of material of the same quality he used in a structure under con­ditions which cause it to bear a simple pull of 6 tons per square inch ; we conclude at once that the actual load is one-fifth of that which would cause rupture, irrespective of the extent to which the material might contract in section if overstrained. The stresses which occur in engineering practice are, or ought to be, in all cases within the limits of elasticity, and within these limits the change of cross-section caused by longitudinal pull or push is so small that it may be neglected in reckoning the intensity of stress.

Ultimate tensile strength and ultimate shearing strength are well defined, since these modes of stress (simple pull and simple shearing stress) lead to distinct fracture if the stress is sufficiently increased. Under compression some materials yield so continu­ously that their ultimate strength to resist compression can scarcely be specified ; others show so distinct a fracture by crushing (§ 43 below) that their compressive strength may be determined with some precision. In what follows, the three kinds of ultimate strength will be designated by the symbols *ft, fs,* and *fc,* for tension, shearing, and crushing respectively.

Some of the materials used in engineering, notably timber and wrought-iron, are so far from being isotropic that their strength is widely different for stresses in different directions. In the case of wrought-iron the process of rolling develops a fibrous structure on account of the presence of streaks of slag which become inter­spersed with the metal in puddling ; and the tensile strength of a rolled plate is found to be considerably greater in the direction of rolling than across the plate. Steel plates, being rolled from a nearly homogeneous ingot, have nearly the same strength in both directions.

17. In applying a knowledge of the ultimate strength of materials to determine the proper sizes of parts in an engineering structure, these parts are proportioned so that the greatest intensity of stress (which for brevity is called the working stress) will be only a certain fraction of the ultimate strength. The ratio ultimate strength/working stress is called the factor of safety.@@1 The choice of a factor of safety depends on many considerations, such as the probable accuracy of the theory on which the calculation of working stress has been based ; the uniformity of the material dealt with, and the extent to which its strength may be expected to conform to the assumed value or to the values determined by experiments on samples ; the deviations from the specified dimensions which may be caused by bad workmanship ; the probable accuracy in the estimation of loads ; the extent to which the materials will deteriorate in time. The factor is rarely less than 3, is very commonly 4 or 5, and is sometimes as much as 12, or even more.

The ultimate strength for any one mode of stress, such as simple pull, has been found to depend on the time rate at which stress is applied ; this will be noticed more fully later (§§ 28-34). It has also been found to depend very greatly on the extent and frequency of variation in the applied stress. A stress considerably less than the normal ultimate strength will suffice to break a piece when it is frequently applied and removed ; a much smaller stress will cause rupture if its sign is frequently reversed ; and hence in a structure which has to bear what is called live load the permis­sible intensity of stress is less than in a structure which has to bear only load and also on its frequency of variation (§§ 45, 46 below).

18. From an engineering point of view, the structural merit of a material, especially when live loads and possible shocks have to be sustained, depends not only on the ultimate strength but also on the extent to which the material will bear deformation without rupture. This characteristic is shown in tests made to determine tensile strength by the amount of ultimate elongation, and also by the contraction of the cross-section which occurs through the flow of the metal before rupture. It is often tested in other ways, such as by bending and unbending bars in a circle of specified radius, or by examining the effect of repeated blows. Tests by impact are generally made by causing a weight to fall through a regulated distance on a piece of the material supported as a beam.

19. Ordinary tests of strength are made by submitting the piece to direct pull, direct compression, bending, or torsion. Testing machines are frequently arranged so that they may apply any of these four modes of stress ; tests by direct tension are the most common,

and next to them come tests by bending. When the samples to be tested for tensile strength are mere wires, the stress may be applied directly by weights ; for pieces of larger section some mechanical multiplication of force becomes necessary. Owing to the plasticity of the materials to be tested, the applied loads must be able to follow considerable change of form in the test-piece : thus in test­ing the tensile strength of wrought-iron or steel provision must be made for taking up the large extension of length which occurs before fracture. In most modern forms of large testing machines the loads are applied by means of hydraulic pressure acting on a piston or plunger to which one end of the specimen is secured, and the stress is measured by connecting the other end to a lever or system of levers provided with adjustable weights. In small

machines, and also in some large ones, the stress is applied by screw gearing instead of by hydraulic pressure. Springs are sometimes used instead of weights to measure the stress, and another plan is to make one end of the specimen act on a diaphragm forming part of a hydrostatic pressure-gauge (§ 23 below).

20. Figs. 5 and 6 show an excellent form of single-lever testing machine designed by Mr J. H. Wicksteed,@@2 in which the stress is applied by an hydraulic plunger and is measured by a lever or steelyard and a movable weight. The illustration shows a 30-ton machine, but machines of similar design have been built to exert a force of 100 tons or more. AA is the lever, on which there is a graduated scale. The stress on the test-piece T is measured by a weight W of 1 ton (with an attached vernier scale), which is moved along the lever by a screw-shaft S ; this screw- shaft is driven by a belt from a parallel shaft R, which takes

@@@1 French engineers usually estimate the permissible working stress as a certain fraction of the elastic strength (that is, of the stress which reaches the limit of elasticity), instead of estimating it as a certain fraction of the ultimate strength.

@@@2 *Proc. Inst. Mech. Eng.,* August 1882.