its motion, through bevel-wheels and a Hooke’s joint in the axis of the fulcrum, from the hand-wheel H. (The Hooke’s joint in the shaft R is shown in a separate sketch above the lever in fig. 6.) The holder for the upper end of the sample hangs from a knife-edge three inches from the fulcrum of the lever. The lower holder is jointed to a crosshead C, which is connected by two vertical screws to a lower cross­head B, upon which the hydraulic plunger P, shown in sec­tion in fig. 5, exerts its thrust. G is a counterpoise which pushes up the plunger, when the water is allowed to escape. Hydraulic pressure may be applied to P by pumps or by an accumulator. In the present instance it is applied by means of an auxiliary plunger Q, which is pressed

by screw gearing into an auxiliary cy­linder. Q is driven by a belt on the pulley D. This puts stress on the specimen, and the weight W is then run out along the lever so that the lever is just kept floating between the stops E, E. Before the test-piece is put in, the distance between the holders is regulated by means of the screws con­necting the upper and lower cross­heads C and B, these screws being turned by a handle applied at F. Fig. 7 is a section of one of the holders, showing how the test-piece T is gripped by serrated wedges. The knife-edges are made long enough to prevent the load on them ever exceeding 5 tons to the linear inch.

21. 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 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. Probably the earliest machine of this class was that of Major Wade,@@2 in which one end of the specimen was held in a fixed support, and the stretch was taken up by screwing up the fulcrum plate of one of the levers. In most multiple-lever machines, however, the fulcrums are fixed, and the stress is applied to one end of the specimen by hydraulic power or by screw gearing, which of course takes up the stretch, as in the single-lever machines already described. Mr Kirkaldy, who was one of the earliest as well as one of the most assiduous workers in this field, applies in his 1,000,000 fb machine a horizontal hydraulic press directly to one end of the horizontal test-piece. The other end of the piece is connected to the short vertical arm of a bell-crank lever ; the long arm of this lever is horizontal, and is connected to a second lever to which weights are applied. In some of Messrs Fairbanks’s machines the multiple-lever system is carried so far that the point of application of the weight moves 24,000 times as far as the point of attachment to the test-piece. The same makers have employed a plan of adjusting automatically the position of the measuring weight, by making the scale lever complete an electric circuit when it rises or falls so that it starts an electric engine which runs the weight out or in.@@3 Generally the measuring weight is adjusted by hand. In some, chiefly small, machines, the weight adjusts itself by means of another device. It is fixed at one point of a lever which is arranged as a pendulum, so that, when the test-piece is pulled by force applied at the other end, the pendulum lever is de­flected from its originally vertical position and the weight acts with

increasing leverage.

Multiple-lever machines have the advantage that the measuring weight is reduced to a conveniently small value, and that it can be easily varied to suit test-pieces of different strengths. On tho other hand, their multiplicity of joints makes the leverage some­what uncertain and increases friction. Another drawback is the inertia of the working parts. It is impossible to avoid oscilla­tions of the levers : and, to prevent them from producing important errors in the recorded stress, the inertia of the oscillating system should be minimized. In a testing machine in which the specimen is directly loaded the inertia is simply that of the suspended weight M. In a lever machine, which multiplies the weight *n* times, the weight applied to the lever is reduced to M*∕n*, but its inertia, when referred to the test-piece, is (M*/n)* × *n*2 or Mn. The inertia which is effective for producing oscillation is thus increased *n* times, so far as the weight alone is concerned, and this detri­mental effect of leverage is increased by the inertia of the levers themselves. Tho effect will be more serious the greater is the leverage n.

22. Whitworth and others employ machines 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.

23. In another important class of testing machines the stress (applied as before to one end of the piece, by gearing or by hydraulic pressure)

is measured by con­

necting the other end to a flexible dia­phragm, on which a liquid acts whose pressure is deter­mined by a gauge.

Fig. 8 shows a sim­ple machine of this class (used in 1873 for testing wire by Sir W. Thomson and the late Prof. F.

Jenkin). The wire is stretched by means of a screw at the top, and pulls up the lower side of a hydrostatic bellows ; water from the bel­lows rises in the gauge-tube G, and its height measures the stress. Fig. 9 is 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 made use of in the testing machines of Chauvin and Marin-

Darbel, Maillard,@@4 and Bailey. It has found its most important ap­plication in the remarkable testing machine of Watertown arsenal, built in 1879 by the U.S. Government to the designs of Mr A. H. Emery. This is a horizontal machine, taking specimens of any length up to 30 feet, 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.@@5

24. 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 Mr Kirkaldy.@@6 Up to the elastic limit these diagrams show sensibly the same rate of extension tor all the materials to which they refer. Soon after the limit of elasticity is passed, a point, which has been called by Prof. Kennedy the yield-point, is reached, which is marked by a very sudden extension of

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

@@@2 *Report of Experiments on Metals for Cannon,* Philadelphia, 1856 ; also Ander­son’s *Strength of Materials,* p. 15.

@@@3 Abbott, *On Testing Machines,* New York, 1884, or *Van Nostrand's Engineer­ing Mag.,* 1884.

@@@4 For descriptions of several of these machines, see a paper by MM. Denizeau

and Lechien, *Mémorial de l’Artillerie et de Ia Marine,* l883.

@@@5 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, appendix 24.*

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