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 (§ 29 below).

25. Fig. 11 is a stress-strain diagram for cast-iron in extension and compression, taken from Hodgkinson’s experiments.@@@1 The extension was mea­

sured on a rod 50

feet long ; the com­

pression was also

measured on a long

rod, which was pre­

vented from buckl­

ing by being sup­

ported in a trough

with partitions.

The full line gives

the strain produced

by loading ; it is

continuous through

the origin, showing

that Young’s mod­

ulus is the same for

pull and push.

(Similar experi­

ments on wrought-

iron and steel in

extension and com­

pression have given

the same result.)

The broken line shows the set produced by each load. Hodgkinson found that some set could be detected after even the smallest loads had been applied. This is probably due to the existence of initial internal stress in the metal, produced by unequally rapid cooling in different portions of the cast bar. A second loading of the same piece showed a much closer approach to perfect elasticity. The elastic limit is, at the best, ill defined ; but by the time the ultimate load is reached the set has become a more considerable part of the whole strain. The pull curves in the diagram extend to the point of rupture ; the compression curves are drawn only up to a stage at which the bar buckled (between the partitions) so much as to affect the results.

26. Testing machines are now frequently fitted with autographic appliances for drawing strain diagrams. When the load is meas­ured by a weight travelling on a steelyard, the diagram may be drawn by connecting the weight with a drum by means of a wire or cord, so that the drum is made to revolve through angles proportional to the travel of the weight. At the same time

another wire, fastened to a clip near one end of the specimen, and passing over a pulley near the other end, draws a pencil through distances proportional to the strain, and so traces a diagram of stress and strain on a sheet of paper stretched round the drum. Apparatus of this kind has been used by Messrs Fairbanks, Unwin, Aspinall, and others.@@2 In Mr Wicksteed’s autographic recorder the stress is determined by reference, not to the load on the lever, but to the pressure in the hydraulic cylinder by which stress is applied. The main cylinder is in communication with a small auxiliary hydraulic cylinder, the plunger of which is kept rotating to avoid friction at its packing. This plunger abuts against a spring, so that the distance through which it is pushed out varies with the pressure in the main cylinder. A drum covered with paper moves with the plunger under a fixed pencil, and is also caused to rotate by a wire from the specimen through distances propor­tional to the strain. The scale of loads is calibrated by occasional reference to the weighted lever.@@@3 In Prof. Kennedy’s machine autographic diagrams are drawn by applying the stress to the test- piece through an elastic master-bar of larger section. The master- bar is never strained beyond its elastic limit, and within that limit its extension furnishes an accurate measure of the stress ; this gives motion to a pencil, which writes on a paper moved by the extension of the test-piece.@@4 In Prof. Thurston’s pendulum machine for torsion tests, a cam attached to the pendulum moves a pencil through distances proportional to the stress, while a paper drum attached to the other end of the test-piece turns under the pencil through distances proportional to the angle of twist.@@5

27. The elastic extension or compression of a test-piece of ordinary dimensions is so small as to require for its measurement refined methods which are seldom employed in everyday practical testing. Measurements of this class must be made simultaneously on oppo­site sides of the test-piece, to guard against error through the bend­ing of the piece. Microscopes and also various forms of micro­meter calipers are used for the purpose.@@6 A method capable of great delicacy, which has been used by Bauschinger@@7 and others, is to measure the strain by light reflected from a pair of small mirrors attached to rollers which turn as the specimen extends or contracts. With apparatus of this kind it may be shown that iron, steel, or other materials with a well-defined yield-point begin to show a marked defect of elasticity at a somewhat lower stress. The true elastic limit comes considerably earlier in the test than the point which usually passes by that name.@@8

28. In testing a plastic material such as wrought-iron or mild steel it is found that the behaviour of the metal depends very materially on the time rate at which stress is applied. When once the elastic limit is passed the full strain corresponding to a given load is reached only after a perceptible time, sometimes even a long time. If the load be increased to a value exceeding the elastic limit, and then kept constant, the metal will be seen to draw out (if the stress be one of pull), at first rapidly and then more slowly. When the applied load is considerably less than the ultimate strength of the piece (as tested in the ordinary way by steady increment of load), it appears that this process of slow extension comes at last to an end. On the other hand, when the applied load is nearly equal to the ultimate strength, the flow of the metal continues until rupture occurs. Then, as in the former case, extension goes on at first quickly, then slowly, but, finally, instead of approaching an asymptotic limit, it quickens again as the piece approaches rupture. The same phenomena are observed in the bending of timber and other materials when in the form of beams. If, instead of being subjected to a constant load, a test- piece is set in a constant condition of strain, it is found that the stress required to maintain this constant strain gradually decreases.

29. The gradual flow which goes on under, constant stress— approaching a limit if the stress is moderate in amount, and con­tinuing without limit if the stress is sufficiently great—will still go on at a diminished rate if the amount of stress be reduced. Thus, in the testing of soft iron or mild steel by a machine in which the stress is applied by hydraulic power, a stage is reached soon after the limit of elasticity is passed at which the metal begins to flow with great rapidity. The pumps often do not keep pace with this, and the result is that, if the lever is to be kept floating, the weight on it must be run back. Under this reduced stress the

@@@1 *Report of the Commissioners on the Application of Iron to Railway Structures,*

@@@2 For descriptions of these and other types of autographic recorder, see a paper by Prof. Unwin, “On the Employment of Autographic Records in Testing Materials,” *Jour. Soc. Arts,* Feb., 1886; also Prof. Kennedy’s comprehensive paper, “ Οn the Use and Equipment of Engineering Laboratories,” *Min. Proc. Inst. C.E.,* 1886, which contains much valuable information on the whole sub­ject of testing and testing machines.

@@@3 *Proc. Inst. Mech. Eng.,* 1S86. An interesting feature of this apparatus is a device for preventing error in the diagram through motion of the test-piece as a whole.

@@@4 *Proc. Inst. Mech. Eng.,1886;* also *Min. Proc. Inst. C.E.,* vol.lxxxviii., 1886, pl. 1.

@@@5 Thurston's *Materials of Engineering,* part ii. For accounts of work done with this machine, see *Trans. Amer. Soc. Civ. Eng.,* from 1876; also, *Report* of the American Board, cited above.

@@@6 See a paper by Prof. Unwin, *Phil. Mag.,* March, 1887.

*@@@*7 *Mitth. aus dem Mech.-Tech. Lab. in München,* Heft 5.

@@@8 *Cf.* Bauschinger, *loc. cit.;* Kennedy, *loc. cit.;* Jenny *Festigkeits Versuche,* Vienna, 1878.