weigh-beam and from the other of which the shackle holding the upper end of the specimen is hung, and (2) the weight of the travelling poise. The weight of the poise is readily ascertained by using a supplementary known weight to apply a known moment to the beam, and measuring how far the poise has to be moved to restore equilibrium. The distance between the knife-edges is then found by hanging a known heavy weight from the shackle, and again observing how far the poise has to be moved. Another example of the single-lever type is the Werder testing machine, much used on the continent of Europe. In it the specimen is horizontal; one end is fixed, the other is attached to the short vertical arm of a bell-crank lever, whose fulcrum is pushed out horizontally by an hydraulic ram.@@1

*Multiple-lever Testing Machines.—* In many other testing machines a system of two, three or more levers is employed to reduce the force between the specimen and the measuring weight. In most cases the fulcrums are fixed, and the stress is applied to one end of the specimen by hydraulic power or by screw gear­ing, which takes up the stretch, as in the single-lever machines already described. David Kirkaldy, who was one of the earliest as well as one of the most assiduous workers in this field, applied in his 1,000,000 lb machine a horizontal hydraulic press directly to one end of the horizontal test-piece. The other end of the piece was connected to the short vertical arm of a bell­crank lever; the long arm of this lever was horizontal, and was connected to a second lever to which weights were applied.

Machines have been employed in which one end of the speci­men is held in a fixed support; an hydraulic press acts on the other end, and the stress is calculated from the pressure of fluid in the press, this being observed by a pressure-gauge. Machines of this class are open to the obvious objection that the friction of the hydraulic plunger causes a large and very uncertain difference between the force exerted by the fluid on the plunger and the force exerted by the plunger on the speci­men. It appears, however, that in the ordinary conditions of packing the friction is very nearly proportional to the fluid pressure, and its effect may therefore be allowed for with some exactness. The method is not to be recommended for work requiring precision, unless the plunger be kept in constant rota­tion on its own axis during the test, in which case the effects of friction are almost entirely eliminated.

*Diaphragm Testing Machines.—*In another class of testing machines the stress (applied as before to one end of the piece, by gearing or by hydraulic pressure) is measured by connecting the other end to a flexible diaphragm, on which a liquid acts whose pressure is determined by a gauge. Fig. 9 shows

Thomasset’s testing machine, in which one end of the specimen is pulled by an hydraulic press A. The other end acts through a bell-crank lever B on a horizontal diaphragm C, consisting of a metallic plate and a flexible ring of india-rubber. The pressure on the diaphragm causes a column of mercury to rise in the gauge-tube D. The same principle is applied in the remarkable testing machine of Watertown arsenal, built in 1879 by the U.S. government to the designs of A. H. Emery. This is a horizontal machine, taking specimens of any length up

to 30 ft., and exerting a pull of 360 tons or a push of 480 tons by an hydraulic press at one end. The stress is taken at the other end by a group of four large vertical diaphragm presses, which communicate by small tubes with four similar small diaphragm presses in the scale case. The pressure of these acts on a system of levers which terminates in the scale beam. The joints and bearings of all the levers are made frictionless by using flexible steel connecting-plates instead of knife-edges. The total multiplication at the end of the scale beam is 420,000.@@2

*Stress-strain Diagrams.—*The results of tests are very com­monly exhibited by means of stress-strain diagrams, or diagrams showing the relation of strain to stress. A few typical diagrams for wrought iron and steel in tension are given in fig. 10, the data for which are taken from tests of long rods by Kirkaldy.@@3 Up to the elastic limit these diagrams show sensibly the same rate of extension for all the materials to which they refer. Soon after the limit of elasticity is passed, a point, which has been called by Sir A. B. W. Kennedy the yield-point, is reached, which is marked by a very sudden extension of the specimen. After this the extension becomes less rapid; then it continues at a fairly regular and gradually increasing rate; near the point of rupture the metal again begins to draw out rapidly. When this stage is reached rupture will occur through the flow of the metal, even if the load be somewhat decreased. The diagram may in this way be made to come back towards the line of no load, by with­drawing a part of the load as the end of the test is approached.

Fig. 11 is a stress-strain diagram for cast iron in ex­tension and compression, taken from Eaton Hodg­kinson’s experiments.@@4 The extension was measured on a rod 50 ft. long; the compression was also mea­sured on a long rod, which

*@@@1 Maschine zum Prüfen d. Festigkeit d. Materialen,* &c. (Munich, 1882).

@@@2 See *Report of the U.S. Board appointed to test Iron, Steel and other Metals* (2 vols., 1881). For full details of the Emery machine, see *Report of the U.S. Chief of Ordnance* (1883), aρρ. 24.

*@@@3 Experiments on the Mechanical Properties of Steel by a Committee of Civil Engineers* (London, 1868 and 1870).

*@@@4 Report of the Commissioners on the Application of Iron to Railway Structures* (1849).