STRAIN DIAGRAMS—WHAT THEY ARE AND WHAT THEY TELL US.

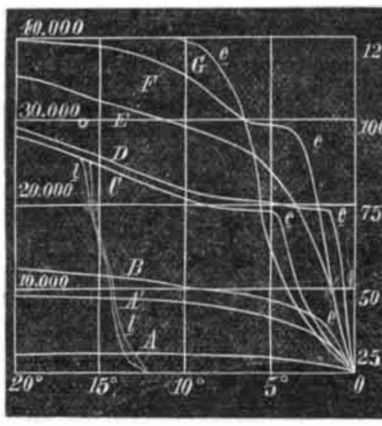
BY PROFESSOR R. H. THURSTON.

A strain diagram is a graphical representation of the variation, of the resistance of a specimen of any material, with the change of form which occurs when it is strained by external forces. It is usually a curve, sometimes of regular form, but generally of an irregular shape. Were the material always perfectly homogeneous, and absolutely uniform throughout, in composition, texture, and in the distribution of the molecular forces, this diagram would be a smooth, graceful, regular curve; but every variation from homogenousness and uniformity, in any of its properties, must affect the curve, and, as a strain diagram, it becomes a record from which an accomplished observer should be able to deduce the true physical character, and sometimes even the chemical nature, of the material represented.

Strain diagrams of the material of construction are best obtained, where accuracy and completeness of information are desirable, by means of an autographic recording apparatus, attached to a machine for testing by torsion, in the manner adopted by the writer and already several times referred to in the columns of the SCIENTIFIC AMERICAN; but, in the works of Rodman, Captain King, and others, may be found strain diagrams produced by plotting carefully the results of experiments made in the ordinary manner. The finest curves yet published are to be found in the account of the experiments of the Swedish Royal Commission, written by K. Styffe, of the School of Technology at Stockholm.

Referring to the illustrated article published in the SCIENTIFIC AMERICAN of January 17, the reader will readily see how to construct such diagrams for himself. To secure satisfactory results, however, great care must be taken, in observation and record of the first effects of the applied force, since the most valuable indications are often obtained from that part which represents the first six or eight degrees of twist.

Fig. 1 represents this portion of the strain diagrams produced at the Stevens Institute of Technology, by specimens of iron and other metals, of standard size, five eighths inch diameter and one inch long, in the reduced part, by the au-



tographic machine. It will be seen that they are so formed that each point of the curve is so situated that its hight above the base line (that is its ordinate, as it is called), measures the force which strains the piece to a degree which is proportional to the distance of the point from the right hand border of the diagram, that is to say, the latter distance is the abscissa of the given point.

Space will not permit an extended explanation of the methods of determination of the meaning of each peculiarity of the curve, or of the operations of verification, as they are described in sufficient detail in the account of the research published elsewhere.* It is only necessary to state here that an early acquired familiarity with steam engine indicator cards and long practice in their interpretation, probably first prompted the critical examination of these diagrams; and, as with the indicator diagrams, careful observation and comparison led to interesting and useful deductions as to their meaning.

The curves, A A′ and E, are the regular lines, parabolic in form, which are given by metals of homogeneous character. A and A′ are curved from the start, and are thus known to be the strain diagrams of inelastic as well as homogeneous metals. The line, E, which is at first straight and inclined, is, by that fact, known to be produced by an elastic material, while the regularity and smoothness of the succeeding portion of the curve indicates homogeneousness of structure.

These diagrams are respectively those of forged and cast copper, and of the beautiful specimen of iron described and pictured as No. 22 in the article of January 17. B, in Fig. 1, is similar in its general character to A and A′. It is the beginning of the strain diagram of a soft bronze.

Diagrams C and D are so different from the preceding that the most careless observer notices their peculiarities, and can recognize the distinction, not only between these curves and A, B, and E, but also between themselves. C rises in a curve convex toward the base, turns a sharp corner at *e*, runs nearly horizontally some distance, and finally pursues a course which would be seen to be parabolic, could the remainder be shown. D rises more nearly vertically, but curves slightly to the left, turns a well marked corner also, and then also runs a little way, almost horizontally, before resuming the upward movement.

There is a strong resemblance, and yet an evident difference here. The diagrams are those of two well known brands of iron, good specimens both.

The striking peculiarity of C, its reversed curvature, is supposed to be produced by the existence, in considerable amount, of the internal strain of which the effects were described in the SCIENTIFIC AMERICAN of April 11, and which is there described as a lack of homogeneousness as to strain. Were there not an appreciable amount of internal strain, this portion of the line would present the appearance seen in D and in E, and would be parallel to the elasticity line, *l l*. The degree of this reversed curvature, and the deviation from parallelism with *l l*, shows how much the metal is affected by this strain. It is noticeable that C is evidently weaker than D, which fact is, not improbably, a consequence, and perhaps a measure, of the ill effect of the observed fault.

After the piece has been strained to *l*, and the force producing distortion is first removed and then renewed, producing the double line, *l l*, just referred to as the elasticity line, much of this internal strain has been relieved by the mere stretching of fibers, and *l l* is thus nearly made a straight line. It is now also seen that the latter line indicates more correctly the real elasticity of the material than does the initial part of the line up to *e*, where these internal forces interfere with elastic properties. We therefore always determine the elasticity of the material by forming lines like *l l*. One of the important discoveries which has followed these investigations is that the elasticity of the metal remains the same, quite up to the point at which rupture commences.

The point, *e*, at which the line turns and becomes pretty nearly horizontal, indicates where the change of form becomes considerable with comparatively small accessions of force, and where the set becomes approximately proportional to the amount of distortion, and it is called the limit of elasticity. In A, A′, and B, it is not well marked; in E, it is more readily determined, and, in C, D, F, and G, it is well marked and is easily determined.

This is generally the point which it is considered most important to determine. Many experienced engineers think it more important to know the resistance at the limit of elasticity than even the ultimate strength of the material. It is extremely difficult to determine it accurately by the usual methods of test. Here, it is so well shown that, except with a few hard and, at the same time, very homogeneous materials, the most casual inspection of the strain diagram reveals it.

No materials should ever be subjected, in permanent structures, to stresses nearly approaching this elastic limit. A factor of safety, with reference to this point, of one half, that is straining the material to one half its elastic limit of resistance, is considered good practice.

Passing the elastic limit, the considerable deviation from the parabolic curve, and the consequent approach to the horizontal, which is observed so plainly in the strain diagrams C and D, and is less evident in F, and still less in G, shows a lack of another kind of homogeneousness, a defect of homogeneousness in structure. This is produced in irons, like C and D, by the presence of cinder, which cannot be perfectly expelled by the puddler, or by the subsequent processes of squeezing or hammering and rolling, and which produces the well known appearance of fiber. In E, this cinder has been so perfectly expelled, and the metal, by thorough and careful working, has been so purified, that no cinder is indicated, and the fracture, as already illustrated in an earlier article, shows excellent quality of metal and no fiber.

In the low steels, of which F and G are parts of the strain diagrams, this same want of homogeneousness occurs, but usually in a far less degree, in consequence of the existence of porosity in the ingot. In the rolling mill these pores are drawn out into very minute lines or channels of microscopic dimensions, producing the same effect upon the mechanical properties of the metal as is produced by the fiber in iron.

Comparing the several curves, we see that the line, C, is from a slightly better worked iron than D, although working cold is probably the cause of the internal strain in C; that E is almost perfect in both kinds of homogeneousness; that the Bessemer steel, F, is from a more porous ingot than the higher Siemens-Martin steel, G.

We see that the copper and bronze, of which A, A′, and B are strain diagrams, are apparently perfectly homogeneous in structure as well as free from internal strain.

Comparing the angle made with the vertical by the part of each curve lying beneath the elastic limit *e*, we find that, in order of stiffness, they stand: D, F, E, C, and lastly G, B, A′, A. In elastic resistance, the order is: C, F, E, D, C, B, A′, A. Could we follow the whole extent of each diagram, we should find this last to be also the order of ultimate resistance to rupture. As a general rule, the ultimate strength is pretty nearly proportional to the resistance at the elastic limit.

Thus, by constructing on paper the curves which will represent accurately the results of experiments made in the ways already described, we obtain strain diagrams from which we deduce useful information respecting nearly every valuable property of the material. The length of this article forbids entering upon an explanation of the method of determining the ductility of the material and its power of resisting shock, or describing the way in which the action of time, the effects of tempering, and other interesting subjects have been investigated.

It will be seen, by inspecting the figure, that the horizontal scale is one of degree, or of elongation; the vertical scale at the right is one of moments of torsion; and that on the left is an approximate scale of tension in pounds of stress per square inch of section on those lines of particles which are most strained.

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*Trans. Am. Soc. C. E., March, 1874, *et seq.* *Journal Franklin Inst.*, April, 1874, *et seq.*

SCIENTIFIC AND PRACTICAL INFORMATION.

CURIOUS PROPERTY OF TARTARIC ACID.

M. Pasteur, in the course of his investigations, has noted a curious splitting of racemic acid into two tartaric acids, identical as to their composition, but one of which rotates the plane of polarization to the right, and the other to the left. M. Bertholdy has recently made some interesting researches into this subject, with regard to the quantity of heat evolved. He find sthat the right acid dissolved in water absorbs 3·275, and the left acid, 3·270 calorific units. Racemic acid, on the other hand, absorbs 5·420 units. The combination of this same acid with two equivalents of water disengages 6·900 units. It results that the solution of this hydrate in water represents a movement of heat equal to the difference of the two preceding numbers, or 1·480 units. Now it is curious to note that this last exactly coincides with the number recently found by M. Dessains as representing the heat of melting ice, and hence the odd result may be stated, that if solid tartaric acid were united with solid water, or ice, there would be no disengagement of heat.

TROILITE.

The above name is given to a sulphuret of iron largely found in meteorites. The majority of mineralogists have considered the substance as a protosulphuret of iron, but such, according to a note recently presented to the French Academy of Sciences by M. Daubrée, appears not to be its true constitution. The proper formula is said to be $Fe_7 S_8$. There is a variety of mineral known as magnetic pyrites, or pyrothene, found at Horbach, in Baden, in specimens identical, both in composition and density, with those which fall from interplanetary spaces. This conclusion is strengthened by chemical analysis, as the protosulphurets possess certain properties which render them readily recognized. Under the influence, for example, of bisulphate of potash, the pyrothene gives off sulphuretted hydrogen. This the meteoric mineral does not do.

A FLORAL CHAMELEON.

The French Bishop of Canton has just sent to the *Jardin d'Acclimatation*, at Paris, a plant whose flower changes color three times a day. It is spoken of as another wonderful evidence of Chinese art in leading Nature out of her customary paths. It appears, however, that it is, if not the same, at least not more remarkable than a natural floral freak found in Southern Australia. It is a beautiful flower, similar to our well known morning glory, with five streaks of color on its bell-shaped calyx. In the early morning the color streaks are pale blue. Toward noon they turn to a rich purple tint, which changes to a light pink during the afternoon. As the day declines the color fades, disappearing entirely after sunset, when the flower closes and dies.

How Sea Lions Enjoy Life.

Charles Nordhoff, in the April number of *Harpers'*, has this interesting account of the habits of sea lions:

It is an extraordinary, interesting sight to see the marine monsters, many of them bigger than an ox, at play in the surf, and to watch the superb skill with which they know how to control their own motions when a huge wave seizes them and seems likely to dash them in pieces against the rocks. They love to lie in the sun upon the bare and warm rocks; and here they sleep, crowded together, and lying upon each other in inextricable confusion. The bigger the animal, the greater his ambition appears to be to climb to the highest summit; and when a huge, slimy beast has, with infinite squirming, attained a solitary peak, he does not tire of raising his sharp-pointed, maggot-like head, and complacently looking about him. They are a rough set of brutes—rank bullies, I should say; for I have watched them repeatedly, as a big fellow shouldered his way among his fellows, reared his huge front to intimidate some lesser seal which had secured a favorite spot, and, first with howls, and if these did not suffice, with teeth and main force, expelled the weaker from his lodgment. The smaller sea lions, at least those which have left their mothers, appear to have no rights which any one is bound to respect. They get out of the way with an abject promptness which proves that they live in terror of the stronger members of the community; but they do not give up their places without harsh complaints and piteous groans.

Plastered against the rocks, and with their lithe and apparently boneless shapes conformed to the rude and sharp angles, they are a wonderful, but not a graceful or pleasing sight. At a little distance they look like huge maggots, and their slow, ungainly motions upon land do not lessen this resemblance. Swimming in the ocean, at a distance from the land, they are inconspicuous objects, as nothing but the head shows above water, and that only at intervals. But when the vast surf, which breaks in mountain waves against the weather side of the Farallones with a force which would in a single sweep dash to pieces the biggest Indiaman—when such a surf, vehemently and with apparently irresistible might, lifts its tall white head, and with a deadly roar lashes the rocks half-way to their summit—then it is a magnificent sight to see a dozen or half a hundred great sea lions at play in the very midst and fiercest part of the boiling surge, so completely masters of the situation that they allow themselves to be carried within a foot or two of the rocks, and, at the last and imminent moment, with an adroit twist of their bodies, avoid the shock, and, diving, re-appear beyond the breaker.

WOOD ASHES are stated to be an effective remedy for currant worms. Dust the bushes in the morning with the dry ashes. Three applications, thoroughly done, will be sufficient.

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