actly fit where two surfaces intersect, as at the junction of the dome to the main shell? The sheets are not very easily trimmed in this case. Figure 4 will illustrate the forms, the upper being the ordinary boiler and dome, and the lower the intersection of two circular cylinders of equal diameters at right angles.

In the construction of machines, work has often to be laid out, holes drilled, and other operations performed on pieces which have to come together exactly and fit perfectly, and which cannot be tried and made to suit. Geometrical methods are adapted to this purpose, and it is marvellous how accurately such work can be done. A similar example, and one perhaps more familiar to you, is in stonecutting. The stones are cut to shape and put in place, and I never remember seeing one taken down and altered. Many examples of difficult geometrical construction in stonework may be seen around the doorways and arches in University College.

From these examples it will be seen how universally geometry is employed in the mechanical trades, and how necessary a knowledge of its elementary principles at least is to all artisans. Let it not be understood, however, that it is always preferable in the practice of the mechanic arts to employ theoretical geometrical methods. Very often such is not the case, and mechanical aids are to be preferred. Who would think, for instance, of drawing a line perpendicular to another line, or of finding out if two plane surfaces were at right angles by Euclid's method, when an accurate steel square was obtainable? What would be thought of a

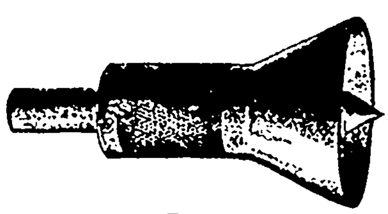

Fig. 5.
Bell Centering Punch.

machinist, who, when told to centre a circular shaft, tried to do so by bisecting the perpendicular through the middle point of any chord? As an example of mechanical methods, I will describe three ways in which this would usually be done. The bell centering punch (Fig 5), consists of a hollow cone with the punch constrained to move along the axis. This answers very well if the shafting is small and no great accuracy is required. A second method is to make a mark by a centre punch, as near the centre as possible, and then rotate the shaft between the lathe centres. It will be immediately seen when it is accurately centred by the periphery of the shaft revolving truly. If it does not run truly, the mark is punched over to the required side and again tested. As soon as the shaft runs truly, a small hole is drilled at the centre thus obtained, and this hole is countersunk by a centre reamer ground to the proper angle to fit the centres. A third and perhaps commoner method is to place the shaft in the lathe, the ordinary conical tail centre being replaced by what is called a square centre. This has the form of a square pyramid, the angle between the opposite edges being usually 60°. If the shaft is made to rotate against this square centre, while its periphery rubs against a bar firmly fixed in the tool post, it is evident that, as the sharp edges of the centre cut into the end of the shaft, they will form a conical hole. This hole will be exactly in the centre, for the outside of the shaft is constrained to move truly. The two latter methods depend of course on the geometrical property of the invariability in length of radii of the same circle.

Another problem continually arising is the division of circles, or rather the circumferences of circles, into any given number of equal parts. Euclid's method, by inscribing regular figures, is never used in practice. It

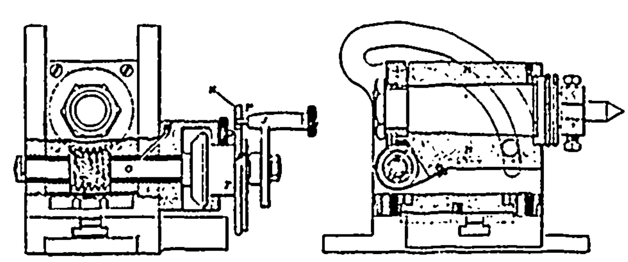

Fig. 6.

is too tedious, is only adapted for a few divisions, and is wanting in accuracy. When the division is made by hand, the circumference is always stepped off by trial with a pair of steel dividers with fine points. When the arc included by the dividers becomes so near the required one that the points cannot be moved a small enough distance by the adjusting screw, the final adjustment is made by rubbing down the proper sides of the points on an oil stone. It is by this method that large cast gears, used in mill work, three or four feet in diameter, and six inch face, have the teeth spaced off regularly, drawn to the proper form, and then chipped and filed to suit.

As in the method of centering, dividing by machine is decidedly more convenient, accurate, and expeditious. Wherever there is a milling machine, all dividing or indexing, as it is sometimes called, is performed by the index head of the machine. The head of which you see two views in the figure (Fig. 6), consists of a worm wheel, which is firmly attached to the work spindle, while gearing into this worm wheel is a worm attached to the spindle O. The worm wheel has usually 40 teeth, so that one revolution of the worm spindle, which has the crank J attached, gives 1-40th of a revolution of the work spindle, or will divide a circle attached to the work spindle into 40 parts. Suppose it is wished to divide a circle into, say, 76 parts. Then the worm

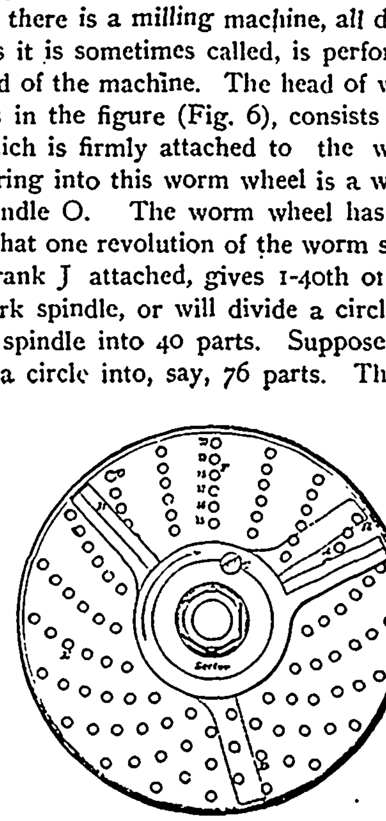

Fig 7.

must turn 40-76th's or 10-19th's of a revolution. Fastened to the side of the head (I, fig 6), concentric with the worm spindle is an index plate (fig. 7), consisting of circles of concentric equally spaced holes into