cutters and feeding simultaneously. Corner-locking, or cutting parallel tongues and grooves in the edges of boxes, &c., is a rather more rapid operation than dovetailing, and is done with suitable cutter blocks or disks of appropriate thickness and pitching apart.

The general joiner, as its name implies, will do a large variety of operations, and is used in shops and on estates where a complete plant of machines would be out of the question. It usually has a circular saw and sometimes a band-saw also, together with planing and moulding apparatus, a moulding spindle, boring spindle ana tenoning apparatus.

The lathes used in woodworking comprise the plain hand types with a simple T-rest on which the turner rests the tools to deal with the work revolving between centres, and the copying or Blanchard lathes, in which a master form or copy is rotated and caused by the contact and coercion of a roller to move the cutter rest in a corre­sponding fashion, so that the work is cut away until it exactly matches the shape of the copy.

Sand-papering machines, which finish the surface of wood to a high degree, deal with both flat and curved faces. Flat boards, panels, &c., can be done by contact against revolving drums or disks covered with glass-paper, being fed along over them by hand or by rotating rollers. In one class of machine a revolving disk is placed at the end of a series of jointed arms, by which the disk can be moved about over the work resting on a table underneath.

XIII.—Measurement

An advance of the greatest importance made in mechanical engineering is that of measurement. Since the beginning of the 19th century steady movement has been going on in this direction until it seems impossible that much greater refinement can now be looked for. Probably the chief advances to be expected will lie in the general extension in workshop practice of the knowledge already acquired, rather than in the acquisition of higher degrees of refinement.

Methods of measurement adopted in woodworking have but little application in high-class engineers’ work. They are adopted, how­ever, to a considerable extent in the metal trades which are allied to engineering, as sheet metal working, girder work, &c. When a carpenter or joiner sets about constructing a door, window sash, roof or box he takes a two-foot rule, a flat lead pencil, and marks off the dimensions and lines by which he intends to work. If he has to work very carefully, then instead of using a pencil he cuts a line with the edge of a keen scriber or chisel-like tool, by which to saw, plane or chisel. If outlines are curved, the compasses are brought into requisition, and these cut a fine line or lines on the surface of the wood. But in any case the eye alone judges of the coincidence of the cutting with the lines marked. Whether the tool used be saw, chisel, gouge or plane, the woodworker estimates by sight alone whether or not the lines marked are worked by.

The broad difference between his method and that of the engineer’s machinist lies in this, that while the first tests his work by the eye, the second judges of its accuracy or otherwise by the sense of touch. It may seem that there cannot be very much difference in these two methods, but there is. To the first, the sixty-fourth part of an inch is a fine dimension, to the second one-thousandth of an inch is rather coarse. Now the thickness of tissue paper is about one-thousandth of an inch, and no one could possibly work so closely as that by the eye alone. Engineers’ steel rules usually have one inch which is divided into one hundred parts. Tolerably keen sight is required to distinguish those divisions, and few could work by them by ocular measurement alone, that is, by placing them in direct juxtaposition with the work. A thousandth part of an inch seems by com­parison a fine dimension. But it is very coarse when considered in relation to modern methods of measurement. In what are called ‘ limit gauges ” the plugs and rings are made of slightly different dimensions. If a plug is made a thousandth of an inch less than its ring it will slip through it easily with very perceptible slop. The common rule is therefore scarcely seen in modern machine shop, while the common calipers fill but a secondary place, their function having been invaded by the gauges. A minute dimension cannot be tested by lines of division on a rule, neither can a dimension which should be fixed be tested with high precision with a movable caliper of ordinary type. Yet it must not be supposed that the adoption of the system of gauging instead of the older methods of rule measurement relieves men of responsibility. The instruments of precision require delicate handling. Rough forcing of gauges will not yield correct results. A clumsy workman is as much out of place in a modem machine shop as he would be in a watch factory. Without correctness of measurement mechanical constructions would be impossible, and the older device of mutual fitting of parts is of lessening value in face of the growth of the inter­changeable system, of international standards, and of automatic machine tools which are run with no intervention save that of feeding stock.

The two broad divisions of measurement by sight and by contact are represented in a vast number of instruments. To the first- named belong the numerous rules in wood and metal and with English and metric divisions, and the scales which are used for setting out dimensions on drawings smaller than those of the real objects, but strictly proportional thereto. The second include all the gauges. These are either fixed or movable, an important sub- division. The first embrace two groups—one for daily workshop service, the other for testing and correcting the wear of these, hence termed “ reference gauges.” They arc either made to exact standard sizes, or they embody "limits of tolerance,” that is, allowances for certain classes of fits, and for the minute degrees of inaccuracy which are permissible in an interchangeable system of manufacture. The movable group includes a movable portion, either corresponding with one leg of a caliper or having an adjustable rod, with pro- vision for precise measurement in the form of a vernier or of a screw thread divided micrometrically. These may be of general character for testing internal or external diameters, or for special functions as screw threads. Subtitles indicate some particular aspect or design of the gauges, as “ plug and ring,” “ caliper,” “ horseshoe,” “ depth,” “ rod,” “ end measure,” &c. So severe are the requirements demanded of instruments of measurement that the manu- facture of the finer kinds remains a speciality in the hands of a very few firms. The cost and experience necessary are so great that prices rule high for the best instruments. As these, however, are not required for ordinary workshop use, two or three grades are manufactured, the limits of inaccuracy being usually stated and a guarantee given that these are not exceeded.

*Measurement by Sight. Rules and Scales.—*The rules are used for marking off distances and dimensions in conjunction with other instruments, as scribers, compasses, dividers, squares; and for test- ing and checking dimensions when marked, and work in course of reduction or erection, directly or from calipers. They are made in boxwood and in steel, the latter being either rigid or flexible, as when required to go round curves. Rules are fitted in combination with other instruments, as sliding calipers, squares, depth gauges, &c. The scales are of boxwood, of ivory, the value of which isdis- counted by its shrinkage, and of paper. They are of flat section with bevelled edges, and of oval and of triangular sections, each giving a thin edgy to facilitate readings. They are fully divided, or open divided; in the first case each division is alike subdivided, in the second only the end ones are thus treated.

*The Gauges. Fixed Gauges.—*These now embrace several kinds, the typical forms being represented by the cylindrical or plug and ring gauges and by the caliper form or snap gauges. The principle in each is that a definite dimension being embodied in the gauge, the workman has not to refer to the rule, either directly or through the medium of a caliper. This distinction, though slight, is of immense importance in modern manufacturing. Broadly it corresponds with the difference between the older heterogeneous and the present interchangeable systems.

*Plug and Ring Gauges.—*The principal ones and the originals of all the rest, termed Whitworth gauges after the inventor, arc the plug and ring gauges (fig. 67, *A* and *B).* the principle on which they depend is that if the two gauges are made to fit with perfect accuracy, without tightness on the one hand or slop on the other, then any work which is measured or turned and bored or ground by them will also fit with equal accuracy. Bored holes are tested by the plug gauge, and spindles are tested by the ring gauge, and such spindles and holes make a close fit if the work is done carefully. Of course, in prac- tice, there is very much variation in the character of the work done, and the finest gauges are too fine for a large proportion of engineers’ work. It is possible to make these gauges within 1/50000 of an inch. But they are seldom required so fine as that for shop use; 1/5000 is generally fine enough. For general shop work the gauges are made to within about 1/1000 of an inch. Standard gauges in which the plug and ring are of the same diameter will only fit by the application of a thin film of oil and by keeping the plug in slight movement within the ring. Without these precautions the two would "seize ” so hard that they could not be separated without force and injury.

*Plug and Ring* v. *Horseshoe Gauges.—*The horseshoe, snap or caliper gauges (fig. 68) are often used in preference to the plug and ring types. They are preferred because the surfaces in contact are narrow. These occur in various designs, with and without handles, separately and in combination and in a much larger range of dimensions than the plug and ring. Ring gauges are not quite such delicate instruments as the fixed caliper gauges. But since they measure diameter only, and turned work is not always quite circular, the caliper gauges are not so convenient for measurement as the round gauges, which fit in the same manner as the parts have to fit to one another.

*Fixed Gauges. Limit Gauges.—*Some fits have to be what is termed in the shops “ driving fits,” that is, so tight that they