CHAPTER XV.—MEASURING TOOLS.

FOR what may be termed the length measurements of lathe work it is obvious that caliper gauges, such as shown in Fig. 1402, may be employed. Since, however, these length measurements rarely require to be so accurate as the diametrical measurements, the ordinary lineal rule is very commonly employed in work not done under the standard gauge system. It is obvious, however, that when a number of pieces are to be turned to corresponding lengths, a strip of sheet iron, or of iron rod made to the required length, may be employed; a piece of sheet iron filed to have the necessary steps being used where there are several steps in the work; but if the lineal measuring rule is used, and more than one measurement of length is to be taken, some one point, as one end of the work, should be taken wherefrom to measure all the other distances. Suppose, for example, that Fig. 1442 represents a crank pin requiring to have its end collar $\frac{1}{4}$ inch thick, the part A 2 inches long, part B 3 inches long, collar C $\frac{1}{2}$ inch thick, and the part D 7 inches long. If the length of each piece were taken separately and independently of the others, any errors of measurement would multiply; whereas, if some one point be taken as a point wherefrom to measure all the other distances, error is less liable to occur, while at the same time an error in one measurement would not affect the correctness of the others. In the case of the crank pin shown, the collar C would be the best point wherefrom to take all the other measurements. First, it would require to be made to its proper thickness, and the lengths of B, A, and the end collar should be measured from its nearest radial face. The length of D should then be measured from the same radial face, the thickness of the collar being added to the required length of D, or D may be measured from the nearest radial face of C, providing C be of its exact proper thickness. In measuring the length of the taper part D, a correct measurement will not be obtained by laying the rule along its surface, because that surface does not lie parallel to its axis, hence it is necessary to apply the measuring rule, as shown in Fig. 1443, in which S is a straight-edge held firmly against the radial face of the crank pin (the radial face being of course turned true), and R is the measuring rule placed true with the axial line of the crank pin. Whenever the diameters of the lengths to be measured vary, this mode of measuring must be employed. On small work, or on short distances requiring to be very exact, a gauge such as shown in Fig. 1444 at A may be employed, which will not only give more correct results, but because it is more convenient, as it can be conveniently held or tried to the work with one hand while the other hand is applied to the feed screw handle to withdraw the cutting tool at the proper moment, and to the feed nut to unlock it and stop the feed.

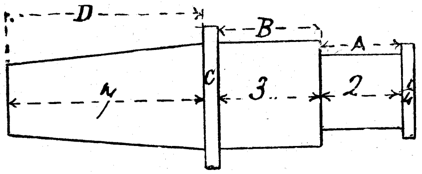

Fig. 1442.

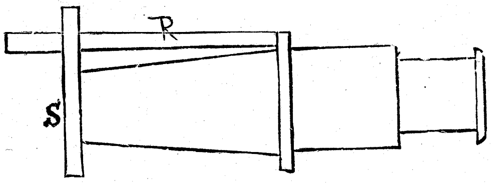

Fig. 1443.

On long work a wooden strip is the best, especially if the work has varying diameters and a number of pieces of work require to be made exactly alike. In Fig. 1445 S represents the wooden strip, and W the work. The strip is marked across by lines representing the distances apart the shoulders of the work require to be; thus the lines A, B, C, D, E, F, G, represent the distances apart of the radial faces *a*, *b*, *c*, *d*, *e*, *f*, *g*, on the work, and these lines will be in the same plane as the shoulders if the latter are turned to correct lengths. To compare the radial faces with the lines, a straight-edge must be held to each successive shoulder (as already described) that is of smaller diameter than the largest radial face on the work.

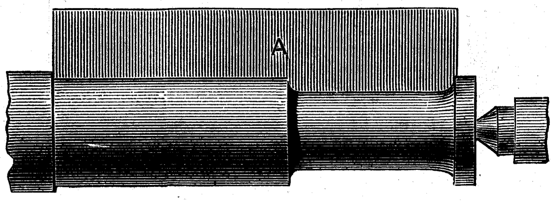

Fig. 1444.

If the wooden strip be made the full length of the work the dog or clamp driving the work will require to be removed every time the wooden gauge is applied, and since the work must be turned end for end in the lathe to be finished, it would be as well to let the length of the wood gauge terminate before reaching the work driver, as, say, midway between E and F.

When a lineal distance is marked by lines, and this distance is to be transferred to another piece of work and marked thereon by lines, the operation may be performed, for short distances or radii, by the common compasses employed to mark circles, but for greater distances where compasses would be cumbersome, the trammels are employed.

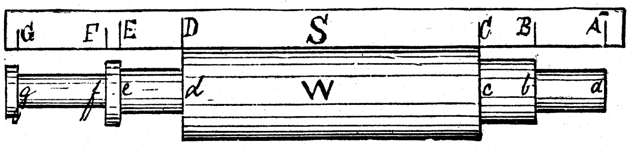

Fig. 1445.

Fig. 1446 represents a pair of trammels made entirely of metal, and therefore suitable for machinists' use, in which the points require to be pressed to the work to mark the lines. A A represents a bar of square steel; or for very long trammels wood may be used. B represents a head fastened tightly to one end, and through B passes the leg or pointer C, which is thus adjustable as to its projecting distance, as C can be fastened in any position by the thumb-screw D. The head E is made to a good sliding fit upon the bottom and two side faces of A A; but at the top there is sufficient space to admit a spring, which passes through E. F is the leg screwed into E, which is locked in position by the thumb-screw G. The head E is thus adjustable along the whole length of the bar or rod A A. The object of the spring is as follows:—If the head E were made to fit the bar A A closely on all four sides, the burrs raised upon the top side of the rod A A by the end of the thumb-screw G would be likely to impede its easy motion. Then again, when the sliding head E has worn a trifle loose upon the bar A A, and is loosened for adjustment, it would be liable to hang on one side, and only to right itself when the screw G brought it to a proper bearing upon the under side of the bar A A, and thus tightening the head E would alter the adjustment of the point. The spring, however, always keeps the lower face of the square hole through E bearing evenly against the corresponding face of the bar, so that tightening the screw G does not affect the adjustment, and, furthermore, the end of the set-screw, bearing against the spring instead of against the top of the rod, prevents the latter from getting burred.

The flat place at I I is to prevent the burrs raised by the thumb-screw end from preventing the easy sliding of leg C through B.

In some cases a gib is employed, as shown at A in Fig. 1447, instead of a spring, the advantage being that it is less liable to come out of place when moving the head along the bar.

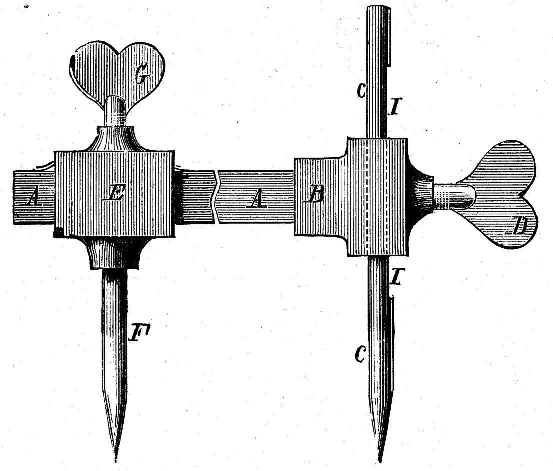

Fig. 1446.

The trammels should always be tried to the work in the same relative position as that in which they were set, otherwise the deflection of the bar may vitiate the correctness of the measurement; thus, if the rod or bar stood vertical when the points were adjusted for distance to set them to the required distance, it should also stand vertical upon the work when applied to transfer that distance, otherwise the deflection of the bar from its own weight will affect the correctness of the operation. Again, when applied to the work the latter should be suspended as nearly as convenient in the same position as the work will occupy when erected to its place.

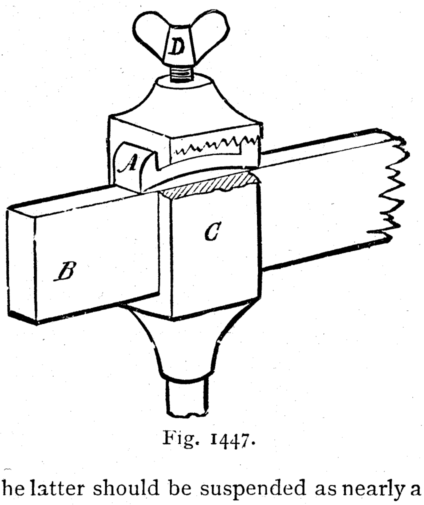

Fig. 1447.

Thus, suppose the trammels be set to the crank pin centres of a locomotive, then the bar will stand horizontally. Now the side rod, or coupling rod, as it may be more properly termed, should be stood on edge and should rest on its ends, because its bearings wherever it will rest when on the engine are at the ends; thus the deflection of the trammel rod will be in the same direction when applied to the work as it was when applied to the engine, and the deflection of the coupling rod will be in the same direction when tried by the trammel as when on the engine. The importance of this may be understood when it is mentioned that if the coupling rod be a long one, resting it on its side and supporting it in the middle instead of at its ends will cause a difference of $\frac{1}{50}$th inch in its length.

Another lineal measuring gauge employed in the machine shop is shown in Fig. 1448. It is employed to measure the distance between two faces, and therefore in place of inside calipers, in cases where from the extreme distance to be measured it would require the use of inside calipers too large to be conveniently handled. Its application is more general upon planing machine work than any other, although it is frequently used by the lathe hand or turner, and by the vice hand and erector. It consists of two legs A and B, held together by the screws C D, which screw into nuts. These nuts should have a shoulder fitting into the slots in both legs, so as to form a guide to the legs. The screws are set up so as to just bind both legs together but leaving them free enough to move under a slight friction. The gauge is then set to length by lightly striking the ends E, and when adjusted the screws C D are screwed firmly home. The ends E are rounded somewhat, as is shown, to prevent them from swelling or burring by reason of the blows given to adjust them.

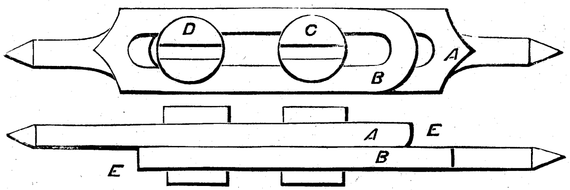

Fig. 1448.

For striking circles we have the compasses or dividers, which are made in various forms.

Thus, Fig. 1449 represents a pair of spring dividers, the bow spring at the head acting to keep the points apart, and the screw and nut being employed to close and to adjust them.

Another form is shown in Fig. 1450, the legs being operated by a right and left-hand screw, which may be locked in position by the set-screw shown.

For very small circles the fork scriber shown in Fig. 1451 is an excellent tool, since it may be used with great pressure so as to cut a deep line in the surface of the work. This tool is much used by boiler makers, but is a very useful one for the machinist for a variety of marking purposes, which will be described with reference to vice work

For larger work we have the compasses, a common form of which is shown in Fig. 1452, in which the leg A is slotted to receive the arc piece C, which has a threaded stem passing through E, and is provided with a nut at B; at D is a spring which holds the face of the nut B firmly against the leg E; at A is a thumb-screw for securing the leg to the arm C. The thumb-screw A being loosened, the compass legs may be rudely adjusted for distance apart, and A is then tightened. The adjustment is finally made by operating the nut B, which, on account of its fine thread, enables a very fine adjustment to be easily made.

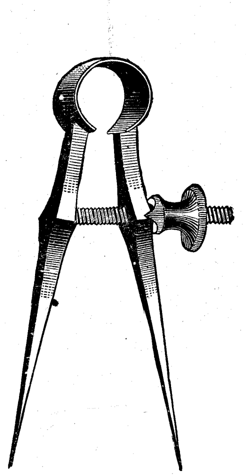

Fig. 1449.

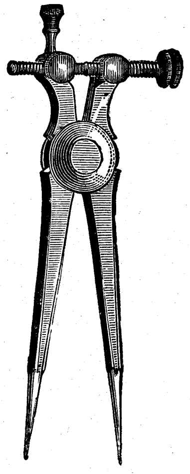

Fig. 1450.

It is often very convenient to be able to set one leg of a pair of dividers to be longer than the other, for which purpose a socket B, Fig 1453, is provided, being pierced to receive a movable piece A, and split so that by means of a set-screw C the movable piece A may be gripped or released at pleasure.

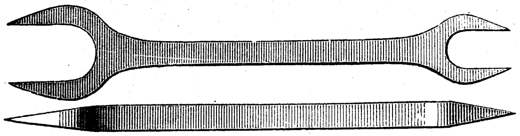

Fig. 1451.

For finding the centres of bodies or for testing the truth of a centre already marked, the compass calipers shown in Fig. 1454, are employed. It is composed of one leg similar to the leg of a pair of compasses, while the other is formed the same as the leg of an inside caliper. The uses of the compass calipers are manifold, the principal being illustrated as follows :—

Let it be required to find the centre of a rectangular block, and they are applied as in Fig. 1455, the curved leg being rested against the edge and a mark being made with the compass leg. This being done from all four sides of the work gives the centre of the piece.

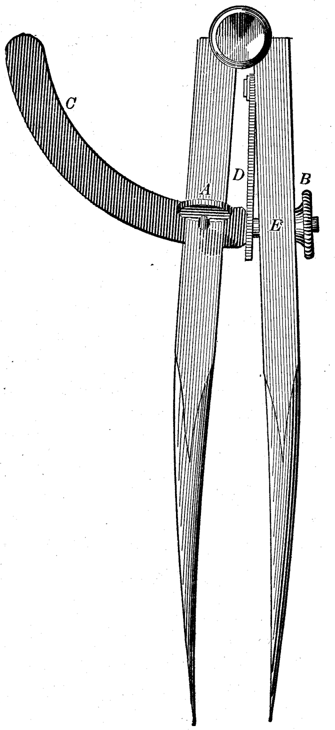

Fig. 1452.

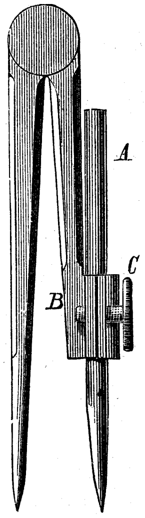

Fig. 1453.

In the case of a hole its bore must be plugged and the compass calipers applied as in Fig. 1456.

For marking a line true with the axial line of a cylindrical body, we have the instrument W in Fig. 1457, which is shown applied to a shaft S. The two angles of the instrument are at a right angle one to another, so that when placed on a cylindrical body the contact will cause the edge of W to be parallel with the axis of the shaft. The edge is bevelled, as shown, so that the lines of division of inches and parts may come close to the work surface, and a scriber may be used to mark a line of the required length. A scriber is a piece of steel wire having a hardened sharp point wherewith to draw lines.

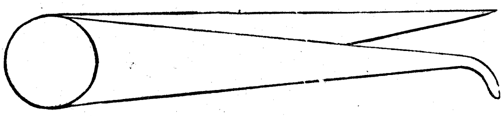

Fig. 1454.

On account of the instrument W finding its principal application in marking key seats upon shafts, it is termed the "key-seat rule."

For marking upon one surface a line parallel to another surface, the scribing block or surface gauge shown in Fig. 1458 is employed. It consists of a foot piece or stand D carrying a stem. In the form shown this stem contains a slot running centrally up it. Through this slot passes a bolt whose diameter close to the head is larger than the width of the slot, so that it is necessary to file flat places on the side of the slot to permit the bolt to pass through it.

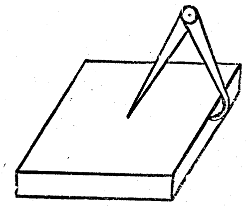

Fig. 1455.

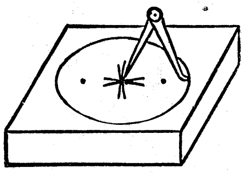

Fig. 1456.

On the stem of the bolt close to the head, and between the bolt head and the stem of the stand, passes the piece shown at F. This consists of a piece of brass having a full hole through which the bolt passes clear up to the bolt head. On the edge view there is shown a slot, and on each side of the slot a section of a hole to receive a needle. A view of the bolt is given at E, the flat place to fit the slot in the stem being shown in dotted lines, and the space between the flat place and the bolt head is where the piece of brass, shown in figure, passes. This piece of brass being placed on the bolt, and the bolt being passed through the slot in the stem, the needle is passed through the split in the brass, and the thumb-nut is screwed on so that tightening up the thumb-nut causes the needle to be gripped in the brass split in any position in the length of the stem slot in which the bolt may be placed. The advantage of this form over all others is that the needle may be made of a simple piece of wire, and therefore very readily. Again, the piece of brass carrying the needle may be rotated upon the pin any number of consecutive rotations backwards and forwards, and there is no danger of slacking the thumb-nut, because the needle is on the opposite side of the stem to what the thumb-nut is, and the flat place prevents the bolt from rotating. Furthermore, the needle can be rotated on the bolt for adjustment for height without becoming loosened, whereas when the thumb-nut is screwed up firmly the needle is held very fast indeed, and finally all adjustments are made with a single thumb-nut.

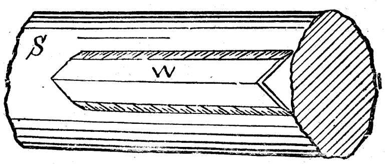

Fig. 1457.

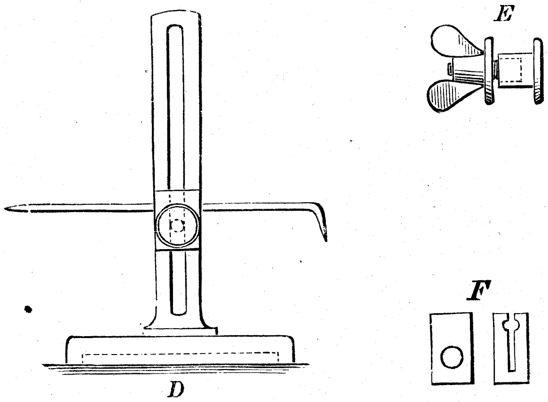

Fig. 1458.

The figure represents a view of this gauge from the bolt head and needle side of the stem, the thumb-nut being on the opposite side.

This tool finds its field of application upon lathe work, planer work, and, indeed, for one purpose or another upon all machine tools, and in vice work and erecting, examples of its employment being given in connection with all these operations.

Fig. 1459 represents a scribing block for marking the curves to which to cut the ends of a cylindrical body that joins another, as in the case of a T-pipe. It is much used by pattern-makers. In the figure A is a stem on a stand E. A loose sleeve B slides on A carrying an arm C, holding a pencil at D. A piece of truly surfaced wood or iron W, has marked on it the line J. Two Vs, G, G, receive the work P. Now, if the centres of G, G and of the stand E all coincide with the line J then E will stand central to P, and D may be moved by the hand round P, being allowed to lift and fall so as to conform to the cylindrical surface of P, and a line will be marked showing where to cut away the wood on that side, and all that remains to do is to turn the work over and mark a similar line diametrically opposite, the second line being dotted in at K

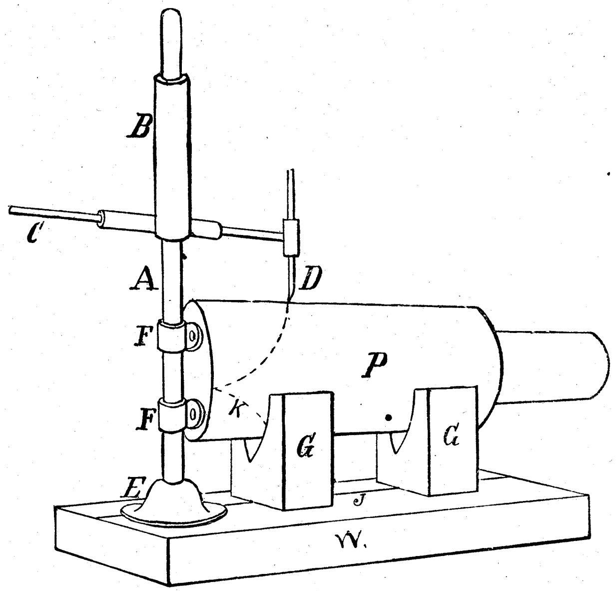

Fig. 1459.

The try square, Fig. 1460, is composed of a rectangular back F, holding a blade, the edges of the two being at a right angle one to the other and as straight as it is possible to make them. The form shown in the figure is an L-square.

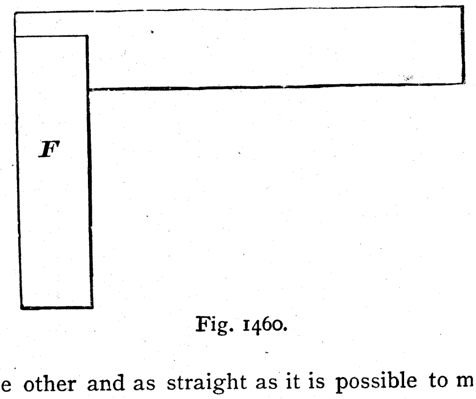

Fig. 1460.

Fig. 1461 represents the T-square, whose blade is some distance from the end of the back and is sometimes placed in the middle. When the square edges are at a true right angle the square is said to be true or square, the latter being a technical term meaning at practically a true right angle.

The machinists' square is in fact a gauge whereby to test if one face stands at a right angle to another. It is applied by holding one edge firmly and fairly bedded against the work, while the other edge is brought to touch at some part against the face to be tested.

If in applying a square it be pressed firmly into the corner of the work, any error in the latter is apt to escape observation, because the square will tilt and the error be divided between the two surfaces tested. To avoid this the back should be pressed firmly against one surface of the work and the square edge then brought down or up to just touch the work, which it will do at one end only if the work surface is out of square or not at a right angle to the face to which the square back is applied.

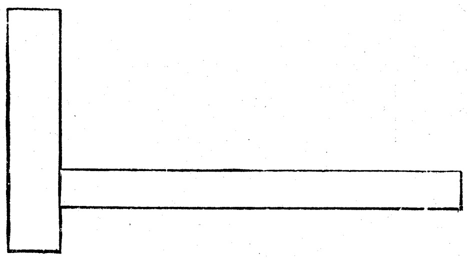

Fig. 1461.

An application of the T-square is shown in Fig. 1462, in which W is a piece of work requiring to have the face A of the jaw C at a right angle to the face B C. Sometimes the L-square is employed in conjunction with a straight-edge in place of the T-square This is usually done in cases where the faces against which the square rests are so far apart as to require a larger T-square than is at hand. It is obvious that if the face A of the work is the one to be tested, the edge *b* is the part pressed to the work; or per contra, if B C is the face to be tested, the edge of the blade is pressed to the work.

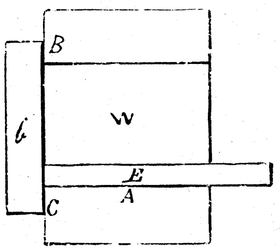

Fig. 1462.

The plane of the edges of a square should, both on the blade and on the back, stand at a right angle to the side faces of the body or stock, and the side of the blade should be parallel to the sides of the back and not at an angle to either side, nor should it be curved or bent, because if under these conditions the plane of the square edge is not applied parallel with the surface of the work the square will not test the work properly. This is shown in Fig. 1463, in which W is a piece of work, and S a square having its blade bent or curved and applied slightly out of the vertical, so that presuming the plane of the blade edge to be a right angle to the stock or back of the square the plane of the blade edge will not be parallel with the plane of the work, hence it touches the work at the ends A B only,

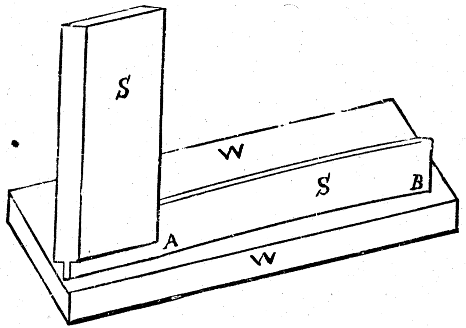

Fig. 1463.

whereas if placed vertically the blade edge would coincide with the work surface all the way along. It is obvious then that by making the edge of the blade at a right angle, crossways as well as in its length, to the stock, the latter will serve as a guide to the eye in adjusting the surface of the blade edge parallel to that of the work by placing the stock at a right angle to the same.

There are three methods of testing the angle of a square blade to the square back. The first is shown in Fig. 1464, in which A is a surface plate having its edge a true plane. The square S is placed in the position shown by full lines pressed firmly to the edge of the surface plate and a fine line is drawn with a needle point on the face of the surface plate, using the edge of the square blade as denoted by the arrow C as a guide. The square is then turned over as denoted by the dotted lines and the edge is again brought up to the line and the parallelism of the edge with the line denotes the truth, for whatever amount the blade may be out of true will be doubled in the want of coincidence of the blade edge with the line.

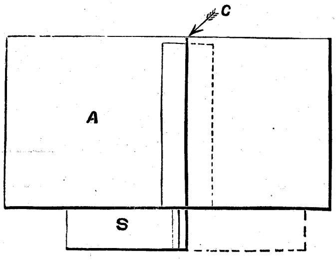

Fig. 1464.

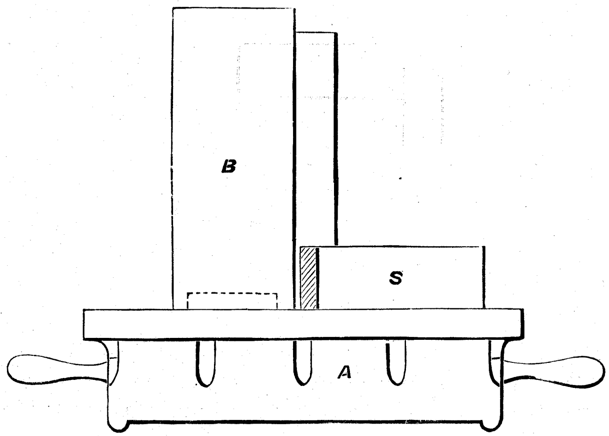

Fig. 1465.

A better plan is shown in Fig. 1465, in which A is the surface plate, B a cylindrical piece of iron turned true and parallel in the lathe and having its end face true and cupped as denoted by the dotted lines so as to insure that it shall stand steadily and true. The surface of A and the vertical outline of B forming a true right angle we have nothing to do but make the square S true to them when placed in the position shown.

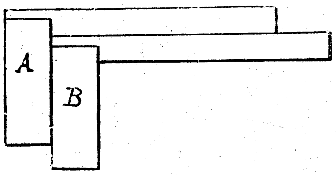

Fig. 1466.

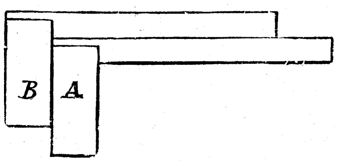

Fig. 1467.

If we have two squares that are trued and have their edges parallel, we may test them for being at a right angle by trying them together as in Figs. 1466 and 1467, in which A, B, are the two squares which, having their back edges pressed firmly together (when quite clean), must coincide along the blade edges; this being so we may place them on a truly surfaced plate as shown in Fig. 1468, in which S is one square and S′ the other, P being the surface plate. Any want of truth in the right angle will be shown doubled in amount by a want of coincidence of the blade edges.

For some purposes, as for marking out work on a surface plate, it is better that the square be formed of a single piece having the back and blade of equal thickness, as shown in Fig. 1469, which represents a side and edge view of an L and T-square respectively.

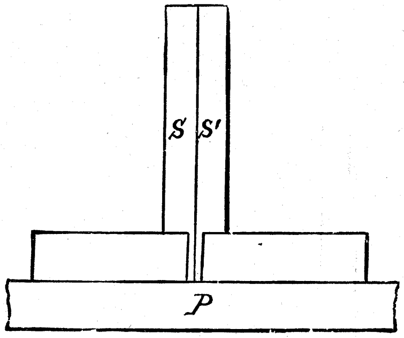

Fig. 1468.

For angles other than a right angle we have the bevel or bevel square (as it is sometimes called), shown in Fig. 1470, A representing the stock or back, and B the blade, the latter being provided with a slot so that it may be extended to any required distance (within its scope) on either side of the stock. C is the rivet, which is made sufficiently tight to permit of the movement by hand of the blade, and yet it must hold firmly enough to be used without moving in the stock. Instead of the rivet C, however, a thumb-screw and nut may be employed, in which case, after the blade is set to the required angle, it may be locked in the stock by the thumb-screw.

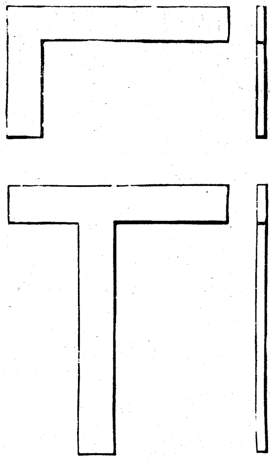

Fig. 1469.

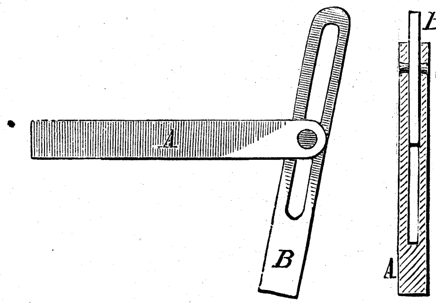

Fig. 1470.

Fig. 1471 represents a Brown and Sharpe bevel protractor, with a pivot and thumb-nut in the middle of the back with a half-circle struck from the centre of the pivot and marked to angular degrees. The pointer for denoting the degrees of angle has also a thumb-screw and nut so that the blade may, by loosening the pivot and pointer, be moved to project to the required distance on either side of the back.

Swasey's improved protractor, however, is capable of direct and easy application to the work, forming a draughtsman's protractor, and at the same time a machinist's bevel or bevel square, while possessing the advantage that there is no protruding back or set-screw to prevent the close application of the blade to the work. This instrument is shown in Fig. 1472. The blade A is attached to the circular piece D, the latter being recessed into the square B B, and marked with the necessary degrees of angle, as shown, while the mark F upon the square B serves as an index point. The faces of A, B B, and D are all quite level, so that the edges will meet the lines upon the work and obviate any liability to error. The piece D is of the shape shown in section at G, which secures it in B B, the fit being sufficient to permit of its ready adjustment and retain it by friction in any required position. The dotted lines indicate the blade as it would appear when set to an angle, the point E being the centre of D, and hence that from which the blade A operates.

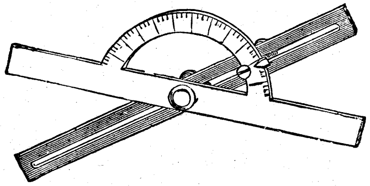
Fig. 1471.

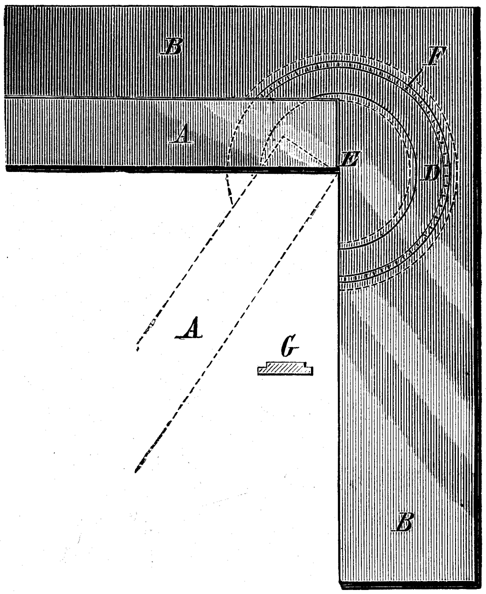

Fig. 1472.

On account, however, of the numerous applications in machine work of the hexagon (as, for instance, on the sides of both heads and nuts), a special gauge for that angle is requisite, the usual form being shown in Fig. 1473. The edges A, B, form a hexagon gauge, and edges C, D, form a square, while the edge E serves as a straight-edge.

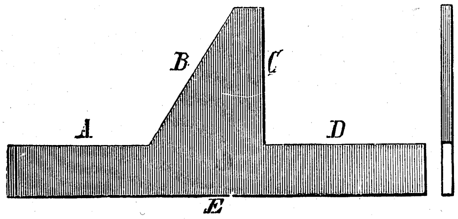

Fig. 1473.

All these tools should be made of cast steel, the blades being made of straight saw blade, so that they will not be apt to permanently set from an ordinary accidental blow; while, on the other hand, if it becomes, as it does at times, necessary to bend the blade over to the work, it will resume its straightness and not remain bent.

For testing the straightness, in one direction only, of a surface the straight-edge is employed. It consists in the small sizes of a piece of steel whose edges are made straight and parallel one to the other. When used to test the straightness of a surface without reference to its alignment with another one, it is simply laid upon the work and sighted by the eye, or it may have its edge coated with red marking, and be moved upon the work so that its marking will be transferred to the high spots upon the work. The marking will look of the darkest colour in the places where the straight-edge bears the hardest. The most refined use of the straight-edge is that of testing the alignment of one surface to the other, and as this class of work often requires straight-edges of great length, as six or ten feet, which if made of metal would bend of its own weight, therefore they are made of wood.

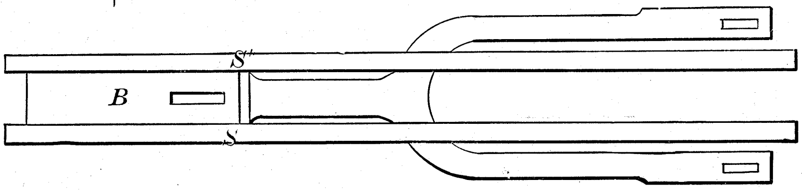

Fig. 1474.

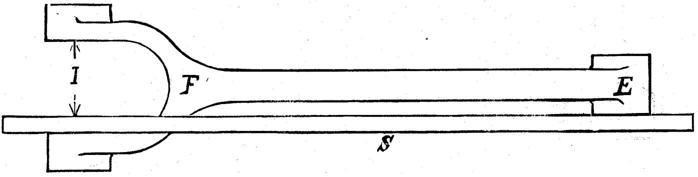

Fig. 1475.

Fig. 1474 represents an example of the use of straight-edge for alignment purposes. It represents a fork and connecting rod, and it is required to find if the side faces of the end B are in line with the fork jaws. A straight-edge is held firmly against the side faces of B in the two positions S and S', and it is obvious that if they are in line the other end will be equidistant from the jaw faces, at the two measurements.

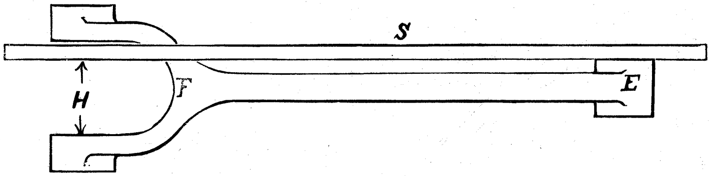

Fig. 1476.

Figs. 1474, 1475, 1476, 1477, and 1478 represent the process of testing the alignment of a link with a straight-edge. First to test if the single eye E is in line with the double eye F at the other end, the straight-edge is pressed against the face of E, as in Fig. 1475, and the distance I is measured. The straight-edge is then applied on the other side of E, as in Fig. 1476, and the distance H is measured, and it is clear that if distances H and I are equal, then E is in line with the double eye. To test if the double eye F is in line with the single eye E, the straight-edge is pressed against the face of the double eye in the positions shown in Figs.

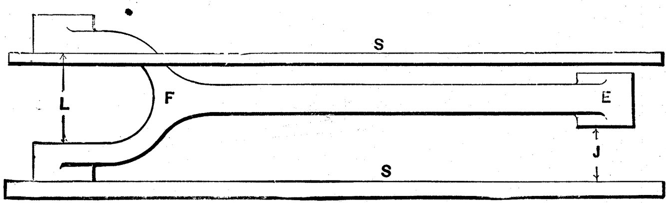

Fig. 1477.

1477 and 1478, and when distances J and K measure equal the jaws of the double eye F are in line with those of the single eye E.

It is obvious, however, that we have here tested the alignment in one direction only. But to test in the other direction we may use a pair of straight-edges termed winding strips, applying them as in Fig. 1479, to test the stem, and as in Fig. 1480 to test the eye E, and finally placing the winding strip C on the eye of F while strip D remains upon E, as in Fig. 1480. The two strips are sighted together by the eye, as is shown in Fig. 1481, in which S and S' are the strips laid upon a connecting rod, their upper edges being level with the eye, hence if they are not in line the eye will readily detect the error. Fig. 1482 represents an application to a fork ended connecting rod. Pattern-makers let into their winding strips pieces of light-coloured wood as at C, C, C, C, in Fig. 1483, so that the eye may be assisted in sighting them.

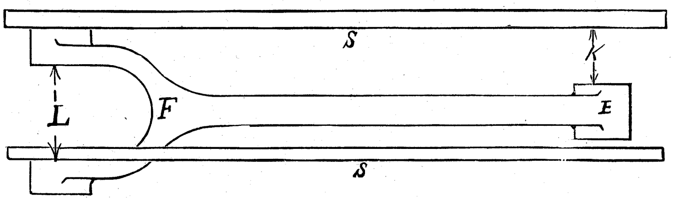

Fig. 1478.

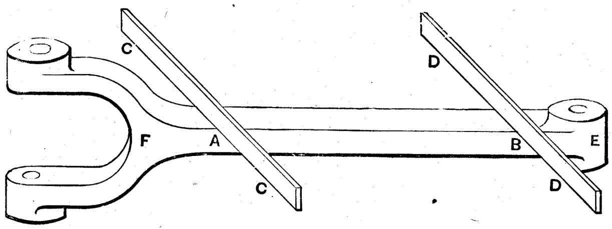

Fig. 1479.

It is obvious that in using winding strips they should be parallel one to the other; thus, for example, the ends A, B, in Fig. 1481, should be the same distance apart as ends C, D.

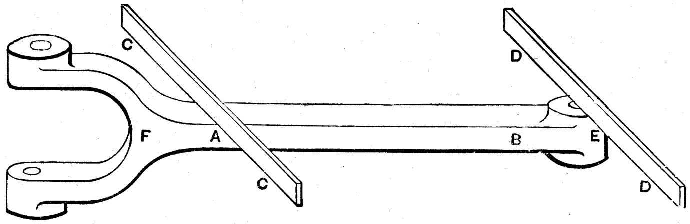

Fig. 1480.

If less than three straight-edges or parallel strips are to be trued they must be trued to a surface plate or its equivalent, but if a pair are to be made they should have the side faces made true, and be riveted together so that their edges may be trued together, and equal width may be more easily obtained. For this purpose copper rivets should be used, because they are more readily removable, as well as less likely to strain the work in the riveting.

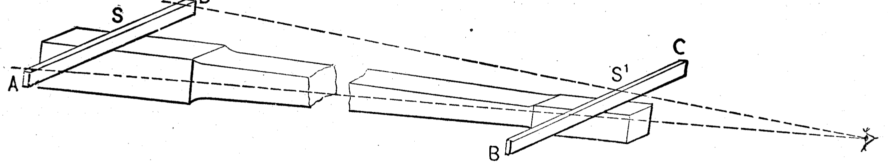

Fig. 1481.

By riveting the straight-edges together the surface becomes broader and the file operates steadier, while the edges of the straight-edge are left more square. Furthermore parallelism is more easily obtained as one measurement at each end of the batch will test the parallelism instead of having to measure each one separately at each end. If three straight-edges are to be made they may be riveted together and filed as true as may be with the testing conveniences at hand, but they should be finally trued as described for the surface plate.

In using straight-edges to set work, the latter is often heated to facilitate the setting, and in this case the straight-edge or parallel strips should be occasionally turned upside down upon the work, for if the heated work heats one side of the straight-edge more than the other the increased expansion of the side most heated will bend the straight-edge or strips, and throw them out of true.

In applying a straight-edge to test work it must never be pressed to the work surface, because in that case it will show contact with the work immediately beneath the parts where such pressure is applied. Suppose, for example, a true straight-edge be given a faint marking, and be applied to a true surface, the straight-edge itself being true; then if the hands are placed at each end of the straight-edge, and press it to the work while the straight-edge is given motion, it will leave the heaviest marks at and near the ends as though the work surface was slightly hollow in its length; while were the hand pressure applied to the middle of the length of the straight-edge the marks on the work would show the heaviest in the middle as though the work surface were rounding. This arises from the deflection due to the weakness of the straight-edge.

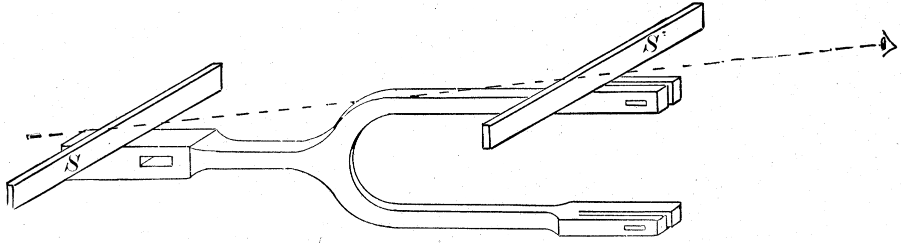

Fig. 1482.

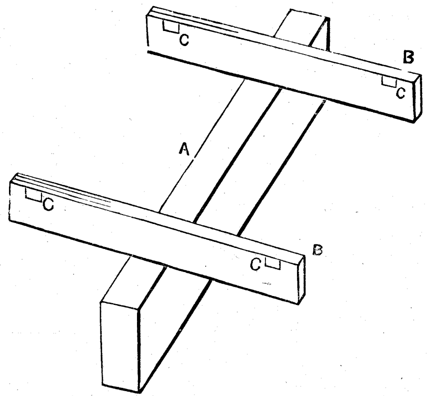

Fig. 1483.

For testing the truth of flat or plane surfaces the machinist employs the surface plate or planometer. The surface plate is a plate or casting having a true flat surface to be used as a test plate for other surfaces. It is usually made of cast iron, and sometimes of chilled cast iron or hardened cast steel, the surface in either of these two latter cases being ground true because their hardness precludes the possibility of cutting them with steel tools. A chilled or hardened surface plate cannot, however, be so truly surfaced as one that is finished with either the scraper or the file.

The shape of the surface plate is an element of the first importance, because as even the strongest bars of metal deflect from their own weight, it is necessary to shape the plate with a view to make this deflection as small as possible in any given size and weight of plate. In connection, also, with the shape we must consider the effect of varying temperatures upon the metal, for if one part of the plate is thinner than another it will, under an increasing temperature, heat more rapidly, and the expansion due to the heating will cause that part to warp the plate out of its normal form, and hence out of true. The amount that a plate will deflect of its own weight can only be appreciated by those who have had experience in getting up true surfaces, but an idea may be had when it is stated that it can be shown that it is easily detected in a piece of steel three inches square and a foot long.

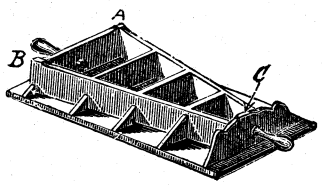

Fig. 1484.

Now this deflection will vary in direction according to the points upon which the plate rests. For instance, take two plates, clean them properly, and rest one upon two pieces of wood, one piece under each end, and then place another plate upon the lower one and its face will show hollow, and, if the upper plate is moved backwards and forwards laterally it will be found to move from the ends as centres of motion. Then rest the lower plate upon a piece of wood placed under the middle of its length, and we shall find that (if the plates are reasonably true) the top one will move laterally with the middle of its length as a centre of motion. Now although this method of testing will prove deflection to exist, it will not show its amount, because the top plate deflects to a certain extent, conforming itself to the deflection of the lower one, and if the test is accurately made it will be found that the two plates will contact at whatever points the lower one is supported.

If plates, tested in this manner, show each other to have contact all along however the lower one is supported, it is because they are so light that the upper one will readily bend to suit the deflection of the lower one, and true work is, with such a plate, out of the question.

To obviate these difficulties the body of the plate is heavily ribbed, and these ribs are so arranged as to be of equal lengths, and are made equal in thickness to the plate, so that under variations of temperature the ribs will not expand or contract more quickly or slowly than the body of the plate, and the twisting that would accompany unequal expansion is avoided.

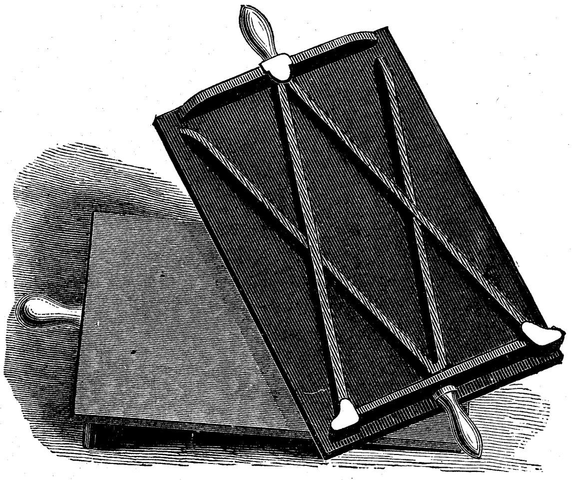

Fig. 1485.

In Fig. 1484 is shown the form of surface plate designed by Sir Joseph Whitworth for plates to be rested upon their feet. The resting points of the plate are small projections shown at A, B, and C. The object of this arrangement of feet is to enable the plate to rest with as nearly as possible an equal degree of weight upon each foot, the three feet accommodating themselves to an uneven surface. It is obvious, however, that more of the weight will fall upon C than upon A or B, because C supports the whole weight at one end, while at the other end A and B divide the weight.

Fig. 1485 shows the form of plate designed by Professor Sweet.

In Fig. 1486 is shown a pair of angle surface plates resting upon a flat one. The angle plates may be used for a variety of purposes where it is necessary to true a surface standing at a true right angle to another.

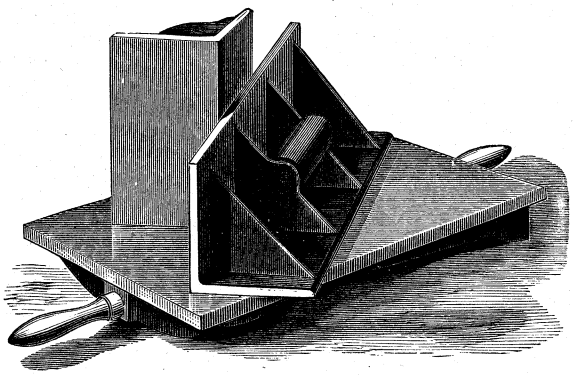

Fig. 1486.

The best methods of making surface plates are as follows :—

The edges of the plates should be planed first, care being taken to make them square and flat. The surfaces should then be planed, the plates being secured to the planer *by the edges*, which will prevent as far as possible the pressure necessary to hold them against the planing tool cut from springing, warping, or bending the plates. Before the finishing cut is taken, the plates or screws holding the surface plate should be slackened back a little so as to hold them as lightly as may be, the finishing cut being a very light one, and under these circumstances the plates may be planed sufficiently true that one will lift the other from the partial vacuum between them.

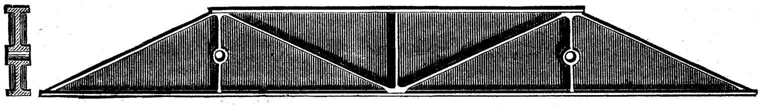

Fig. 1487.

After the plates are planed, and before any hand work is done on them, they should be heated to a temperature of at least 200° Fahr., so that any local tension in the casting may be as far as possible removed.

Surface plates for long and narrow surfaces are themselves formed long and narrow, as shown in Fig. 1487, which represents the straight-edge surface plate made at Cornell University.

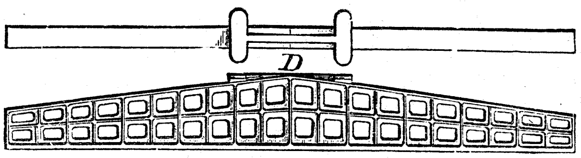

Fig. 1488.

The Whitworth surfacing straight-edge, or long narrow surface plate, is ribbed as in Fig. 1488, so as to give it increased strength in proportion to its weight, and diminish its deflection from its own weight. The lugs D are simply feet to rest it on.

Straight-edges are sometimes made of cast steel and trued on both edges. These will answer well enough for small work, but if made of a length to exceed about four feet their deflection from their own weight seriously affects their reliability. The author made an experiment upon this point with a very rigid surface plate six feet long, and three cast steel straight-edges 6 feet long, $4\frac{1}{2}$ inches wide, and $\frac{1}{2}$ inch thick. Both edges of the straight-edges were trued to the surface plate until the light was excluded from between them, while the bearing surface appeared perfect;

thin tissue paper was placed between the straight-edges and the plate, and on being pulled showed an equal degree of tension. The straight-edges were tried one with the other in the same way and interchanged without any apparent error, but on measuring them it was found that each was about $\frac{1}{50}$ inch wider in the middle of its length than at the ends, the cause being the deflection. They were finished by filing them parallel to calipers, using the bearing marks produced by rubbing them together and also upon the plate; but, save by the caliper test, the improvement was not discernible.

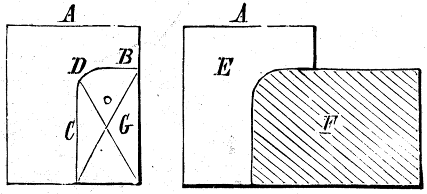

Fig. 1489.

In rubbing them together no pressure was used, but they were caused to slide under their own weight only.

A separate and distinct class of gauge is used in practice to copy the form of one piece and transfer it to another, so that the one may conform to or fit the other. To accomplish this end, what are termed male and female templates or gauges are employed. These are usually termed templates, but their application to the work is termed gauging it.

Suppose, for example, that a piece is to be fitted to the rounded corner of a piece F, Fig. 1489, and the maker takes a piece of sheet metal A, and cuts it out to the line B C D, leaving a female gauge E, which will fit to the work F. We then make a male gauge G, and apply this to the work, thus gauging the round corner.

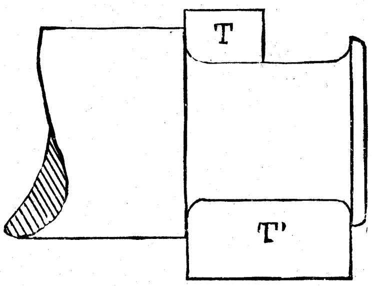

Fig. 1490.

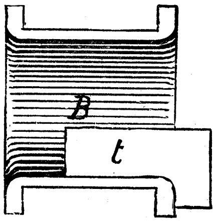

Fig. 1491.

Fig. 1490 represents small templates applied to a journal bearing, and it is seen that we may make the template as at T, gauging one corner only, or we may make it as at T', thus gauging the length of the journal as well as the corners.

Fig. 1491 represents a female gauge applied to the corner of a bearing or brass for the above journal, it being obvious that the male and female templates when put together will fit as in Fig. 1492.

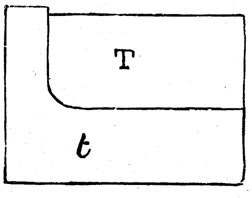

Fig. 1492.

For measuring the diameters of metal wire and the thickness of rolled sheet metal, measuring instruments termed wire gauges and sheet metal measuring machines are employed. A simple wire gauge is usually formed of a piece of steel containing numerous notches, whose widths are equal to the intended thickness to be measured in each respective notch. These notches are marked with figures denoting the gauge-number which is represented by the notch.

For wire, however, a gauge having holes instead of notches is sometimes employed, the wire being measured by insertion in the hole, an operation manifestly impracticable in the case of sheet metal.

In Fig. 1493 is shown one of Brown and Sharpe's notch wire-gauges, the notches being arranged round the edge as shown:

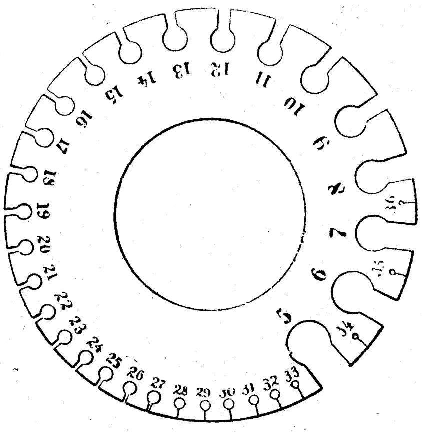

Fig. 1493.

The thickness of a given number of wire-gauge varies according to the system governing the numbering of the gauge, which also varies with the class of metal or wire for which the gauge has been adopted by manufacturers. Thus, in the following table are given the gauge-numbers and their respective sizes in decimal parts of an inch, as determined by Holtzapffel in 1843, and to which sizes the Birmingham wire-gauge is made. The following table gives the numbers and sizes of the Birmingham wire-gauge.

BIRMINGHAM WIRE GAUGE.

Mark	Size.	Mark.	Size.	Mark.	Size.	Mark.	Size.
36	·004	26	·018	16	·065	6	·203
35	·005	25	·020	15	·072	5	·220
34	·007	24	·022	14	·083	4	·238
33	·008	23	·025	13	·095	3	·259
32	·009	22	·028	12	·109	2	·284
31	·010	21	·032	11	·120	1	·300
30	·012	20	·035	10	·134	0	·340
29	·013	19	·042	9	·148	00	·380
28	·014	18	·049	8	·165	000	·425
27	·016	17	·058	7	·180	0000	·454

In this gauge it will be observed that the progressive wire gauge numbers do not progress by a regular increment.

This gauge is sometimes termed the Stubs wire-gauge, Mr. Stubs being a manufacturer of instruments whose notches are spaced according to the Birmingham wire-gauge. Since, however, Mr. Stubs has also a wire-gauge of his own, whose numbers and gauge-sizes do not correspond to those of the Birmingham gauge, the two Stubs gauges are sometimes confounded. The second Stubs gauge is employed for a special drawn steel wire, made by that gentleman to very accurate gauge measurement for purposes in which accuracy is of primary importance.

From the wear of the drawing dies in which wire is drawn, it is impracticable, however, to attain absolute correctness of gauge measurement. The dies are made to correct gauge when new, and when they have become worn larger, to a certain extent, they are renewed. As a result the average wire is slightly larger than the designated gauge-number. To determine the amount of this error the Morse Twist-Drill and Machine Company measured the wire used by them during an extended period of time, the result being given in table No. 2, in which the first column gives the gauge-number, the second column gives the thickness of the gauge-number in decimal parts of an inch, and the third column the actual size of the wire in decimal parts of an inch as measured by the above Company.

DIAMETER OF STUBS'S DRAWN STEEL WIRE IN FRACTIONAL PARTS OF AN INCH.

No. by Stubs's wire-gauge.	Stubs's Dimensions.	Measurement by Morse Twist-Drill and Machine Co.	No. by Stubs's wire-gauge.	Stubs's Dimensions.	Measurement by Morse Twist-Drill and Machine Co.	No. by Stubs's wire-gauge.	Stubs's Dimensions.	Measurement by Morse Twist-Drill and Machine Co.
1	·227	·228	23	·153	·154	45	·081	·082
2	·219	·221	24	·151	·152	46	·079	·080
3	·212	·213	25	·148	·150	47	·077	·079
4	·207	·209	26	·146	·148	48	·075	·076
5	·204	·206	27	·143	·145	49	·072	·073
6	·201	·204	28	·139	·141	50	·069	·070
7	·199	·201	29	·134	·136	51	·066	·067
8	·197	·199	30	·127	·129	52	·063	·064
9	·194	·196	31	·120	·120	53	·058	·060
10	·191	·194	32	·115	·116	54	·055	·054
11	·188	·191	33	·112	·113	55	·050	·052
12	·185	·188	34	·110	·111	56	·045	·047
13	·182	·185	35	·108	·110	57	·042	·044
14	·180	·182	36	·106	·106	58	·041	·042
15	·178	·180	37	·103	·104	59	·040	·041
16	·175	·177	38	·101	·101	60	·039	·040
17	·172	·173	39	·099	·100	61	·038	·039
18	·168	·170	40	·097	·098	62	·037	·038
19	·164	·166	41	·095	·096	63	·036	·037
20	·161	·161	42	·092	·094	64	·035	·036
21	·157	·159	43	·088	·089	65	·033	·035
22	·155	·156	44	·085	·086			

The following table represents the letter sizes of the same wire :—

LETTER SIZES OF WIRE.

A.	0·234	J.	0·277	S.	0·348
B.	0·238	K.	0·281	T.	0·358
C.	0·242	L.	0·290	U.	0·368
D.	0·246	M.	0·295	V.	0·377
E.	0·250	N.	0·302	W	0·386
F.	0·257	O.	0·316	X.	0·397
G.	0·261	P.	0·323	Y.	0·404
H.	0·266	Q.	0·332	Z.	0·413
I.	0·272	R.	0·339		

By an Order in Council dated August 23rd, 1883, and which took effect on March 1st, 1884, the standard department of the British Board of Trade substituted for the old Birmingham wire-gauge the following :—

Descriptive number B. W. G.	Equivalents in parts of an inch.	Descriptive number B. W. G.	Equivalents in parts of an inch.
No.	Inch.	No.	Inch.
7/0	0·500	23	0·024
6/0	·464	24	·022
5/0	·432	25	·020
4/0	·400	26	·018
3/0	·372	27	·0164
2/0	·348	28	·0148
0	·324	29	·0136
1	·300	30	·0124
2	·276	31	·0116
3	·252	32	·0108
4	·232	33	·0100
5	·212	34	·0092
6	·192	35	·0084
7	·176	36	·0076
8	·160	37	·0068
9	·144	38	·0060
10	·128	39	·0052
11	·116	40	·0048
12	·104	41	·0044
13	·092	42	·0040
14	·080	43	·0036
15	·072	44	·0032
16	·064	45	·0028
17	·056	46	·0024
18	·048	47	·0020
19	·040	48	·0016
20	·036	49	·0012
21	·032	50	·0010
22	·028		

The gauge known as the American Standard Wire-Gauge was designed by Messrs. Brown and Sharpe to correct the discrepancies of the old Birmingham wire-gauge by establishing a regular proportion of the thirty-nine successive steps between the 0000 and 36 gauge-number of that gauge. In the American Standard (which is also called the Brown and Sharpe gauge) the value of 0·46 or $\frac{46}{100}$ has been taken as that for 0000 or the largest dimension of the gauge. Then by successive and uniform decrements, each number following being obtained from multiplying its predecessor by 0·890522 (which is the same thing as deducting 10·9478 per cent.), the final value for number 36 is reached at 0·005, which corresponds with number 35 of the Birmingham wire-gauge. The principle of the gauge is shown in Fig. 1495, which represents a gauge for jewelers, having an angular aperture with the gauge-numbers marked on the edge, the lines and numbers being equidistant.

The advantage of this system is that the instrument is easy to produce, the difference between any two gauge-numbers being easily found by calculation ; and the gauge is easy to originate, since the opening, being of the proper width at the open end, the sides terminating at the proper distance and being made straight, the intermediate gauge-sizes may be accurately marked by the necessary number of equidistant lines.

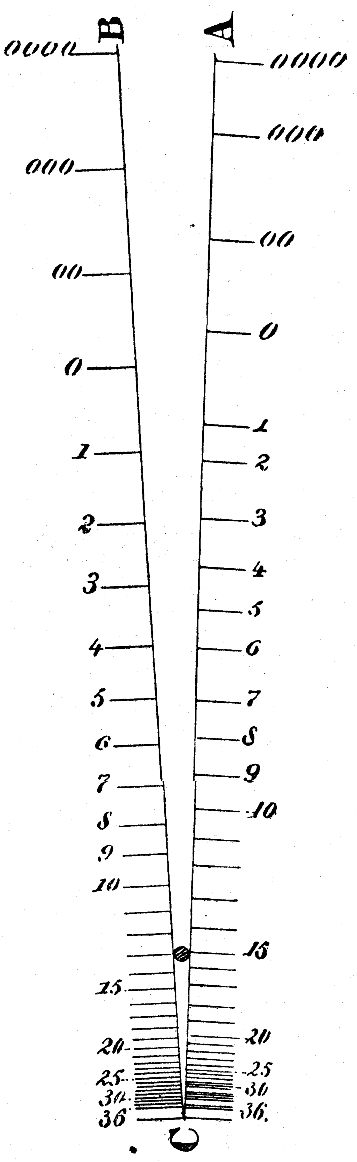

Fig. 1494.

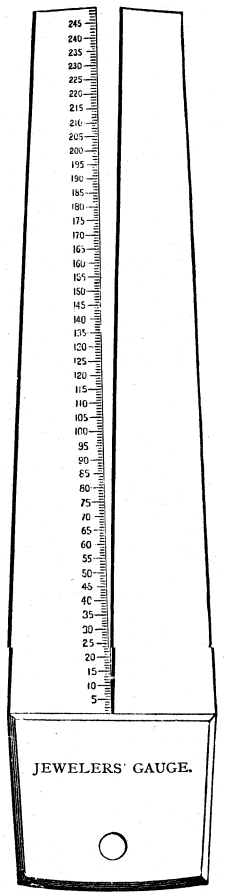

Fig. 1495.

Wire, to be measured by such a gauge, is simply inserted into and passed up the aperture until it meets the sides of the same, which gives the advantage that the size of the wire may be obtained, even though its diameter vary from a gauge-number. This could not be done with a gauge in which each gauge-number and size is given in a separate aperture or notch. A comparison between the Brown and Sharpe and the Birmingham wire-gauge is shown in Fig. 1494, in which a piece of wire is inserted, showing that No. 15 by the Birmingham gauge is No. 13 by the Brown and Sharpe gauge.

The gauge-numbers and sizes of the same in decimal parts of an inch, of the American standard or Brown and Sharpe gauge, are given in the table following:—

No. of Wire-Gauge.	American or New Standard.		No. of Wire-Gauge.	American or New Standard.	
	Size of each number in decimal parts of an inch.	Difference between consecutive numbers in decimal parts of an inch.		Size of each number in decimal parts of an inch.	Difference between consecutive numbers in decimal parts of an inch.
0000	·460	——	19	·03589	·00441
000	·40964	·05036	20	·03196	·00393
00	·36480	04484	21	·02846	·00350
0	·32495	·03994	22	·02535	·00311
1	·28930	·03556	23	·02257	·00278
2	·25763	·03167	24	·0201	·00247
3	·22942	·02821	25	·0179	·00220
4	·20431	·02511	26	·01594	·00196
5	·18194	·02237	27	·01419	·00174
6	·16202	·01992	28	·01264	·00155
7	·14428	·01774	29	·01126	·00138
8	·12849	·01579	30	·01002	·00123
9	·11443	·01406	31	·00893	·00110
10	·10189	·01254	32	·00795	·00098
11	·09074	·01105	33	·00708	00087
12	·08081	·00993	34	·0063	·00078
13	·07196	·00885	35	.00561	·00069
14	·06408	·00788	36	·005	·00061
15	·05707	·00702	37	·00445	·00055
16	·05082	·00625	38	·00396	·00049
17	·04525	·00556	39	·00353	·00043
18	·0403	·00495	40	·00314	·00039

This gauge is now the standard by which rolled sheet brass and seamless brass tubing is made in the United States. It is also sometimes used as a gauge for the copper wire used for electrical purposes, being termed the American Standard; but unless the words "American Standard" are employed, the above wire is supplied by the Birmingham wire-gauge numbers. The brass wire manufacturers have not yet adopted the Brown and Sharpe gauge; hence, for brass wire the Birmingham gauge is the standard.

Gauges having simple notches are not suitable for measuring accurately the thickness of metal, because the edges of the sheets or plates frequently vary from the thickness of the body of the plate. This may occur from the wear of the rolls employed to roll out the sheet, or because the sheets have been sheared to cut them to the required width, or to remove cracks at the edges, which shearing is apt to form a burr or projection on one side of the edge, and a slight depression on the other.

Again, a gauge formed by a notch requires to slide over the metal of the plate, and friction and a wear causing an enlargement of the notch ensues, which destroys the accuracy of the gauge. To avoid this source of error the form of gauge that was shown in Fig. 1370 may be used, it having the further advantage that it will measure thicknesses intermediate between the sizes of two contiguous notches, thus measuring the actual thickness of the sheet when it is not to any accurate sheet metal gauge thickness.

It is to be observed that in the process of rolling, the sheet is reduced from a greater to a lesser thickness, hence the gauge will not pass upon the plate until the latter is reduced to its proper thickness.

In applying the gauge, therefore, there is great inducement for the workman to force the gauge on to the sheet, in order to ascertain how nearly the sheet is to the required size, and this forcing process causes rapid wear to the gauge.

It follows, therefore, that a gauge should in no case be forced on, but should be applied lightly and easily to the sheet to prevent wear. Here may be mentioned another advantage of the Brown and Sharpe gauge, in that its gauge-number measurements being uniform, it may be more readily known to what extent a given plate varies from its required gauge thickness.

Suppose, for example, a sheet requiring to be of Number 1 Birmingham gauge is above the required thickness, but will pass easily through the 0 notch of the gauge, the excessive variation of those two gauge numbers (over the variations between other consecutive numbers of the gauge) leaves a wider margin in estimating how much the thickness is excessive than would be the case in using the Brown and Sharpe gauge. Indeed, if the edge of the plate be of uniform thickness with the body of the plate, the variation from the required thickness may be readily ascertained by a Brown and Sharpe gauge, by the distance the plate will pass up the aperture beyond the line denoting the 0 gauge number, or by the distance it stands from the 1 on the gauge when passed up the aperture until it meets both sides of the same.

In addition to these standard gauges, some firms in the United States employ a standard of their own; the principal of these are given in comparison with others in the table following.

DIMENSIONS OF SIZES, IN DECIMAL PARTS OF AN INCH.

Number of Wire Gauge.	American or Brown & Sharpe.	Birmingham, or Stubs's.	Washburn & Moen Mfg. Co., Worcester, Ms.	Trenton Iron Co., Trenton, N. J.	G. W. Prentiss, Holyoke, Mass.	Old English, from Brass Manufacturers' List.
000000	—	—	·46	—	—	—
00000	—	—	·43	·45	—	—
0000	·46	·454	·393	·4	—	—
000	·40964	·425	·362	·36	·3586	—
00	·3648	·38	·331	·33	·3282	—
0	·32495	·34	·307	·305	·2994	—
1	·2893	·3	·283	·285	·2777	—
2	·25763	·284	·263	·265	·2591	—
3	·22942	·259	·244	·245	·2401	—
4	·20431	·238	·225	·225	·223	—
5	·18194	·22	·207	·205	·2047	—
6	·16202	·203	·192	·19	·1885	—
7	·14428	·18	·177	·175	·1758	—
8	·12849	·165	·162	·16	·1605	—
9	·11443	·148	·148	·145	·1471	—
10	·10189	·134	·135	·13	·1351	—
11	·090742	·12	·12	·1175	·1205	—
12	·080808	·109	·105	·105	·1065	—
13	·071961	·095	·092	·0925	·0928	—
14	·064084	·083	·08	·08	·0816	·083
15	·057068	·072	·072	·07	·0726	·072
16	·05082	·065	·063	·061	·0627	·065
17	·045257	·058	·054	·0525	·0546	·058
18	·040303	·049	·047	·045	·0478	·049
19	·03539	·042	·041	·039	·0411	·04
20	·031961	·035	·035	·034	·0351	·035
21	·028462	·032	·032	·03	·0321	·0315
22	·025347	·028	·028	·027	·029	·0295
23	·022571	·025	·025	·024	·0261	·027
24	·0201	·022	·023	·0215	·0231	·025
25	·0179	·02	·02	·019	·0212	·023
26	·01594	·018	·018	·018	·0194	·0205
27	·014195	·016	·017	·017	·0182	·01875
28	·012641	·014	·016	·016	·017	·0165
29	·011257	·013	·015	·015	·0163	·0155
30	·010025	·012	·014	·014	·0156	·01375
31	·008928	·01	·0135	·013	·0146	·01225
32	·00795	·009	·013	·012	·0136	·01125
33	·00708	·008	·011	·011	·013	·01025
34	·006304	·007	·01	·01	·0118	·0095
35	·005614	·005	·0095	·009	·0109	·009
36	·005	·004	009	·008	·01	·0075
37	·004453	—	·0085	·00725	·0095	·0065
38	·003965	—	·008	·0065	·009	·00575

In the Whitworth wire-gauge, the mark or number on the gauge simply denotes the number of $\frac{1}{1000}$ths of an inch the wire is in diameter; thus Number 1 on the gauge is $\frac{1}{1000}$th inch, Number 2 is $\frac{2}{1000}$ths inch in diameter, and so on.

Below is given the Washburn and Moen Manufacturing Company's music wire-gauge.

SIZES OF THE NUMBERS OF STEEL MUSIC WIRE-GAUGE.

No. of Gauge.	Size of each No. in decimal parts of an inch.	No. of Gauge.	Size of each No. in decimal parts of an inch.
12	·0295	21	·0461
13	·0311	22	·0481
14	·0325	23	·0506
15	·0343	24	·0547
16	·0359	25	·0585
17	·0378	26	·0626
18	·0395	27	·0663
19	·0414	28	·0719
20	·043	—	—

These sizes are those used by the Washburn and Moen Manufacturing Company, of Worcester, Mass., manufacturers of steel music wire.

In the following table is the French Limoges wire-gauge.

Number on gauge.	Diameter, millimètre.	Inch.	Number on gauge.	Diameter, millimètre.	Inch.
0	·39	·0154	13	1·91	·0725
1	·45	·0177	14	2·02	·0795
2	·56	·0221	15	2·14	·0843
3	·67	·0264	16	2·25	·0886
4	·79	·0311	17	2·84	·112
5	·90	·0354	18	3·40	·134
6	1·01	·0398	19	3·95	·156
7	1·12	·0441	20	4·50	·177
8	1·24	·0488	21	5·10	·201
9	1·35	·0532	22	5·65	·222
10	1·46	·0575	23	6·20	·244
11	1·68	·0661	24	6·80	·268
12	1·80	·0706			

The following table gives the Birmingham wire-gauge for rolled sheet silver and gold.

Gauge number.	Thickness.	Gauge number.	Thickness.
	Inch.		Inch.
1	·004	19	·064
2	·005	20	·067
3	·008	21	·072
4	·010	22	·074
5	·013	23	·077
6	·013	24	·082
7	·015	25	·095
8	·016	26	·103
9	·019	27	·113
10	·024	28	·120
11	·029	29	·124
12	·034	30	·126
13	·036	31	·133
14	·041	32	·143
15	·047	33	·145
16	·051	34	·148
17	·057	35	·158
18	·061	36	·167

The following table gives the gauge thickness of Russia sheet iron,* the corresponding numbers by Birmingham wire gauge, and the thicknesses in decimal parts of an inch.

Russia gauge number.	Birmingham wire-gauge number.	Thickness in decimal parts of an inch.
7	29	·013
8	28	·014
9	27	·016
10	26	·018
11	25	·020
12	24½	·021
13	24	·022
14	23¼	—
15	22⅜	—
16	21½	—

The following table gives the gauge numbers to which galvanized iron is made.†

Gauge number.	Thickness.	Gauge number.	Thickness.
	Inch.		Inch.
14	·083	23	·025
16	·065	24	·022
17	·058	25	·02
18	·049	26	·018
19	·042	27	.016
20	·035	28	·014
21	·032	29	·013
22	·028		

In the following table is given the American gauge sizes and their respective thicknesses for sheet zinc.

Gauge and Thickness.			Gauge and Thickness.		
Number.	Approximate Birmingham wire-gauge.	Thickness in fractions of an inch.	Number.	Approximate Birmingham wire-gauge.	Thickness in fractions of an inch.
1	—	0·0039	16	—	0·0447
5	—	0·0113	17	—	0·0521
6	—	0·0132	18	—	0·0596
7	—	0·0150	19	—	0·0670
8	28	0·0169	20	—	0·0744
9	27	0·0187	21	—	0·0818
10	26	0·0224	22	—	0·0892
11	25	0·0261	23	—	0·0966
12	24	0·0298	24	—	0·1040
13	—	0·0336	25	—	0·1114
14	—	0·0373	26	—	0·1189
15	—	0·0410			

The Belgian sheet zinc gauge is as follows:

Gauge number.	Thickness in decimal parts of an inch.	Gauge number.	Thickness in decimal parts of an inch.
1	·004	14	·037
2	·006	15	·041
3	·008	16	·045
4	·009	17	·052
5	·011	18	·059
6	·013	19	·067
7	·015	20	·074
8	·017	21	·082
9	·019	22	·089
10	·022	23	·097
11	·026	24	·104
12	·030	25	·111
13	·034	26	·120

The gauge sizes of the bores of rifles are given in the following table,* in which the first column gives the proper gauge diameter of bore, and the second the actual diameter containing the errors found to exist from errors of workmanship. The standard diameters are supposed to be based upon the number of spherical bullets to the pound weight, if of the same diameter as the respective gauge sizes.

No. of Gauge.		Diameter of Bore.	No. of Gauge.		Diameter of Bore.
4	varies from	1·052 to 1·000	14	varies from	·693 to ·680
6	,,	·919 ,, ·900	16	,,	·662 ,, ·650
8	,,	·835 ,, ·820	20	,,	·615 ,, ·610
10	,,	·775 ,, ·760	24	,,	·579 ,, ·577
12	,,	·729 ,, ·750	28	,,	·550 ,, ·548

The following table gives the result of some recent experiments made by Mr. David Kirkaldy, of London, to ascertain the tensile strength and resistance to torsion of wire made of various materials:

Kind of wire tested.	Pulling stress per sq. in.	
	Unannealed.	Annealed.
	Pounds.	Pounds.
Copper	63,122	37,002
Brass	81.156	51,550
Charcoal iron	65.834	46,160
Coke iron	64,321	61,294
Steel	120,976	74,637
Phosphor bronze, No. 1	159,515	58,853
,, No. 2	151,119	64,569
,, No. 3	139,141	54,111
,, No. 4	120,900	53.381

Kind of wire tested.	Ultimate extension in per cent. Annealed.	No. of twists in 5 inches.	
		Unannealed.	Annealed.
Copper	34·1	86·8	96
Brass	36·5	14·7	57
Charcoal iron	28	48	87
Coke iron	17	26	44
Steel	10·9	†	79
Phosphor bronze, No. 1	46·6	13 3	66
,, No. 2	42·8	15·8	60
,, No. 3	44·9	17·3	53
,, No. 4	42·4	13	124

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* This iron comes in sheets 28 × 56 inches = 10·88 square feet of area.

† Galvanized iron is made to the Birmingham wire-gauge, the thickness includes the galvanizing, the sheets being rolled thinner to allow for it.

* From *The English Mechanic.*

† Of the eight pieces of steel tested, three stood from forty to forty-five twists, and five stood one and a half to four twists.

The following, on some experiments upon the elasticity of wires, is from the report of a committee read before the British Association at Sheffield, England.

"The most important of these experiments form a series that have been made on the elastic properties of very soft iron wire. The wire used was drawn for the purpose, and is extremely soft and very uniform. It is about No. 20 B.W.G., and its breaking weight, tested in the ordinary way, is about 45 lbs. This wire has been hung up in lengths of about 20 ft., and broken by weights applied, the breaking being performed more or less slowly.

"In the first place some experiments have been tried as to the smallest weight which, applied very cautiously and with precautions against letting the weight run down with sensible velocity, will break the wire. These experiments have not yet been very satisfactorily carried out, but it is intended to complete them.

"The other experiments have been carried out in the following way: It was found that a weight of 28 lbs. does not give permanent elongation to the wire taken as it was supplied by the wire drawer. Each length of the wire, therefore, as soon as it was hung up for experiment, was weighted with 28 lbs., and this weight was left hanging on the wire for 24 hours. Weights were then added till the wire broke, measurements as to elongation being taken at the same time. A large number of wires were broken with equal additions of weight, a pound at a time, at intervals of from three to five minutes—care being taken in all cases, however, not to add fresh weight if the wire could be seen to be running down under the effect of the weight last added. Some were broken with weights added at the rate of 1 lb. per day, some with $\frac{3}{4}$ lb. per day, and some with $\frac{1}{2}$ lb. per day. One experiment was commenced in which it was intended to break the wire at a very much slower rate than any of these. It was carried on for some months, but the wire unfortunately rusted, and broke at a place which was seen to be very much eaten away by rust, and with a very low breaking weight. A fresh wire has been suspended, and is now being tested. It has been painted with oil, and has now been under experiment for several months.

"The following tables will show the general results of these experiments. It will be seen, in the first place, that the prolonged application of stress has a very remarkable effect in increasing the strength of soft iron wire. Comparing the breaking weights for the wire quickly broken with those for the same wire slowly broken, it will be seen that in the latter case the strength of the wire is from two to ten per cent. higher than in the former, and is on the average about five or six per cent. higher. The result as to elongation is even more remarkable, and was certainly more unexpected. It will be seen from the tables that, in the case of the wire quickly drawn out, the elongation is on the average more than three times as great as in the case of the wire drawn out slowly. There are two wires for which the breaking weights and elongations are given in the tables, both of them 'bright' wires, which showed this difference very remarkably. They broke without showing any special peculiarity as to breaking weight, and without known difference as to treatment, except in the time during which the application of the breaking weight was made. One of them broke with $44\frac{1}{4}$ lbs., the experiment lasting one hour and a half; the other with 47 lbs., the time occupied in applying the weight being 39 days. The former was drawn out by 28·5 per cent. on its original length, the latter by only 4.79 per cent.

"It is found during the breaking of these wires that the wire becomes alternately more yielding and less yielding to stress applied. Thus from weights applied gradually between 28 lbs. and 31 lbs. or 32 lbs., there is very little yielding, and very little elongation of the wire. For equal additions of weight between 33 lbs. and about 37 lbs. the elongation is very great. After 37 lbs. have been put on, the wire seems to get stiff again, till a weight of about 40 lbs. has been applied. Then there is a rapid running down till 45 lbs. has been reached. The wire then becomes stiff again, and often remains so till it breaks. It is evident that this subject requires careful investigation."

TABLES SHOWING THE BREAKING OF SOFT IRON WIRES AT DIFFERENT SPEEDS.

I.—WIRE QUICKLY BROKEN.

Rate of adding weight.	Breaking weight in pounds.	Per cent. of elongation on original length.
*Dark Wire.**		
$0\frac{1}{2}$ lb. per minute . . .	45	25 4
1 " 5 minutes . .	$45\frac{1}{4}$	25·9
" 5 " . . .	$45\frac{1}{4}$	24·9
" 4 " . . .	$44\frac{1}{4}$	24·58
" 3 " . . .	$44\frac{1}{4}$	24 88
" 3 " . . .	$45\frac{1}{4}$	29·58
" 5 " . . .	$44\frac{1}{4}$	27·78
*Bright Wire.**		
1 lb. per 5 minutes . . .	$44\frac{1}{4}$	28·5
" 5 " . . .	$44\frac{1}{4}$	27·0
" 4 " . . .	$44\frac{1}{4}$	27·1

II.—WIRE SLOWLY BROKEN.

Weight added and number of experiment.	Breaking weight in pounds.	Per cent. of elongation on original length.
1. 1 lb. per day . .	48	7·58
2. " " . .	46	8·13
3. " " . .	47	7·05
4. " " . .	47	6·51
5. " " . .	47	8·62
6. " " . .	47	5·17
7. " " . .	46	5·50
8. " " . .	47	6·92 bright wire
1. $\frac{3}{4}$ lb. per day . .	49	8·50
2. " " . .	$48\frac{1}{4}$	8·81
3. " " . .	Broken	by accident.
4. " " . .	46	7·55
5. " " . .	46	6·41
6. " " . .	$45\frac{1}{2}$	6·62
1. $\frac{1}{2}$ lb. per day . .	48	8·26
2. " " . .	50	8·42
3. " " . .	49	7·18
4. " " . .	47	4·79 } bright wires
5. " " . .	$46\frac{1}{2}$	6·00 }

The American Standard diameters of solid drawn or reamless brass and copper tube are as in the following table.

Outside diameter.	Thickness Stubs's wire-gauge.	Weight per running foot. Brass tubes.	Weight per running foot. Copper tubes.
$\frac{5}{8}$	18	$\frac{3}{8}$	$\frac{3}{8}$
$\frac{3}{4}$	17	$\frac{1}{2}$	$\frac{1}{2}$
$\frac{13}{16}$	17	$\frac{9}{16}$	$\frac{9}{16}$
$\frac{7}{8}$	17	$\frac{5}{8}$	$\frac{5}{8}$
$\frac{15}{16}$	16	$\frac{11}{16}$	$\frac{11}{16}$
1	16	$\frac{3}{4}$	$\frac{3}{4}$
$1\frac{1}{8}$	16	$\frac{7}{8}$	$\frac{7}{8}$
$1\frac{1}{4}$	12 and 14	$1\frac{1}{4}$	$1\frac{1}{4}$
$1\frac{3}{8}$	12 " 14	$1\frac{3}{8}$	$1\frac{3}{8}$
$1\frac{1}{2}$	12 " 14	$1\frac{1}{2}$	$1\frac{6}{10}$
$1\frac{5}{8}$	12 " 14	$1\frac{5}{8}$	$1\frac{7}{10}$
$1\frac{3}{4}$	12 " 14	$1\frac{3}{4}$	$1\frac{8}{10}$
$1\frac{13}{16}$	12 " 14	$1\frac{13}{16}$	$1\frac{9}{10}$
$1\frac{7}{8}$	12 " 14	$1\frac{7}{8}$	$1\frac{15}{16}$
$1\frac{15}{16}$	12 " 14	2	$2\frac{1}{10}$
2	12 " 14	$2\frac{1}{5}$	$2\frac{1}{4}$
$2\frac{1}{8}$	12 " 14	$2\frac{1}{4}$	$2\frac{3}{8}$
$2\frac{1}{4}$	12 " 14	$2\frac{3}{8}$	$2\frac{1}{2}$
$2\frac{3}{8}$	12 " 14	$2\frac{1}{2}$	$2\frac{2}{3}$
$2\frac{1}{2}$	11 " 13	$2\frac{3}{4}$	3
$2\frac{5}{8}$	11 " 13	3	$3\frac{1}{8}$
$2\frac{3}{4}$	11 " 13	$3\frac{1}{8}$	$3\frac{1}{4}$
$2\frac{7}{8}$	11 " 13	$3\frac{1}{4}$	$3\frac{3}{8}$
3	11 " 13	$3\frac{1}{3}$	$3\frac{1}{2}$
$3\frac{1}{8}$	11 " 13	$3\frac{1}{2}$	$3\frac{3}{4}$
$3\frac{1}{4}$	11 " 13	$3\frac{7}{8}$	$4\frac{1}{8}$
$3\frac{3}{8}$	11 " 13	$4\frac{1}{8}$	$4\frac{1}{4}$
$3\frac{1}{2}$	11 " 13	$4\frac{1}{4}$	$4\frac{3}{8}$
4	11 " 13	5	$5\frac{1}{4}$
$4\frac{1}{4}$	11 " 13	6	$6\frac{1}{2}$
5	10 " 12	7	8
6	10 " 12	9	10

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* The wire used was all of the same quality and gauge, but the "dark" and "bright" wire had gone through slightly different processes for the purpose of annealing.