mineral oils seem to have no dissolving power on the copper, the only effect being a slight discoloration on the copper slip of a greyish color.

"SWISS WATCHMAKERS' TEST FOR FLUIDITY AND CAPACITY TO RESIST COLD.—It seems, according to the *Watchmaker and Jeweller* (a monthly trade journal), that the plan I have described, and what may be called the warm glass test, seems to be looked upon with favor for testing oil in Switzerland. The degree of heat used for testing the fluidity of oil is 200° Fahr., and if this causes the oil to become a varnish two or three days after the test the oil is considered unfit for use. Another test is one to which I have not alluded, and that is, capacity to resist low temperatures. Oils are tried for their capability to withstand low temperature in the following manner: Fifteen parts of Glauber salts are put into a small glass vessel, a small bottle of oil to be tested is immersed into this; this done, a mixture of five parts of muriatic acid and five parts of cold water is placed over the salt. By means of a thermometer the temperature is indicated, and when it shows a very low temperature, the behavior of the oil, subject to this freezing mixture, may be observed and noted. Mr. Thomson, however, considers that this mixture is not so good or so cheap as ice alone, or a mixture of ice and common salt.

"BLOTTING-PAPER TEST.—It seems it is considered that the blotting-paper test for fluidity is more reliable, according to the writer of the article, than the inclined plane experiment. In order to use this test we must saturate the strip of blotting-paper with oil, and watch whether the drops fall off in pearls or have an inclination to spread out. The latter is a certain sign, the writer says, of a viscid oil. Although this may be considered viscid oil, and may not be valuable for watches, it may, however, be a good oil for heavier machinery."

The amount of friction between a journal and its bearing varies with the kind of metal of which the journal and bearing are composed; on the area of surface in contact in proportion to the load or pressure sustained by the bearing surfaces; on the nature or degree of the lubrication afforded; on the diameter of the journal in proportion to its length; on the manner in which the journal fits or beds to its bearing, and on the kind of motion, as whether the same be continuous, intermittent, rotatory, or reciprocating.

Referring to the friction as influenced by the nature of the metals in contact: the friction varies with the hardness of the metal; thus, with hard cast iron, there will, under equal conditions, be less friction than with soft cast iron. The friction is greater when the surfaces in contact are both of the same metal than when they are of different metals. Mr. Rankine summarizes General Morin's experiments on the friction of various bodies not lubricated as follows:—

GENERAL MORIN'S EXPERIMENTS ON FRICTION.

Surfaces.	Angle of repose.	Friction in terms of the weight.
	degrees.	
Wood on wood, dry	14 to 26½	·25 to ·5
" " soaped	11½ " 2	·2 " ·04
Metals on oak, dry	26½ " 31	·5 " ·6
" " wet	13½ " 14½	·24 " ·26
" " soapy	11½	·2
" elm, dry	11½ " 14	·2 " ·25
Hemp on oak, dry	28	·53
" " wet	18½	·33
Leather on oak	15 " 19½	·27 " ·38
" metals, dry	29½	·56
" " wet	20	·36
" " greasy	13	·23
" " oily	8½	·15
Metals on metals, dry	8½ " 11½	·15 " ·2
" " wet	16½	·3
Smooth metal surfaces occasionally greased	4 " 1½	·07 " ·08
" " " continuously greased	3	·05
" " " best results	1¾ " 2	·03 " ·036
Bronze on lignum-vitæ, constantly wet	3 (?)	·05 (?)

"The 'angle of repose' given in the first column is the angle which a flat surface will make with the horizon when a weight placed upon it just ceases to move by gravity. The column of 'friction in terms of the weight' means the proportion of the weight which must be employed to draw the body by a string in order to overcome its friction, and the proportionate weight is sometimes called the *coefficient of friction*." *

In the following table are given some of the results obtained from Morin's experiments with unguents interposed.

* From Bourne's "Handbook of the Steam Engine."

Nature of surfaces in contact.	Coefficient of friction during motion.	Kind of unguent.
Brass upon brass	·058	Olive oil.
Cast iron upon brass	·078	"
" " " cast iron	·314	Water.
Steel upon cast iron	·079	Olive oil.
" " brass	·056	Tallow or olive oil.
Wrought iron upon brass	·103	Tallow.
" " " cast iron	·066	Olive oil.
" " " wrought iron	·136	"

Morin's experiments demonstrated that friction is always proportional to the pressure and independent of the area pressed in contact, providing that the pressure is not so great as to cause the surfaces to abrade in the manner or to the degree commonly known as cutting, which occurs when the area of bearing surface in proportion to the pressure is so small as to press out the lubricating material.

Now, between the degree of abrasion that is sufficient to cause a bearing to heat and the minimum, possibly lies a wide range that is very difficult of classification, and that influences the friction of the bearing and journal. Under any given dimensions of journal area and any given pressure of the same to its bearing, the abrasion, and, therefore, the friction, will be less in proportion as the fit of the journal to its bearing extends over its whole area and with an equal pressure of contact. Under these conditions, and with a bearing area ample for the given pressure, the surfaces of a journal and bearing have a smooth, glossy appearance, with a surface as glossy as plate-glass.

This degree of perfection, however, is only occasionally reached in practice, because of imperfections in the fitting and lubrication.

Now, between this condition of glossy smoothness and the degree of abrasion known to practical men as *cutting* lies, as already stated, a wide range of degrees of abrasion, and each of these has its own coefficient of friction. This may be readily proved by freely lubricating the bearings of a number of journals working under the usual conditions of practice and smearing the oil just as it passes through the bearings upon a sheet of white note paper, when it will be found to contain fine particles of metal, the number and size of particles in a given quantity of the oil decreasing as the surfaces of the bearings are glossy, and increasing as those surfaces appear dull.

The order of value to resist wear is generally considered in practice to be as follows:—

1st in value, hardened steel running on hardened steel.

2nd (and by some considered equal to the first when the pressure per square inch of area is light), cast iron either upon cast iron, hardened wrought iron, or hardened steel.

3rd, under light duty cast iron upon wrought iron or steel not hardened.

4th, wrought iron upon hard composition or brass.

5th, wrought iron upon some anti-friction metal, as Babbitt metal.

Cast iron appears to be an exception to the general rule, that the harder the metal the greater the resistance to wear, because cast iron is softer in its texture and easier to cut with steel tools than steel or wrought iron, but in some situations it is far more durable than hardened steel; thus when surrounded by steam it will wear better than will any other metal. Thus, for instance, experience has demonstrated that piston-rings of cast iron will wear smoother, better, and equally as long as those of steel, and longer than those of either wrought iron or brass, whether the cylinder in which it works be composed of brass, steel, wrought iron, or cast iron—the latter being the more noteworthy, since two surfaces of the same metal do not, as a rule, wear or work well together. So also slide-valves of brass are not found to wear so long or so smoothly as those of cast iron, let the metal of which the seating is composed be whatever it may; while, on the other hand, a cast-iron slide-valve will wear longer of itself, and cause less wear to its seat, if the latter is of cast iron, than if of steel, wrought iron, or brass. The duty in each of these cases is light; the pressure on the cast iron, in the first instance cited, probably never exceeding a pressure of ten pounds per inch, while in the latter case two hundred pounds per square inch of area is probably the extreme limit under which slide-valves work; and what the result under much heavier pressures would be is entirely problematical.

Cast iron in bearings or boxes is found to work exceedingly smoothly and well under light duty, provided the lubrication is perfect and the surfaces can be kept practically free from grit and dust. The reason of this is that cast iron forms a hard surface skin when rubbed under a light pressure, and so long as the pressure is not sufficient to abrade this hard skin, it will wear bright and very smooth, becoming so hard that a sharp file or a scraper made as hard as fire and water will make it will scarcely cut the skin referred to. Thus in making cast-iron and wrought-iron surface plates or planometers, we may rub two such plates of cast iron together under moderate pressure for an indefinite length of time, and the tops of the scraper marks will become bright and smooth, but will not wear off; while if we rub one of cast iron and one of wrought iron, or two of wrought iron, well together, the wrought-iron surfaces will abrade so that the protruding scraper marks will entirely disappear, while the slight amount of lubrication placed between such surfaces to prevent them from cutting will become, in consequence of the presence of the wrought iron, thick and of a dark blue color, and will cling to the surfaces, so that after a time it becomes difficult to move the one surface upon the other. If, however, the surfaces are pressed together sufficiently to abrade the hard skin from the cast iron, a rapid cutting immediately takes place, which is very difficult to remove.

To obtain the best results from cast-iron bearings the bedding of the journal to the bearing must be full and perfect, and the surfaces bright and smooth, in which case it will wear better than hardened steel, unless it be very heavily loaded.

Again, a cast-iron surface will hold the lubricating oil better than either steel, wrought iron, or brass of any kind. Indeed, if a cast-iron surface be made very true and smooth so that it is polished and no marks are visible upon its surface, it will take *much patient* rubbing and cleaning with *dry clean rag* to remove the oil entirely, whereas other metals will clean comparatively easy. In testing this matter upon surface plates the author has found that the only safe method, and by far the quickest, of removing the oil from cast iron is an application of alcohol or spirits of turpentine, because the oil will enter and to some extent soak into the pores of cast iron and gradually work out again as it is continuously wiped, so that if apparently quite clean (after having been oiled and wiped) a short period of rest will cause oil to again be present to some extent upon the surface.

As a general rule motion in a continuous direction causes more wear under equal conditions than does a reciprocating one, because when a revolving surface commences to abrade, the particles of metal being cut are forced into and add themselves, in a great measure, to the particles performing the cutting, increasing its size and the strain of contact of the surfaces, causing them to cut deeper and deeper until at least an entire revolution has been made, when the severed particles of metal release themselves, and are for the most part forced into the grooves made by the cutting.

In reciprocating surfaces, when any part commences to cut, the edge of the protruding cutting part is abraded by the return stroke; which fact is clearly demonstrated in either fitting or grinding in the plugs of cocks, in which operation it is found absolutely necessary to revolve the plugs back and forth, to prevent the cutting which inevitably and invariably takes place if the plug is revolved in a continuous direction. Furthermore, when a surface revolves in a continuous direction, any grit that may lodge in a speck, hollow spot, or soft place in the metal, will cut a groove and not easily work its way out, as is demonstrated in polishing work in a lathe; for be the polishing material as fine as it may, it will not polish so smoothly unless kept in rapid motion back and forth. Grain emery used upon a side face, such as the radial face of a cylinder cover, will lodge in any small hollow spots in the metal and cut grooves, unless the polishing stick be moved rapidly back and forth between the centre and the outer diameter. If a revolving surface abrades so much as to seize and come to a standstill, it will be found very difficult to force it forward, while it will be comparatively easy to move it backward, which will not only release the particles of metal already severed from the main body, and permit them to lodge in the grooves due to the cutting, but will also dislodge the projecting particles which are performing the cutting, so that a few reciprocating movements and ample lubrication will, in most cases, stop the cutting and wash out the particles already cut from the surfaces of the metal.

In determining the metals to be used for a journal and bearing it is preferable to use the softer metal, or that which will wear the most, in the position in which it can be the most easily and cheaply replaced, which is usually in the bearing rather than in the journal; and since two metals of a different kind run better together than two of the same kind, the bearing is usually of a different kind of metal from that composing the journal. It may be stated, however, that under *light duty* cast iron will wear upon cast iron better than wrought iron or brass upon cast iron (for reasons which have already been stated), especially if the bearing area be broad and the lubrication ample and perfect.

To facilitate the removal of the bearings, brasses or boxes are provided, but in the case of small journals, as, say, of about 3 inches and less in diameter, the duty being light, the lubrication ample and equally distributed, and the journals an easy working fit when new, it is found that solid cast-iron boxes will last for a great length of time without sensible wear.

In some cases cast-iron boxes are cast with a receptacle for some soft metal, such as the various compound metals known under the general name of Babbitt metal.

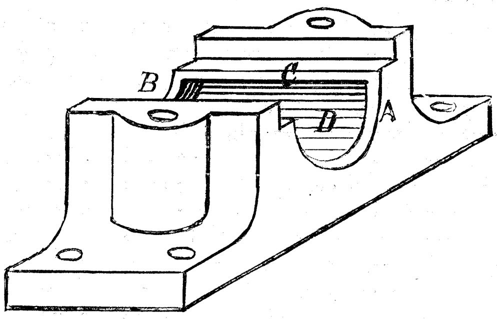

Fig. 2503.

Babbitt metal is composed of tin, antimony, and copper, mixed in varying proportions. A good mixture for general use where the duty is light is composed of 50 parts tin, 5 parts antimony, and 1 part copper. A harder composition, sometimes termed white metal, is composed of tin 96 parts, copper 4 parts, and antimony 8 parts. This mixture is especially suitable for journal boxes or bearings. It is mixed as follows: Twelve parts of copper are first melted, and then 36 parts of tin are added; 24 parts of antimony are put in, and then 36 parts of tin, the temperature being lowered as soon as the copper is melted in order not to oxidize the tin and antimony; the surface of the bath being protected from contact with the air. The alloy thus made is subsequently remelted in the proportion of 50 parts of alloy to 100 tin.

For brass bearings or boxes a mixture of 64 parts copper, 8 parts tin, and 1 part zinc is found to answer well; but for bearings not requiring so hard a metal, the quantity of zinc is increased, and that of the tin diminished.

Bearings or boxes that are to be babbitted are usually cast as in Fig. 2503, there being a rib at A, B, and C, forming a cavity at D, into which the melted metal is poured. The ribs (in new boxes) are sometimes bored out, or for rougher work may be chipped and filed out to fit the shaft, and hold it in line; and to prevent the ribs A, B, &c., from bearing and cutting the shaft, a piece of pasteboard is laid on ribs A and B, thus confining the journal bearing to the babbitt. The best method is to pour the bearing and then rivet the babbitt well into the cavity D, which is made wider at the bottom, to prevent the babbitt from coming loose, and then bore out the bearing in the usual manner.

The principal advantage of a babbitted bearing is the ease with which it can be renewed, and the fact that the metal will soon bed itself to the journal. This is of great advantage in the case of solid bearings in the framing of fast-running machines, and in situations where it would be awkward or difficult to take brasses or bushes out to fit them, or align them to the shaft, which in many cases would also require to be taken out to remove the brasses. On the other hand, any particles of grit that may find ingress to babbitted boxes are apt to become bedded into the babbitt metal and cut or grind away the journal.

Since the babbitt metal in a bearing is apt to close across the bore when cooling after being poured, a mandrel of slightly larger diameter than the diameter of the journal should be used in place of the working journal to run the bearing on. Some effect the same purpose by wrapping writing paper around the journal ; but it is wrong to use the journal, for the following reasons : To get a good, sound, well-fitting babbitt metal box, the metal should be poured as cool as possible, for if made red hot it contracts so much in cooling that it does not fit well in the box or frame of the machine. On the other hand unless the metal be well hot it is apt to cool and set too soon and be unsound. To remedy this the journal, or whatever represents it, must be heated. The heating is very apt to bend it. It is obvious then that instead of the journal a temporary bar of iron of slightly larger diameter than the working journal should be used, heating it to a good black hot heat, so that the babbitt metal may be poured less hot than would otherwise be permissible, and the contraction of the babbitt in the box reduced to a minimum. A little powdered resin sprinkled in the box will help the babbitt to flow easily and make a sound casting.

The temporary spindle, or journal, should also be oiled, and as soon as the metal has well set, the temporary journal should be revolved to free it. Babbitt bearings cast in two halves should be fitted to the journal as already described for brasses, which will well repay the cost and trouble.

To prevent the metal from running out of the bearing, its ends are closed by means of either clay or putty closely packed against the bearing ends and the shaft, and in pouring in the melted metal it is best to pour it on the top of the shaft, and let it run down its sides into the cavity of the bearing. This heats the shaft equally, and prevents it bending from unequal expansion, as it would do if it met the heated metal on its lower half only, it being obvious that if the shaft bends the bore of the bearing will not be cast in line ; hence, the shaft will bear at the end only, and will require to wear the babbitt down to a bearing.

Babbitting is sometimes employed to refit parts that have worn loose, or to bush the bores of work. Suppose, for example, that in a case of emergency a pulley of a certain diameter is required, and that the only one at hand has too large a bore, then we may take a mandrel or arbor of the diameter of the shaft the pulley is required for, and drive on it two thin washers and turn them to fit the bore of the pulley, and cut a recess in each to enable the metal to be poured through. We may then put the arbor and washers in the pulley (the washers serving to hold the arbor true), and fill in the bore with babbitt metal, leaving the pulley set-screw in place and set to just touch the arbor, so as to cast the thread in the babbitt bushing, and thus save drilling and tapping.

PROPORTIONS OF JOURNALS.—It follows from what has been already said that under a given amount of duty the friction will be less and the durability greater in proportion as the bearing area of a journal is increased. But it is an important consideration whether such area shall be obtained in the diameter or in the length of the journal, or, in other words, what shall be the proportions between the diameter and length of a journal. It is found in practice that a journal wears better in proportion as its length exceeds its diameter, providing that the stress is not sufficient to cause sensible flexure, because in that case the pressure is reduced at that part of the journal where the most flexure occurs, and increased where the journal is most rigid. As a result, the abrasion increasing with the pressure becomes locally excessive, the glossy smoothness is lost and increased friction ensues.

If, however, the length of a journal is limited by the exigencies of its location or the design of the machine, the diameter of journal must be increased if necessary in order to obtain sufficient bearing area to withstand the stress without causing undue abrasion.

Referring to the bearing area in proportion to the load, Prof. R. H. Thurston writes, in an article in the *Railroad Gazette* of January 18th, 1878, as follows :—

"A pressure of 800 pounds to the square inch can rarely be attained on wrought iron at even low speeds, while 1,200 pounds is not infrequently adopted on the steel crank-pins of steamboat engines. I have known of several thousand pounds pressure per inch being reached on the slow-working and rarely moved pivots of swing bridges. In my own practice, I never, if I can avoid it, use higher pressures than 600 and 1,000 on iron and on steel, and, for general practice, make the pressure less as the speed is greater."

W. Sellers and Co. state that under a pressure of 50 lbs. per square inch, and with oil well distributed over the surface of the box, the metal of the journal will not touch that of the bearing box bore.

In practice bearings are made with a length varying from that equal to the diameter of the journal to about four times that diameter, and but few cases occur in which these limits are exceeded in either direction. It is to be observed, however, that diminishing the length is apt to increase the abrasion unless the duty is very light indeed, while increasing it increases the durability while not affecting the friction, unless the shaft bends.

There are special cases in which within certain limits the proportions of journals are nearly uniform in practice ; thus the length of engine crank-pin bearings rarely exceeds once and a half times the diameter, while the main shaft bearings are often similarly limited in width from the exigencies of designing the engine so that the eccentric shall come in line with the slide-valve spindle. In the case of crank-pins the pin cannot be held sufficiently rigidly to prevent spring or flexure ; hence it is desirable to limit its length so that its pressure shall be as short a leverage as possible to the crank. The solid bearings in the framing of machines usually admit of room enough to make their lengths three or four times the diameter. Again, in the case of line shafting, boxes having a length equal to three or four times the diameter may be employed, providing that the alignment be made correct, or that the boxes are self-adjusting. But in all cases the longer the bearings the greater the necessity for correct alignment, so that the axis of the bearing bore may be in line with the axis of the shaft, the error manifestly increasing with the length of the bearing.

PLACING TWO CRANKS ON A SHAFT SO THAT THEIR CENTRE LINES SHALL STAND AT A RIGHT ANGLE.—It is obvious that the keyways in both the crank and the shaft must be cut accurately in their proper positions, because it is a tedious operation to file out the sides of the keyways when the cranks are placed upon the shaft. To mark the keyways in the absence of any tools or appliances specially designed for the purpose we proceed as follows : Placing the shaft upon a marking-off table, we plug up the centres upon which the shaft has been turned by driving a piece of lead in them, leaving the surface level with those of the shaft ; and then from the perimeter of the shaft we carefully mark, upon the lead plugs, the centres of the shaft. From this centre we describe a circle whose diameter will be equal to the required widths of the keyway, and then taking a square we place its stock upon the face of the marking-table, and bringing the edge of the blade even with the edge of the circle, we mark a perpendicular line upwards from the circle to the perimeter of the shaft, and then draw a similar line on the other side of the circle, as shown in Fig. 2504, in which A represents the shaft and B the circle, C the perpendicular line struck on one side of the circle, and D the square placed upon the marking-table E, in position to mark the line on the other side of the circle, F and G being wedges to keep the shaft A from moving its position upon the table. We next mark with a scribing-block or surface gauge the depth of the keyway as denoted by the line H, and the marking at that end of the shaft is completed. Passing to the other end of the shaft we find the centre of the shaft, and describe around it a circle equal in diameter to the required width of keyway, and from the edges of the circle to the perimeter of the shaft draw two lines with a scribing-block, as shown in Fig. 2505, A representing the shaft, B the circle, C D the breadth of the keyway, E the marking-off table, F and G the wedges, and H the depth of the keyway, which must, in this case, be marked with a square resting on the table.

If, however, the shaft is too heavy or large to be placed on a marking-off table, we may proceed as follows: Strike as before the circle B, Fig. 2504, equal in diameter to the required width of keyway, and adjust a straight-edge held firmly against the end face of the shaft, so that its upper edge is coincident with the perimeter of this circle, while the straight is horizontally level-tested by a spirit-level. Draw a line along the shaft face, using the straight-edge as a guide. This will give us the line C in Fig. 2505. By a similar process the line D, Fig. 2505, may be drawn.

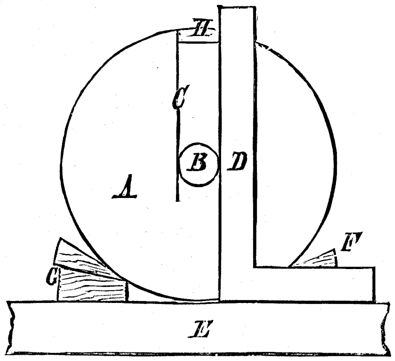

Fig. 2504.

At the other end of the shaft similar lines, but standing vertical, may be marked, which will give the positions of the keyways.

We have now marked off on the end faces of the shaft a keyway at each end, one standing at a right angle to the other; but it must be borne in mind that we have paid no attention as to which crank shall lead; that is to say, suppose in Fig. 2506 A and B represent cranks placed upon the shaft C, and running in the direction indicated by arrow D, it is evident that the crank B leads in the direction in which the engine is to run, and hence the keyway E stands in advance of the keyway F; and therefore, as shown in the figure, the right-hand crank leads. To

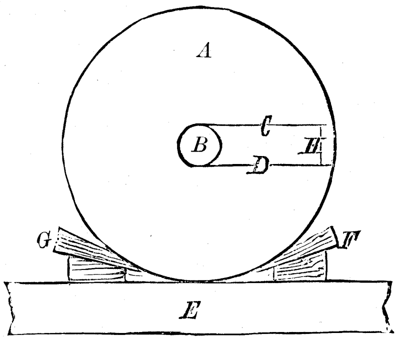

Fig. 2505

have made the left-hand crank lead, when the engine runs in the direction of the arrow D, we should, supposing the keyway F to be already cut, have to cut the keyway E on the directly opposite side of the shaft; or, what is the same thing, supposing the keyway E to be already cut, the keyway F would require to be cut on the diametrally opposite side of the shaft. It is obvious that if the engine ran in the direction of the arrow G, the left-hand crank would lead, supposing in each case the cylinders to stand at H. Here it may be necessary to explain the manner of determining which is the right-hand and which the left-hand crank. Suppose then that the figure represents a locomotive crank, the cylinders being at H, then as the engineer stands in the cab, facing his engine, A will be the left-hand and B the right hand crank. It is usual in locomotives to make the left-hand crank lead when the engine is running forward, the practical difference being, that if the workman were by mistake to make the right-hand crank lead, the engine would run forward when the reversing lever was placed to run backward, and *vice versâ*. It makes no difference whether the shaft can be turned end for end or not: if the right or left crank is required to lead when the crank is required to revolve in a given direction the keyways in the shaft must be marked off in the relative positions on the shaft necessary to obtain that result.

The keyways may be carried along the circumference of the

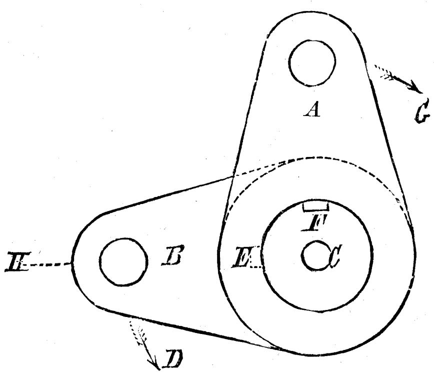

Fig. 2506.

shaft by a square applied to its end face, or if that face is not flat by the ordinary keyway marking tool.

To mark off the keyways in the cranks, we place a centre-piece in the bore of the crank, as shown in Fig. 2507, in which A represents a crank having a centre-piece of sheet iron B placed in the bore. On the face of this centre-piece we mark the centre of the hole into which it fits, and from that centre we describe the circle C, which must be of exactly same diameter as the crank-pin if it is in its place, or otherwise of the crank-pin hole. We then draw the lines D and E, using as a guide a straight-edge placed one end upon the crank-pin journal, or even with the edge of the crank-pin hole, as the case may be, and the other end (of the same edge of the straight-edge) exactly even with the circumference of the circle C. From D and E we find the centre of the circle F, which must be central between D and E, and whose diameter must be exactly equal to the required width of keyway; and we then mark the circle G, describing it from the centre of the hole, and therefore of the circle C. By drawing the lines H and I, which must be even with the circumference of the circles F and G, using a straight-edge as a guide, we shall obtain the correct position for the keyway K, and the whole of the keyways may be cut, care being taken to cut them quite true with the lines, and of an exact equal width.

To put the cranks on the shaft, first provide a temporary key, a

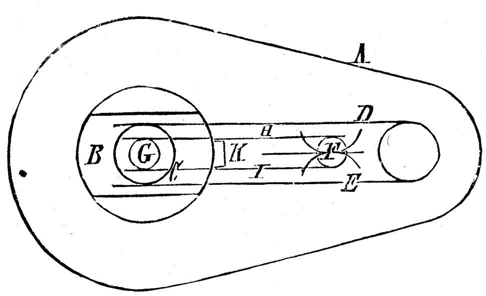

Fig. 2507.

close fit on the sides, but clear top and bottom, so that it will bind just easily on the sides of the keyways in both the shaft and the crank. The shaft must be placed and wedged with its keyway downwards, so that in putting the crank on, the pin end may hang downwards, which will render it more easy both to put on, handle, and adjust. As soon as the shaft has entered the crank, say a quarter of an inch, we must insert the temporary key (which may have its end edges well tapered off to assist the operation of entering it) sufficiently far into the keyway of the shaft that it will not fall out, and we may then proceed to put the crank on the shaft to the necessary distance, keeping the temporary key sufficiently far in the keyway to enable it to act as a guide—that is to say, up to at least half the length of the keyway.

To put on the second crank, we first place the shaft so that the crank already on stands exactly horizontal, setting it by placing a spirit-level, as shown in Fig. 2508, in which A represents either the crank-pin journal or the crank-pin hole in the crank, and B a circle struck on the end face of the shaft and from its centre, the diameter of the circle B being exactly the same as that of A. If then we so adjust the position of the crank that a spirit-level applied to the exact circumferences of the circles A and B stands level, the crank will stand level, and we have only to put the second crank on with its centre-line standing perpendicular, and

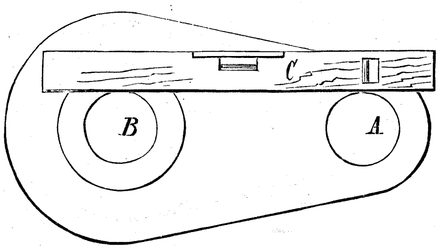

Fig. 2508.

the two cranks will be at a right angle one to the other. We now proceed to put on the second crank, pursuing the same method employed in putting on the first one, save that the temporary key need not be inserted so far into the keyway, because, if the keyways have been cut the least out of true, it will make a great difference at the crank-pin, because of the increased distance of the latter from the centre of the crank-shaft. As soon as the second crank is placed to its position on the shaft we must ascertain if it stands vertical, which we may do by applying the spirit-level as shown in Fig. 2509, bringing its edges exactly fair with the edges of the circles A and B, and moving the crank until the bubble of the level stands true, and taking out the temporary key if it is necessary to adjust the crank at all.

If, however, the crank is to be forced on by hydraulic pressure,

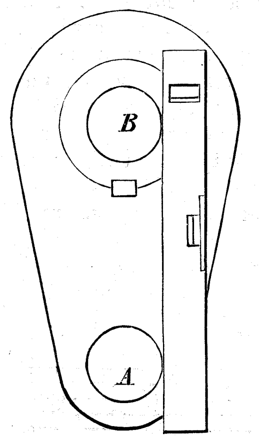

Fig. 2509.

this latter adjustment should be made when the crank is just sufficiently far on the crank shaft to enable it to bind enough to well support its own weight, to facilitate which the end of the shaft is sometimes slightly tapered for a very short distance—a practice which is sometimes rendered unnecessary by reason of there being attachments fitted to the hydraulic presses which of themselves adjust the position of the cranks, and insure their being at a right angle one to the other.

After the cranks are on their places the keys may be fitted, care being taken that, if the crank last put on had to be moved to adjust it, the sides of the keyways be filed even, otherwise driving the key will tend to move the crank.

FITTING ENGINE CYLINDERS.*—When engine cylinders are made in quantities, as in locomotive building shops, a great deal of the fitting work is saved by the machine work; but when a single cylinder or a pair of cylinders only are to be fitted up it will not pay to make jigs and appliances; hence, they are usually fitted up entirely by hand. The first thing to do is to mark off all the holes requiring to be drilled, and have the drilling done.

In marking the holes in the cylinder covers it is to be noted whether that part of the cylinder cover which fits into the cylinder has a portion cut away to give room for the steam to enter (as is usually the case), and if so, first mark a line across the inside flange of the cover, parallel to the part cut away, and then scribe each end of the line across the edge of the flange. Then mark a similar line across the cylinder end, parallel to the steam port where it enters the cylinder, and scribe each end of this line across the cylinder flange, so that, when the cylinder cover is placed into the cylinder and the lines on the flanges of the cylinder and the cover are placed parallel to each other, the piece cut away on the cover will stand exactly opposite to the steam port, as it is intended to do. The cover may then be clamped to the cylinder, and holes of the requisite size for the tap (the tapping holes, as they are commonly called) may be drilled through the cover and the requisite depth into the cylinder at the same time.

The cylinder covers must, after being drilled, as above, be taken from the cylinder, and the clearing drill put through the holes already drilled so that they will admit the bolts or studs, the clearing holes being made $\frac{1}{16}$ inch larger than the diameter of the bolts or studs. The steam chest may be either clamped to the

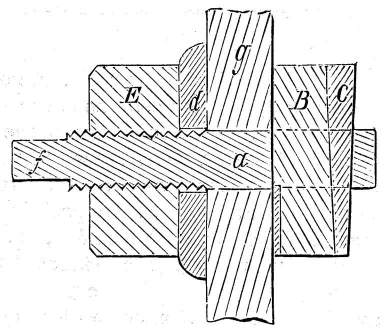

Fig. 2510.

cylinder, and tapping holes drilled through it and the cylinder (the same as done in the case of the covers), or it may have its clearing holes drilled in it while so clamped, care being taken to let the point of the drill enter deep enough to pass completely through the steam chest, and into the cylinder deep enough to cut or drill a countersink nearly or quite equal to the diameter of the drill. If, however, the steam chest is already drilled, it may be set upon the cylinder, and the holes marked on the cylinder face by a scriber or by the end of a piece of wood or of a bolt, which end may be made either conical or flat for the purpose, marking being placed upon it; so that, by putting it through the hole of the chest, permitting it to rest upon the cylinder face (which may be chalked so as to show the marks plainly), and then revolving it with the hand, it will mark the cylinder face. This plan is generally resorted to when the holes in the chest are too deep to permit of being scribed. To true the back face, round a hole against which face the bolt head or the face of the nut may bed, in cases where such facing cannot be done by a pin countersink or a cutter used in a machine, the tool shown in Fig. 2510 may be employed, *a* being a pin provided with a slot at one end to admit the cutter B, which is held fast by the key C, and is also provided with a square end *f*, by which it may be turned or revolved by means of a wrench, and with a thread to receive the nut E, *d* being a washer; so that, by screwing up the nut E, the cutting-edges of the cutter are forced against the cylinder *g*, and will, when revolved, cut the face, against which they are forced, true with the hole in the cylinder through which the pin *a* is passed.

After the drilling the cylinder should be placed on end and all

* From the "Complete Practical Machinist."

the holes that can be got at should be tapped. Then the cover joint, supposing it to be a ground joint, should be made according to the directions given for making ground joints, when the cylinder may be turned upside down and the other cover fitted. Then the holes for the cylinder cocks and for the steam and exhaust pipe

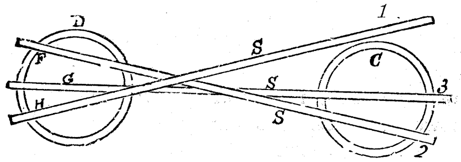

Fig. 2511.

should be tapped, and the faces for these pipe joints fitted as required.

The steam-chest holes should then be tapped and the ports marked out and chipped and filed to the lines, such lines being marked as described in the remarks on lining out work.

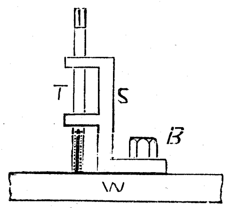

Fig. 2512.

The face for the steam-chest seat and the steam-chest cover may then be prepared by filing, scraping, or grinding, as may be required, and simultaneously the valve seat and valve face may be fitted. If the cylinders are to be bolted together as in a locomotive, the holes for holding them together should be drilled about $\frac{1}{64}$ inch smaller than the bolts, so that they may be reamed out together after the cylinder bores are aligned.

One cylinder face should be marked and drilled first, and the two cylinder bores being set to align true the other cylinder should be marked from the other, or if there is a saddle between the two cylinders both cylinders may be marked and drilled, and also the holes on one side of the saddle. Temporary bolts may then be put through the holes that are drilled in the cylinder and saddle and clamps used to hold the undrilled cylinder to the saddle, when the cylinder bores may be set true one to the other, and the holes on the remaining side of the saddle marked through those already drilled in the cylinder. These latter holes being drilled, temporary bolts of smaller diameter than the holes (so as to give room to move the cylinders to align their bores) may be used to bolt the cylinders together while their bores are accurately aligned, which alignment may be effected as follows:—

The bores should be set as near true as possible, tested by a spirit-level rested on the bore and placed as near true as can be judged with the length of the bore, and a plumb rule may be applied to the end faces where the cover joint comes. Then a straight-edge should be applied, as in Fig. 2511, in which S is the straight-edge, and C and D the two cylinder ends.

The method of testing is shown in Fig 2511, where the straight-edge S is shown in three positions, marked respectively 1, 2, and 3 at one end, and F, G, and H at the other.

The first test should be made by simply placing the straight-edge across the two cylinder faces, as at G 3; and when the cylinders are set apparently true and the spirit-level applied to the respective bores shows them true, greater accuracy may be secured by placing the straight-edge in position 1 H, being pressed firmly to its cylinder face with end 1 above the other cylinder face. Then, while end H is held firmly to its cylinder, let end 1 lower until it passes entirely over the face of cylinder C, whose face it should just touch; if on meeting C the straight-edge strikes it or does not meet it, further adjustment of the cylinder positions is necessary. Next place the straight-edge in position 2, pressing end F firmly against cylinder D, and passing the other end entirely over the end of cylinder C, which it should just touch, and no more. It will then be necessary to repeat this process, pressing the straight-edge against cylinder C and testing the other end with cylinder D, and the cylinders thus set will be (if the end faces are true, as they should be, and usually are) more truly aligned than is

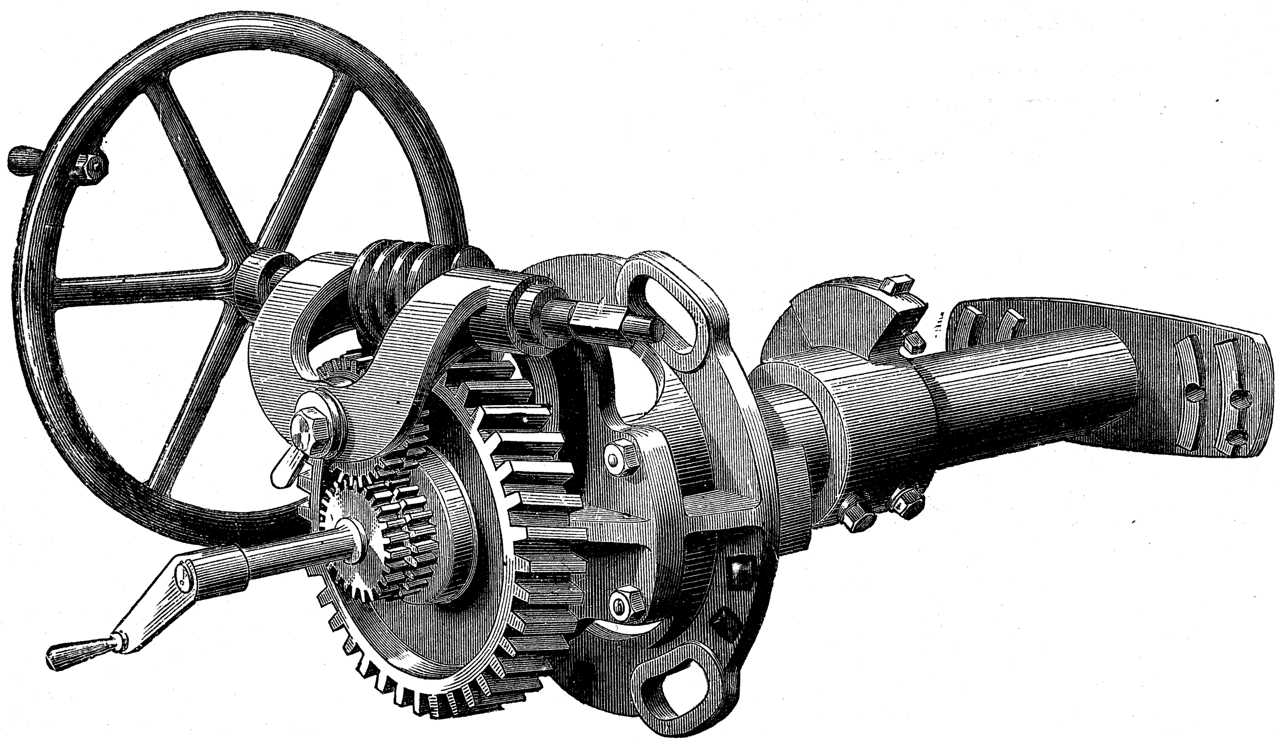

Fig. 2513.

possible by the use of the spirit-level. This method also brings the end faces of the cylinders in the same plane, so that each piston head will travel central in the length of the cylinder bore, approaching the cylinder covers equally, and therefore keeps the clearance equal. Incidentally, also, this secures accuracy in the cross-head traverse on the guide bars (supposing these bars to be bolted to the cylinder cover). The holes for bolting the cylinders together may then be reamed and the bolts driven in and screwed up.

To guide the tap when tapping the cylinder cover and steam-chest holes the guide stand S, shown in Fig. 2512, should be employed. It is bolted to the cylinder face by the bolt B, which passes through a slot in the stand.

The tap T is inserted through the two arms of the stand and its end inserted in the hole to be tapped when bolt B is tightened up.

The stem of the tap should be of slightly larger diameter than the tap thread, so as to fit in the holes of the guide or stand.

When, however, one end of the guide bars is carried on the cylinder cover, it is necessary when setting that cover to be marked

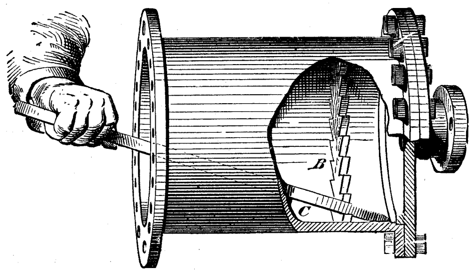

Fig. 2514.

for the drilling, to so set it that the seats for the guide bar ends shall be horizontally level when the cylinder is on the engine; and when setting the bores of the cylinder in line to mark the holes for bolting the cylinders together or to the saddle, this point should also be looked to, as if these seats are not in line the faces of the guide bars will not be in line, and will not, therefore. bed fair to the cross-head guide unless the error is in some way corrected.

It is desirable that these seatings be quite true and in line one with the other on both cylinders, so that if liners require to be made, or if the ends of the bars require to be filed to let the bars together at any time, the surfaces may be filed true to the face of the bar, and thus be set true and to fit the cross-head guides without requiring to put the bars on and off to fit them true by trial.

REBORING CYLINDERS IN THEIR PLACES ON THE ENGINE.—When a cylinder bore becomes so worn out of cylindrical truth, or becomes grooved or cut, as it is termed, as to require to be rebored, it may be done with the class of boring bar shown in Fig. 2513.

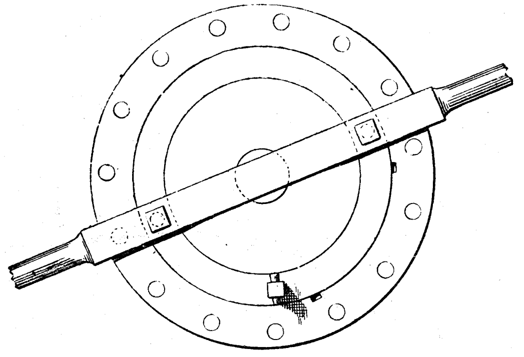

Fig. 2515.

It consists of a bar having journal bearing in castings which bolt on to the two ends of the cylinder in place of the cylinder covers. On the bar is fitted a sliding head carrying the cutting tool and fed by a screw passing within the bar. To operate the bar and simultaneously the feed screw, the hand-wheel and worm-wheel is employed, giving rotary motion to the worm-wheel which is fast upon the bar. Fast also upon the bar is the inside one of the two small gears shown, which operates the inner of the two small gears shown above it. The outer of the upper gears engages with the outer of the lower ones, the latter being fast upon the feed screw. In the inner pair the lower is of largest diameter, but in the outer pair the upper is the largest, and as a result the outer of the lower rotates the fastest, and hence rotates the feed screw, causing the tool to feed to its cut.

The proportions of these wheels are, first or inside pair, lower wheel 36, upper 37; outside pair, upper 37, lower 36, so that the feed per bar rotation is in amount that produced by moving the outer lower gear a part of a rotation equal to twice the pitch of the teeth, the cutting tool motion depending upon the pitch of the feed screw.

To enable the rapid traverse of the head from end to end of the bar, the upper pair of gears are mounted on an eccentric stud, so that by operating the small handle shown they may be disengaged from the lower feed gears and the feed screw operated direct by means of the handle shown.

In setting such a bar to a cylinder bore it is to be remembered that two methods may be employed. First, the bar may be set to accommodate the cylinder bore, truing it out with as light a cut as

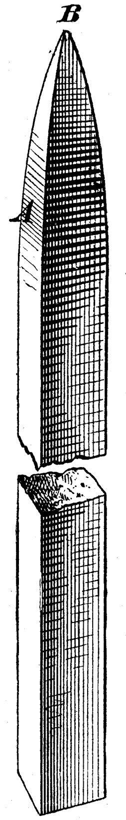

Fig. 2516.

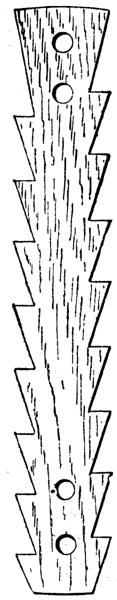

Fig. 2517.

possible. In this case the bore of the cylinder may be made out of line with the guide bars and with the centre of the length of the crank-pin journal.

In the second the bar may be set with a view to bore it out in line with the guide bars and crank pin, and then taking as much cut as will be necessary to true the bore.

The latter plan is the preferable of the two, unless the repairs are so extensive as to require the guide bars to be redressed and the main bearing renewed, in which case those parts requiring to be re-aligned, the cylinder may be rebored with a view to take out as little metal as possible, and the other parts set to suit the new bore.

To set the bar true to the guide bars and crank pin, and thus retain the axis of the new bore true with that of the original bore, the bar should be set true with the recessed counterbore at each end of the cylinder, which being unworn remains true.

If, however, only one cylinder cover can be conveniently taken off, the piece of wood will require to fit in the counterbore at the open end, and in the cylinder bore at the closed end of the cylinder; hence we make it large enough for the counterbore, and after having removed the ridge at that end we cut the length of the wood down to fit the cylinder bore, whereas if we made our rest to fit the bore at first we should require to use wedges to make it fit the counterbore. In some cases holes might be bored near the ends of the rest or fulcrum to serve the same purpose as the notches.

The method of using the scraper, Fig. 2516, is shown in Fig. 2514, which latter represents an engine cylinder. At B is shown the wooden rest or fulcrum; and at C the lever scraper operating on the ridge at the closed end of the cylinder. The lever C is worked on the pulling stroke only, and is so held that the edge presents a keen scraping tool which will cut very freely. The fulcrum B should be adjusted as closely as convenient to the work, so as to obtain good leverage for the scraper. It should be moved in its position, so that during the roughing out only the lower notches in the fulcrum are used.

A plan was lately resorted to on the White Star Line of steamships for re-boring a cylinder. The cylinder heads and piston follower were taken off; a groove was cut from the outer end of the cylinder along the bore as far and as deep as the counterboring was required to be done. The counterboring was then accomplished in the manner shown in Fig. 2515. The junk ring was provided with a small tool holder, such as is used upon boring bars. The tool was fastened in the holder while its cutting edge was in the groove referred to, cut as deep and as far up the cylinder as the counterboring was to be. To the junk ring was fastened, by two long bolts, a wooden lever extending above and across the cylinder. Two men walked around pushing the lever, and when the tool at each revolution arrived at the groove, a fresh cut was taken by moving the engine so as to raise the piston the necessary amount. It is obvious that the piston head may be steadied and held true in the bore of the cylinder by means of a few wooden wedges. Thus we see that in this operation the junk ring was made to serve as a boring bar head, the men furnishing the necessary rotative motion, the feed motion to the tool being obtained by advancing the piston toward the end of the cylinder where the work was being done.

The ridges which in time form at the two ends of a cylinder bore are usually removed by the hand-boring bar shown in Fig. 2513, but they may, in cylinders of from 12 to 24 or 30 inches in diameter, be readily cut out by hand as follows :—

Take a bar of steel $\frac{9}{16}$ inch square and 3 feet 6 inches long; forge it at one end to the shape shown in Fig. 2516, in which from A to B is the forged end. This end must then be heated along its entire length to a cherry red, and dipped vertically into cold water to harden it; after which it must be ground from A to B on all four faces square across, and as nearly of an even curve as can be ascertained by the eye. Next take a piece of hard wood—oak, for instance—about an inch thick and 3 inches wide; cut it to such a length that when placed upright its ends will wedge tightly into the counterbore of the cylinder. Into the edges of this piece of wood saw out a series of notches, making its finished appearance to be such as shown in Fig. 2517. The object of fitting its length tightly into the counterbore of the cylinder is as follows: If both cylinder covers are off or can be conveniently taken off, the ridge can be operated upon at each end of the cylinder; hence our piece of wood, which is merely an improvised rest to act as a fulcrum for the bar scraper shown at the top of the figure, would require to fit into the counterbore.