have to be effected by driving with a hammer or a press, while others have to be “ working fits,” suitable, say, for the revolution of a loose pulley on its shaft or of an axle in its bearings. The “ limit ” or “ difference gauges ” (figs. 67 and 68) are designed for producing these working fits; that is, the plug and ring gauges differ in dimensions so that the work bored will drive tightly, or slide freely over the work turned. These are variously sub-classified. The system which is generally accepted is embodied in the gauges by the Newall Engineering Co. These embrace *force fits,* which require the applica­tion of a screw or hydraulic press; *driving fits,* that require less power, as that of a hammer; *push fits,* in which a spindle can be thrust into its hole by hand; and *running fits,* such as that of shafts in bearings. Fixed gauges are made for each of these, but as this involves a heavy outlay the Newall firm have adjustable limit gauges (fig. 68, *D)* for external dimensions, the standard plug being used for holes. The setting is done by screwed plugs or anvils adjusted by reference bars. In all these gauges the “ go on ” and “ not go on ” ends respectively are stamped on the gauge, or the equivalents of + and —.

*Fixed Reference Gauges. Reference Disks and End Measuring Rods.—*Shop working gauges become in time so damaged by service that they fail to measure so accurately as when new. To correct these errors reference gauges are provided, by which the inaccuracy of the worn ones is brought to the test. These are never used in the shops for actual measurement of work, but are only kept for checking the truth of the working gauges. They include disk, stepped and end measurement gauges. The disk and the stepped are used for testing the ring gauges, the stepped kind comprising essentially a collection of disks in one piece (fig. 67, *D).* The end measure pieces test the external gauges. The end measure standard lengths made by the Pratt & Whithey Co. are so accurate that any sizes taken at random in any numbers from ¼ in. to 4 in., varying by sixteenths of an inch, will, when placed end to end, make up an exact length; this is a difficult test, since slight variations in the lengths of the components would add up materially when multiplied by the number of pieces. The ends are ground off with diamond dust or emery in a special machine under water, and are so true that one piece will support another by cohesive force, and this though the surfaces are less than ¼ in. square.

*Movable Gauges.*—This extensive group may be regarded as compounded of the common caliper and the Whitworth measuring machine. They are required when precise dimensions have to be ascertained in whole numbers and minute fractional parts. They combine the sense of touch by contact, as in the calipers, with the exact dimensions obtained by inspection of graduated scales, either the vernier or the micrometer screw. If gauges must not vary by more than 1/10000 of an inch, which is the limit imposed by modern shop ideals, then instruments must he capable of measuring to finer dimensions than this. Hence, while the coarser classes of micrometers read directly to 1/1000 part of an inch, the finest measure up to 1/100000 of an inch, about 200 times as fine as the diameter of a human hair. They range in price correspondingly from about a sovereign to £100.

*The Calipers.—Common* calipers (fig. 69) are adjusted over or within work, and the dimensions are taken therefrom by a rule or a gauge. They usually have no provision for minute adjustment beyond the gentle tapping of one of the legs when setting. In some forms screw adjustment is provided, and in a few instances a vernier attachment on the side of the pivot opposite to the legs.

*Vernier Calipers.*—The vernier fitting, so named after its inventor, Pierre Vernier, in 1631, is fitted to numerous calipers and caliper rules. It is applied to calipers for engineers’ use to read to 1/1000. of an inch without requiring a magnifier. The beam of the caliper is divided into inches and tenths of the inch, and each tenth into

fourths and the vernier into twenty-five parts, or the beam is divided into fiftieths of an inch (fig. 70) and the vernier has 20 divisions to 19 on the rule. The caliper jaws are adapted to take both external and internal dimensions. These “ beam calipers ” are also made for metric divisions. Minor variations in design by different manufacturers are numerous.