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CANADIAN MAGAZINE OF Science and the Industrial Arts.

Patent Office Record.

Vol. 12. DECEMBER, 1883. No. 12.

Communications relating to the Editorial Department should be addressed to the Editor, Henry T. Bovey, 31 *McTavish Street, Montreal.*

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NEW BOOKS.

Plaster and Plastering—Mortar and Cements—How to make and how to use, by F. T. Hodgson. (The Industrial Publication Co'y, New York.)

The publication of small hand-books for the various Trades having for their object the better instruction of artificers in their special departments, cannot be too highly praised; for until the average workman is fairly master of his business and takes an intelligent interest in it, no good work can be expected of him.

The present little manual—to quote the author's words is intended "to help those who are desirous of helping themselves" and contains a great variety of information on subjects more or less directly connected with plastering, and which will be found useful, not only to the Plasterer, but also the general reader.

It describes the tools required in the work, the various kinds of materials employed, the mode of operation; it tells how to measure the work, and appends a quantity of miscellaneous information, finishing with a glossary of terms.

The least satisfactory part of the book is the illustrated plate of profiles of cornices, which we would have wished had been more judiciously selected. We should be sorry to see any of them executed.

On the whole, however, we have no hesitation in recommending this book to all whom it may concern as likely to prove a good and useful investment.

◆

THE PREVENTION OF INCRUSTATION IN STEAM BOILERS.

In 1858 the Manchester Steam Users Association engaged Dr. R. Angus Smith, to make an analysis of several of the waters used in the works around Manchester, and to prescribe remedies for their treatment, in order to guide the members on this subject. Subsequently several other analyses had been made of waters containing carbonate of lime, coupled with magnesia. Such waters were found to form a fine floury deposit, which led to the overheating of the furnace plates, even though covered with water at the time. In consequence of this, many boiler makers had been unfairly blamed, and the straining of the furnaces attributed to bad workmanship, whereas it was due to the peculiar character of the feed-water. Cases of this sort had been met with in various parts of the country, in London, in Lancaster, in the neighborhood of Widnes, and many other localities.

The number of anti-incrustation compositions was very numerous. Their component parts were veiled in mystery. Many of them proved positively injurious to the boilers on actual trial. Some lined the plates with a glutinous coating, which, while it had the desired effect of keeping off the scale, unfortunately at the same time kept off the water, in consequence of which the furnace crowns became overheated, strained, and bulged out of shape. The members therefore were warned not to adopt any of these compositions without the greatest caution. As the incrustation compositions were costly, blowing out was too often given up when they were used. The practice of neglecting blowing out was strongly objected to, and an explosion that occurred at Bury from that cause was referred to as an illustration.

The course recommended by the Association was to try in the first instance good soda ash. This was not to be introduced at the manhole or safety valve in large intermittent charges when the steam was down, but pumped in along with the feed water at the rate of about 3 lb. per day for a full-sized mill boiler, so that the boiler might regularly be fed with weak soda water, while blowing out should by no means be neglected.

Boilers were not to be emptied violently by blowing the water out under steam pressure, as that would leave the surrounding brickwork hot, and bake the sediment on the plates; but the boilers were to be allowed to stand until cool, and allowing the water to flow out of its own accord. To hasten the cooling, the steam might be blown off at the safety valves, and then when the pressure was down, but not before, the manhole lid might be taken off and cold water poured in so as to mix with the hot, and thus lower the temperature of the mass gradually and generally, and not suddenly and locally.

Should, however, the soda not be found to succeed, and soda would not meet every case, it was recommended that an analysis of the water should be made by a practical chemist with a view to a suitable remedy being prescribed to meet the special requirements.

Soda ash was recommended in preference to soda crystals, because the crystals contained so large an amount of water, so that though the soda ash might cost a little more per pound in the first instance, it was cheaper in the long run. It was stated, however, that as soda ash varied very much in quality, it was important to see that it was good, as otherwise it might contain impurities which were injurious. In one case, which had come under notice, the amount of carbonate contained was only 65 per cent., while in another it was as much as 98 per cent. Also in the first case the quantity of chloride and sulphate of sodium, which were impurities, was as high as 18 per cent., and in the second case as low as 0.5 per cent. Further, there was present in the first case as much as 16 per cent. of water, and only 0.3 per cent in the second. Thus there was a marked difference between the two.

The Porter-Clark process had the advantage of purifying the water before it was pumped into the boiler, whereas all boiler compositions treated the water after it was pumped in, so that while the Porter-Clark process threw down the impurities outside the boiler, the compositions threw them down inside The Porter-Clark process, however, at present was only adapted to deal with carbonates, whereas most of the waters the Association met with were impregnated with sulphates It was hoped that the Porter-Clark process might be extended so as to render it applicable to waters impregnated with sulphate of lime as well as to those impregnated with carbonate of lime —*Engineering*

* * *

"ON THE PRESERVATION OF IRON BY ONE OF ITS OWN OXIDES."

BY BENJAMIN HOWARTH THWAITE, ASSOC. M INST. C.E.

(A paper read before the Inst. of Civil Engineers.)

Concluded from page 331.

In this process the rustier the articles are, the more effective and speedy is the process of oxidation. Old cast-iron water and gas pipes, that were were so covered with rust as to be commercially valueless, have been converted into a condition more durable and valuable than they were when first withdrawn from the moulder's sand. The magnetic oxide coating produced by the Bower furnace, on the surface of the roughest castings is smooth to the touch. The smoothness of the surface is, however, more apparent than real, as by microscopical examination the surface presents a granular appearance. If occasionally the articles are slightly warped, they can, by a *judicious reheating, accompanied by* the application of pressure produced by weights, &c., be brought back to their original shape. A French chemist, Mr. Dodé, discovered some years ago, a singularly cheap and beautiful process for depositing from their salts the noble metals upon the surface of a special description of enamel, which was fused upon the surface of iron and steel articles; but it was discovered that corrosion unfortunately set up under the coating of enamel, and eventually threw it off It was decided to try Mr Dodé's process upon the magnetic oxide coating as produced by the Bower process, and the experiments proved a decided success. The Société Française d'Inoxydation et de Platinage, though proprietors of Mr. Dode's patent, also purchased the continental patents of Mr. Bower, and eventually those of Mr. Barff as well. By a special arrangement of the furnaces, Mr. Roque, the engineer of the Société Française, is able to treat articles of a very considerable length.

The colour of the magnetic oxide coating, as it emerges from the furnace, is a *light tint of French grey*, which can be made to have a silvery lustrous appearance by merely filling the muffle with the vapours of volatilized liquid hydrocarbon, produced from oil poured into a special siphon formed as already described. The colour of French grey will be retained by the magnetic oxide as long as it is free from contact with liquid grease, oil, or other hydro-carbons. The least touch of any of these instantly converts the light French grey colour into one of a bluish black appearance, which no energy of washing or rubbing will remove. But of course the grease or oil is volatilized on exposure to heat, leaving the oxide with its original colour. All articles that are *likely to* be handled should be oiled. Mineral oil is the most suitable; and as the coating of magnetic oxide rapidly absorbs the oil, the least application is sufficient, and after the superfluous oil has been thoroughly rubbed off, the oxide presents a dark and polished appearance, which to some people is preferable to the delicate natural colour of the oxide.

A very pretty effect may be obtained, upon ornamental castings, by oiling the minor or subordinate parts of the ornament, leaving the prominent or main parts untouched. In the preliminary experiments with the magnetic oxide, it was was noticed, that if any foreign metal was rubbed upon its surface, part of the latter was deposited or left on the former, *a property not possessed, as far as the Author knows, by any* other oxide, this remarkable discovery led Mr Bower to make a series of experiments with various descriptions of metallic brushes with wires of all the noble metals, as well as of various alloys, in all cases the results were the same, and oxidized castings can be gilded, plantanized, or bronzed, &c, most charmingly, cheaply and quickly, by merely rubbing over the surface of the magnetic oxide coating, with metallic brushes, with bristles of any description of metallic wire other than iron. In order to permanently fix the gilt, the gilded castings are exposed to very moderate temperature, say 600° Fahrenheit, for about thirty minutes.

As already mentioned, the Société Française d'Inoxydation et de Platinage utilizes the magnetic coating as a base for receiving their special enamel. Upon this enamel, or even direct upon the magnetic oxide coating, gold, silver, platinum, &c., can be permanently deposited by mixing the chlorides of these metals with certain essential oils, and then placing the iron articles, washed with the metallic chlorides, in the furnace *for a short time.*

The novel feature of both the attrition and Mr Dodé's principle of gilding, platinizing &c., is that the same iron article can be ornamented with various articles in conjunction, if desired, with other coatings, such as variously coloured enamels When the oxidized castings require to be enamelled, no costly preliminary process of annealing is necessary, and the enamel can be deposited direct upon the coating of magnetic oxide.

That the strength of constructional ironwork is practically unaltered by the Bower-Barff process, will be seen by the subjoined table of tests made by Sir Joseph Whitworth, and considered by him to be "very satisfactory." Metal tested before and after being subjected to Professor Barff's process :—

No. of METAL, 433.

Before.		After.	
Pressure in Tons.	Alteration.	Pressure in Tons.	Alteration.
Per square inch	Inch.	Per square inch	Inch.
18	Nil	18	Nil
19	“	19	“
20	“	20	“
21	0·0002	21	0·0007
22	0·0009	22	0·0023

No. of METAL, 603.

Before		After.	
Pressure in Tons.	Alteration.	Pressure in Tons	Alteration.
Per square inch	Inch.	Per squere inch	Inch.
18	Nil	18	Nil
19	“	19	“
20	“	20	“
21	0·0002	21	0·0007
22	0·0009	22	0·0023

The following may be taken as a fairly accurate list of the thicknesses of the magnetic oxide coatings required for various descriptions of iron :

	Inch.
Light sheet iron, a thickness of . .	0·0035
" wrought " "	0·0104
Heavy " (such as tubes) a thickness of	0·0188
Light cast " "	0·0183
Heavy " " "	0·0200

As the magnetic oxide is not very pliable, it is not suited for articles which have to be bent after their treatment, and *if struck very violently with another hard metallic body, it is* liable to chip off at the point of contact; but when the process is properly accomplished, the oxide-coating will withstand all ordinary concussions. If a piece of the oxide-coating is, however, removed, the corrosion which may set up in the denuded portion will be strictly local, and will not burrow under the coating remaining intact.

If the magnetic oxide is perfectly formed, it will resist all ordinary corrosive influences, but it is affected by contact with strong corrosive acids, although a piece of oxidized cast iron has been found to resist for a considerable period the the action of dilute acids, such as urine; but the Author would not advise its adoption for apparatus used in the chemical industries, except in the laboratory, where it has been utilized with success for preserving iron tripods, Florence flask-holders, &c.

Fe_3O_4 represent the chemical equivalents forming magnetic oxide, hence the relative equivalent weights will be as follows:—

$$3\,(56) = 168 \text{ or } 72{\cdot}41 \text{ per cent. Fe.}$$
$$4\,(16) = 64 \text{ or } 27{\cdot}59 \text{ per cent. O.}$$

It is magnetic, as its name implies, and has a specific gravity of from 4·98 to 5·20.

To test the character of the magnetic oxide-coating, the oxidized articles are placed upon a damp soil, say for two hours, and are then allowed to become dry in the open air. These alternate processes of exposing the oxidized articles to wet and dry periods, are continued for several days, and if the coating is imperfect, a few days' exposure to the test described will bring its imperfections to light. If the oxide-coating resists satisfactorily the test experiment for a period of five or six days, it is perfect and durable.

One of the greatest advantages possessed by the Bower-Barff process is the completeness with which the oxidation is effected upon every part, however intricate it may be, of the metallic surface of the articles submitted to it, hence its applicability to hollow cylinders, pipes, &c., of intricate shape. Owing to the increased size of the articles submitted to the process, by the addition of solid oxygen, it is necessary that all parts which have to be fitted together, such as screws, bolts, &c., should be slightly run down or otherwise decreased in size, to allow for this addition.

The magnetic oxide-coating, giving as it does a finished appearance and smoothness to the iron, the latter can be painted, if desired, far more easily than if it was unoxidized, and the painted surface will be far more durable.

Ordinary oil-paint, when applied to unoxidized iron, has only a comparatively short life, arising from the fact that the moisture of the condensed aqueous vapour on its surface eventually permeates through the paint, setting up corrosive action, which ultimately throws it off; hence the importance of having iron articles oxidized or Bower-Barffed, even if it is desired that they should be painted as well.

It will no doubt be obvious that the cost of oxidizing by the Bower or Barff process—or, to use a more abbreviated expression, the cost of Bower and Barffing— varies considerably; for example, one thousand small articles may be treated at the same time, and in the same cubical space, that might be occupied by a single large article, but when the latter is hollow, and when possible, the hollow space may be filled up with smaller articles.

Mr. Flamache, engineer for the Belgian State railways, who was sent over by the Belgian Works Department to report on the process, found the cost, exclusive of royalty, to be as follows. 7½ francs per 1,000 kilograms by weight, or ¾ of a centime per kilogram, and superficially, ⅜ of a centime per decimetre cube.

In the Bower furnace of the Société Française at Grenelle, the weight of objects treated in twenty-four hours varies from 47 to 85 cwt., with an expenditure of fuel of from 10 to 12 cwt. of good slack coal. In the Barff furnace, of the same form, the weight of objects that can be treated in twenty-four hours varies from 47 to 106 cwt., with an expenditure of from 15¼ to 17¼ cwt.

For a Barff furnace, having a muffle capacity equal to 124 cubic feet, the quantity of water evaporated per hour to supply the muffle with superheated steam, is equal to from 8 to 10 gallons. One attendant is required for every two furnaces in ordinary working; but auxilliary labour is required when loading or unloading.

The following is a list, necessarily limited, of articles, especially adapted for receiving the coating of magnetic oxide:—

Cast Iron.—Architectural ironwork, horticultural ironwork, sanitary appliances; engineering ironwork, such as water-mains, gas-mains, roof and bridge castings, &c.

Wrought and Sheet Iron, Untempered Steel.—Water-, gas-, and pneumatic-tubes, cramps, roofing-tiles, and generally all ironwork which will not be liable to rough usage, and not require bending or riveting after treatment.

It will probably be seen that the Bower-Barff process is applicable to those articles to which galvanizing is more or less inapplicable, and the former process therefore serves as a useful auxiliary to that well known and excellent process of preserving iron by means of a coating of zinc.

For the Bower furnaces in New York, in place of bituminous coal, anthracite is used in the producers, in conjunction with gas from petroleum oil. The latter is allowed to trickle slowly through the coal charging hopper of the central producer, where, falling upon the anthracite incandescent fuel, it becomes volatilized and produces a powerful reducing or deoxidizing gas. In order to prevent the oil from igniting and firing *back, it is led by* a pipe from a considerable distance. In the New York Bower furnaces, equal periods of both oxidation and deoxidation, of a duration of fifteen minutes each, are found to give very satisfactory results. In the same Bower furnaces Mr. A. S. Bower has been successful in carrying out the Barff process for heavy wrought-iron articles by the following method:—After the wrought-iron articles have been heated by direct combustion inside the muffle apparatus to the temperature of oxidation, the gas and air are shut off from the muffle, the chimney damper is closed, and steam is turned into the recuperator tubes, and in passing through them the muffle becomes highly heated. The steam is kept on continually until the temperature of the articles begins sensibly to decrease, when it is shut off, and the gas and air are turned on (in such relative proportions as not to affect the character of the oxide coating), until the proper temperature is again regained, and the same operation of shutting off gas and air. &c., and turning on steam, is repeated, as often as required to effect a proper thickness of the oxide-coating.—*Trans. Inst. C. E. (Eng.)*

COMPOUND LOCOMOTIVE ENGINES.*

By Mr. Francis W. Webb, of Crewe, Vice-Preesident.

A paper read before the Inst. of Mechanical Engineers, (Eng.)

The object of the present paper is to show what advantages may be obtained by Compounding the Locomotive Engine, and how this may be practically carried out without materially adding to the weight or complicating the working parts. The subject is not a new one, as it has been dealt with in this Institution (Proceedings 1879, page 328) by Mr. Mallet, with regard to the Bayonne and Biarritz Railway. He succeeded in obtaining an economical engine, but in a form not likely to be a steady one on high speeds; great credit however is due to him for the attention he has given to the subject.

About five years ago the author converted an old outside-cylinder engine with 15-in. cylinders into a compound, on the plan adopted by Mr. Mallet, by lining up one of the cylinders and reducing it to 9 in. diameter. This engine has until the last three months been working light passenger trains on the Ashby and Nuneaton branch of the London and North Western Railway; and the elements of success seen in its working led to the construction of the compound locomotive "Experiment," which was what its name implies.

The two main objects the author had in view when designing the "Experiment" were—firstly to attain to greater economy in consumption of fuel, and secondly to do away with coupling-rods, while at the same time obtaining a greater weight for adhesion than would be possible on only one pair of driving wheels without rapid destruction of the road. The driving wheels being no longer coupled, there is less grinding action in passing round curves, and it is not even necessary that one pair should be of the same diameter as the other.

The engine "Experiment" was constructed at the Crewe locomotive works in the latter part of 1881, and has now been at work over twelve months and run nearly 100,000 miles, chiefly with the Scotch and Irish limited mails. While on this work it made a daily run of 319 miles; and this being a longer mileage than the engines are accustomed to run in the time, two drivers and firemen were appointed to work the en-

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* *For illustrations see pages 356, 357, 360, 361.*

COMPOUND LOCOMOTIVES.

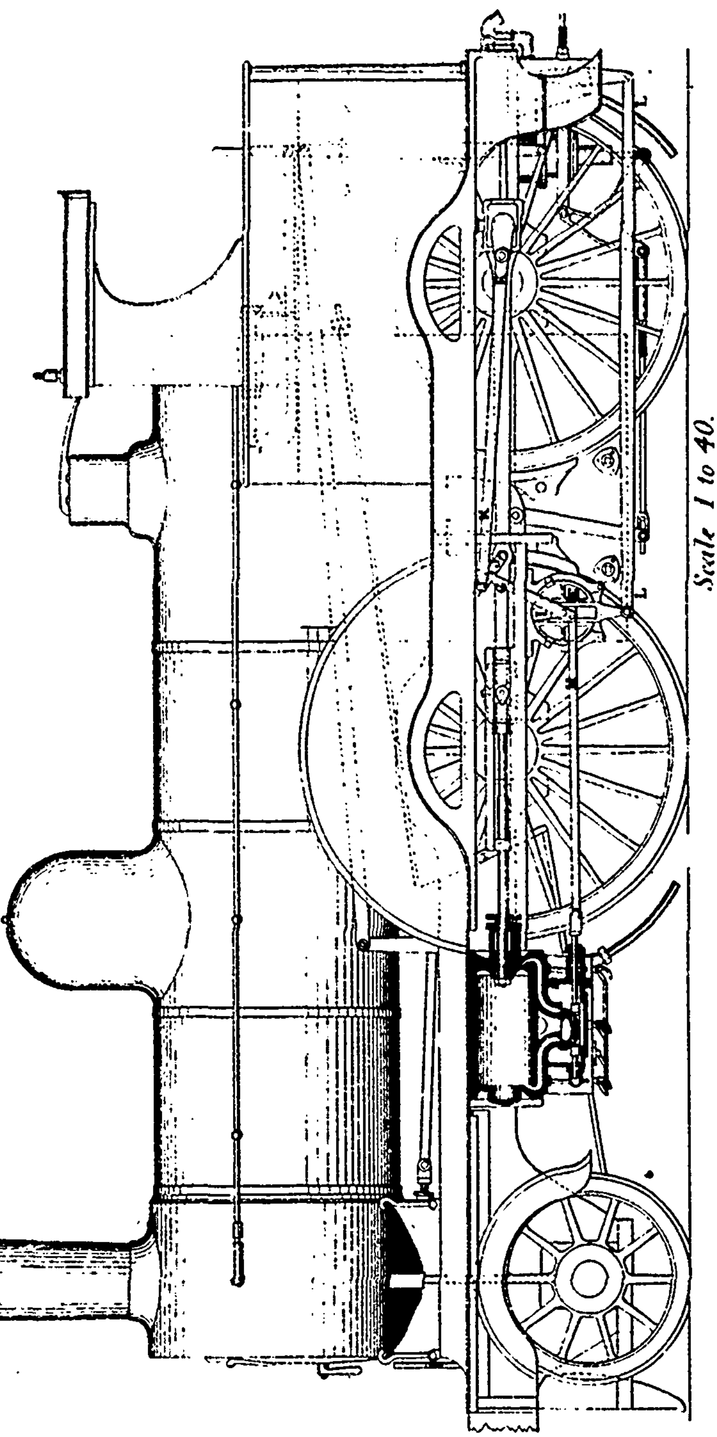


Fig. 1. *General Elevation with Section of High-Pressure Cylinder.*

gine, one for Crewe to London and back one day, and the other the day following, in order thoroughly to test the engine in every way before building any more of a similar class. The engine has throughout proved itself to be very steady when running, which is no doubt due to the arrangement of the cylinders, the engine being practically balanced, and having no coupling-rods, is enabled to run at very high speeds.

The principle having been proved correct, it was thought advisable, owing to the increasing weight and the high speeds of passenger trains, that in designing the new engines they should be made more powerful than the present type. Accordingly the high-pressure cylinders have been increased from 11½ ins. to 13 ins. diam., leaving the low-pressure cylinder of 26 ins. diam. the same as at present, with the exception of the ports, which have been increased from 1½ ins. by 14 ins. to 2 ins. by 16 ins, in order to give more freedom for the exhaust.

The construction will be readily understood from the following description, and from the diagrams, Figs. 1 to 3, Pages 356, 357 & 360. Of these, Fig. 1 is an elevation, with section through

COMPOUND LOCOMOTIVES.

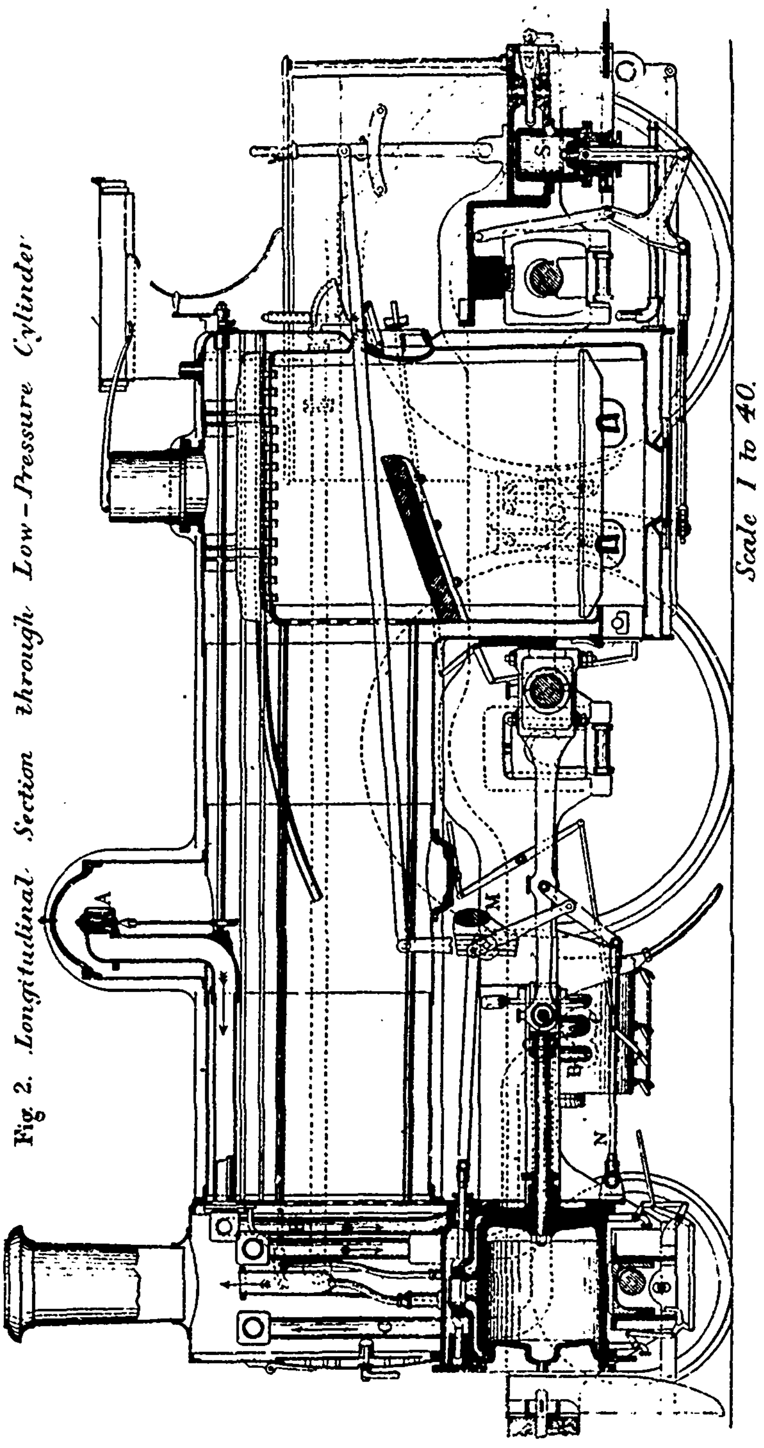


Fig. 2. *Longitudinal Section through Low-Pressure Cylinder*

the high-pressure cylinder, Fig. 2 is a section through the low-pressure cylinder, and Fig. 3 is a plan. There are two outside high-pressure cylinders of 13 in. diam., Figs. 1 and 3, and one inside low-pressure cylinder of 26 in. diam., Figs. 2 and 3, the stroke in each case being the same, namely 24 in. The two high-pressure cylinders have their steam-chests placed underneath, in order to allow the valves to fall from their faces; so that there is no wear when the steam is shut off. These two cylinders are attached to the outside frame-plates immediately under the footplate, about midway between the leading and middle wheels, and are connected through their piston-rods and connecting-rods to two cranks at right angles on the trailing wheels. The low-pressure cylinder, which has its steam-chest on the top, is placed directly ovar the leading axle, and is carried between two cross steel plates, one at either end, securely fixed between the main frames; its connecting-rod lays hold of a single-throw crank on the axle of the middle pair of wheels.

The steam is supplied through the regulator in the dome A, Fig. 2, Page 352, to a brass T pipe on the smoke-box tube-plate, and thence by two 3-in. copper steam-pipes B, running first parallel to the tube-plate, then through the back plate that carries the low-pressure cylinder, and between the plates of the inside and outside frames, to the steam-chests of the high-pressure cylinders. The exhaust steam from these cylinders is returned by two 4-in. pipes C, running parallel with the high-pressure pipes, through the back-plate that carries the low-pressure cylinder, and into the smoke-box . following round the curved sides of the smoke-box nearly to the top, each pipe passes across to the opposite side, and enters the steam-chest of the low-pressure cylinder through passages in the cover. Thus the exhaust steam becomes superheated in these pipes by the waste gases in the smoke-box, while the large capacity of the pipes themselves obviates the necessity *for a separate steam-receiver.* The final exhaust escapes from each side of the steam-chest of the low-pressure cylinder into the blast-pipe, and thence to the chimney in the usual way, the only difference being that there are only half the number of blasts for urging the fire compared with an ordinary engine, yet the compound engine steams very freely, and has a blast-pipe of 4⅝ in. diam. for the final exhaust, compared with 4½ in. in engines of the ordinary type.

The steam-chest cover of the large cylinder is provided with a relief-valve D, Fig. 2, Page 357, so adjusted that the pressure admitted may never exceed 75 lbs. per sq. in. , and a small pipe, connected to the low-pressure steam-pipe, and carried back to a gauge fixed inside the cab, shows at a glance the actual pressure of steam being used in the large cylinder. An arrangement is also made whereby steam direct from the boiler can be admitted to the low-pressure cylinder, which is useful for warming up before starting.

The valve-motion adopted for this engine is that designed by Mr. David Joy, and described at a former Meeting (see Proceedings 1880, p. 418), which does away with all excentric-rods, and considerably reduces the number of working parts per cylinder, as well as the weight for the valve-gear. The arrangement however for the new engines differs slightly from that on "Experiment," in order to do away with the trunnion bearings on the foot-plate. The total number of working or moving parts for the three sets of valve-motion in the compound engine is twenty-nine, and their total weight 284 lbs. ; while the number of working parts in the two sets of valve-motion in the ordinary standard engine is twenty-four, and their weight 793 lbs . the reversing shafts in each case not being taken into consideration. The valve-chests being on the underside of the high-pressure cylinders, the motion-discs E, Fig. 1, Page 356, carrying the quadrant-bars, have to be placed in a corresponding position , and this is done by securing them to the underside of the slide-bars. The quadrant-bars, which are made of soft steel case-hardened, are each grooved to a radius equal to the length of the valve-rod link ; and working in their grooves are brass slide-blocks I, carried by the lifting links G, to the lower end of which is attached the valve-rod link H, and to the upper end the compensating link J on the connecting-rod , the upper end of the compensating link is controlled by a rod K attached to a return crank on the trailing crank-pine. The quadrant bars are lengthened out below the discs, so as to allow attachment to be made, by the link L, with the reversing shaft placed behind the trailing wheels. The reversing is effected by means of a screw-and-lever arrangement connected to the reversing shaft.

The high-pressure slide-valves are of the Trick or Allen type, which gives double the lead shown at the edge of the port *when the piston is at the end of its stroke , they have a travel* of 3⅓ in. in full forward and backward gear. The lap is ¾ in. and the lead ⅛ in. , the port opens ¾ in. for admission, and closes at 70 per cent. of the stroke. The sizes of the ports in the cylinders are, for steam 1⅛ in. × 9 in., exhaust 2½ in. × 9 in.

The valve-motion of the low-pressure cylinder differs slightly from that of the high-pressure. Instead of discs there is a cast-iron shaft M, Figs. 2 and 3, Pages 357 and 360, carried in brackets, which are fixed to the inside frames , and the quadrant guides are bolted to it in the middle of its length. The other parts of the motion are similar to those of the high-pressure cylinders, the only difference being that the end of the compensating link in the low-pressure motion is attached to a radius rod N centred on the back-plate of the cylinder. At one end of the reversing shaft is fixed a lever, which is *coupled direct by a long rod to the reversing handle on the* foot-plate. The travel of the valve in full gear is 4½ in., lap of valve 1 in., lead 3-16ths in. ; the port opens 1 in for admission, and is closed at 75 per cent. of the stroke, and the exhaust closes at 93 per cent. of the stroke. The sizes of the ports are, for steam 2 in. × 16 in., exhaust 3¼ in. × 16 in.

The reversing gears of the high and low-pressure cylinders are designed to work independently of each other, and no inconvenience has been experienced by this arrangement , they could if desired be connected, but this would mean complicating the parts, while no material advantage would be gained.

With regard to the degree of expansion at which the engine is worked, in practice the low-pressure cylinder is kept nearly in full gear, while all the expansion is done in the small high-pressure cylinders, so that no more steam is used than is absolutely necessary to do the work.

The commercial results with the engine "Experiment" have been very satisfactory. During the time the engine was working the Irish mail from Crewe to London, and the limited Scotch mail from London to Crewe, the average consumption per train-mile was 26 6 lbs. of coal, compared with 34 6 lbs. the average consumption of the standard four-coupled passenger engines with 17 in. cylinders and 24 in. stroke, the boilers being precisely the same in each case.

One of the principal features in the new engines has been the adoption of a boiler with the water-space of the fire-box carried under the grate, Fig. 2, Page 42, the space between it and the fire-bars forming the ashpan, just as in the case of the 18 in. goods engine which was fully described at the meeting of the Institution at Barrow (Proceedings 1880, p. 432). The object is to do away with the rigid foundation-ring, which is always a source of trouble , to obtain better circulation for the water ; and to prevent the lodgment of dirt on the sides of the fire-box where subject to the most intense heat. A flanged mouth-piece, similar to that of the fire-door, is formed in the centre of the water-space, and covered with sliding-doors worked from the foot-plate, so that the ashes can be easily removed or dropped , while any sediment that may collect in the water space can readily be removed through the wash-out plugs in the sides of the fire-box, there being a clear passage from side to side when the covers are taken off. The mouth of the ashpan is made of such a width that the tube-plate can be taken out and replaced by a new one, without disturbing the other parts of the fire-box.

The principal features of the compound engine having thus been described, there are one or two other points to which a reference may be interesting. The leading axle, it will be noticed, is placed immediately under the large cylinder, Fig. 2, Page 42, and nearly in a line with the centre of the chimney ; consequently the wheel-base is longer than usual, the distance from leading to front driving-wheels being 9 ft. 4 in., and from front driving to trailing-wheels 8 ft. 3 in., making a total wheel-base of 17 ft. 7 in. To overcome the disadvantage attached to a long rigid wheel-base, the leading axle is provided with a radial box, Figs. 4 to 7, Page 360, having a lateral movement of 1¼ in. to each side of the centre line of the engine. The box is formed in a single casting, with the brasses fitted in each end, and works between curved plate-guides A, stretching across from frame to frame. Inside the box and under the axle are carried two horizontal helical springs B and C, coiled right and left hand, and working one inside the other ; so that when the engine enters a curve, the springs are compressed towards one side, and take any shock that may be transmitted through the wheels from the rails ; and when the engine gets on to the straight again, the springs resume their normal position, and keep the engine central. *This class of axle-box,* but with two sets of side controlling springs, has now been in use seven years with very good results (see Proceedings 1877, p. 307), and 155 engines are fitted with it, 40 of them having one at each end.

The journals of the axles, it will be seen, are long in each case. Those of the leading axle are 10 in. long and 6 in. diam., while those of the front driving-axle are 13½ in. long and 7 in. diam., with crank journal 5½ in. long and 7¾ in. diam. ; and the trailing-axle journals are 9 in. long and 7 in. diam. The advantage of these long journals has been amply proved in the running of the "Experiment."

The engine, although still working on the London section, has been taken off the Irish and Scotch mail trains, because it was not fitted with the gear for working the vacuum brake with which these trains are now provided, and it was not *thought advisable to bring the engine into the shops for the* present in order to apply the vacuum-brake gear. The new engines however are fitted with ejectors and all the necessary gear for working the vacuum brake; and in addition with a steam brake S, Fig. 2, Page 42, acting between the two pairs of driving-wheels. This is also coupled to the tender brake-gear, so that the brake is applied to the engine and tender at the same time. A single movement of the driver's brake-handle serves to apply both the vacuum and the steam brake simultaneously; and similarly to release them together.

Indicator diagrams from the engine are shown in Figs. 8 and 9, Page 361.

Appended is a statement of the leading dimensions, &c. of these engines.

THREE-CYLINDER COMPOUND EXPRESS PASSENGER LOCOMOTIVE.

Cylinders.

Two High-pressure outside cylinders..	Diameter	13	inches.
	Stroke	24	"
One Low-pressure inside cylinder	Diameter	26	"
	Stroke	24	"

Joy's Valve Motion.

Wheels.

	ft.	in.
Diameter of leading wheels, with radial axle-box	3	6
Diameter of front driving-wheels (low-pressure cylinder)	6	6
Diameter of hind driving-wheels (high-pressure cylinders)	6	6
Distance between leading and front driving-wheels	0	4
Distance between front driving and hind driving-wheels	8	3
Total wheel base	17	7

Boiler.

Length of barel	9	10	
Mean diameter of barrel, outside	4	2 3-16tts.	
Length of fire-box, inside..4ft. 9⅜ in. at top	4	10½	at bottom.
Width " "	3	5½	
Height " from top of fire-bars to crown	5	5½	
Length of tubes between tube-plates	10	1	
Diameter of tubes, outside		1⅞	
Number of tubes	198		

Heating Surface.

Fire-box	103·5	square feet.
Tubes	980	"
Total	1083·5	"
Area of Fre-grate	17·1	square feet.

Ratio of heating surface to grate area — 63·35 to 1

Weight.

Weight of engine when empty	34·75 tons.
Weight of engine when in working order—	
Leading wheels	10·40 tons
Front driving-wheels	14 20 tons
Hind driving-wheels	13·15 tons
Total	37·75 tons.

In closing this paper the writer wishes to add, that his motive in laying before the Members of the institution the particulars of his system of compounding locomotives is to draw attention to the subject and encourage its full investigation, as he feels assured that better economical results are to be obtained than those which he has already arrived at. He hopes therefore that other papers on the subject may be forthcoming in the future.

Mr. Webb, in answer to the various questions raised in discussion, said he had not much to add, except in reply to the remarks made and questions asked. The cranks of the high-pressure cylinders were placed at right angles. With regard to the indicator diagrams, the exhaust line of the high-pressure cylinders was not always straight, but sometimes arched upwards in the middle of the stroke, which might be due to the low-pressure crank being in a different position relative to the two high-pressure cranks. The indicator diagrams were taken by two ordinary "*Richards*" indicators, with the connections made as close to the cylinder as possible, the motion was taken from the crossheads of the respective cylinders in the usual way, the diagrams were taken in pairs, from one of the high-pressure cylinders and from the low-pressure cylinder at the same time. The coal used in boat engines was similar in quality, being principally South Wales steam coal, with sometimes at little North Wales main coal. He could not give the coal used in shunting separately, but both engines being on similar work there could not be much difference: the lighting-up coal was also dealt with in the same way in both engines.

Since the paper was written they had turned out at Crewe ten compound locomotives of the same description as the one under discussion. A Sunday or two ago, he had had an opportunity of trying what these engines would do with the 10 o'clock express out of Euston, which on Sundays had eleven stoppages between Euston and Crewe, while the actual running time was much the same as for the 10 o'clock Scotch express on week days with only two stoppages. The compound engine took a train of 19 carriages, composite and saloon out of Euston to Crewe without assistance, and the time occupied in the *run was 4 hours 30 minutes with the eleven stoppages. Last* Monday the 10 o'clock Scotch express, which was one of the fastest trains running, was taken by the compound engine from Euston to Crewe in 3 hours 35 minutes with 16 large carriages, and with two stoppages.

Mr. Rich had asked the question whether there was any trouble with regard to condensation in the big cylinder. So far none had been experienced. The pipes between the two frames were packed in silicate cotton; so was the large cylinder. The whole space between the large cylinder and the frame was also packed with silicate cotton. With reference *to the question of complication in the engine, he had only three* connecting-rods instead of the ordinary two coupling-rods and the two connecting rods. He had thus one rod less, while he had an extra cylinder. The cylinder itself and the valve gearing were so simple that he thought if any member saw the engines themselves he would not say that there was undue complication. With regard to Mr. Crampton's remarks, he did not agree with his view, but he might say that it was in looking at an engine designed by Mr. Crampton—he believed it was when travelling on the Eastern Railway in France—that it occurred to him how easy it would be to utilise an extra portion of the weight of the engine for adhesion without coupling-rods; and that brought to his mind the design of the engine under discussion.

With reference to the question of carrying a sufficient quantity of fuel and water, they could carry sufficient coal to take them through from London to Carlisle, and it was of course well known to most English engineers that on the London and North Western line they picked up water wherever they required it, so that practically they were able to run an engine all the way through from London to Carlisle, and had done so on two or three occasions.

He might mention the first performance ever done by the compound engine "Experiment." Before it was painted, he hooked it on to assist a heavy express from Liverpool with 19 coaches. He tried it with the steam shut off from the other engine for some distance along the Trent valley. They ran without trouble from Crewe to London, when the engine arrived in London it was all right, and he had it turned round and hooked on to the morning Irish mail, which it took to Holyhead. When the engine arrived at Holyhead it was still all right, and he then gave the men something to eat, turned the engine round and hooked it to the boat express, which it took to Crewe. The engine thus did 528 miles as a christening trip.

Mr. Stroudly had remarked that it would have been better if he had tried the system with a goods engine. One engine that he had in hand at the present time was for working on the Underground Railway, where there had lately been some discussion as to the amount of fuel consumed, and the nuisance arising from it. It was one of the engines orriginally designed by Mr. Fowler, and he had taken it in hand and was compounding it. Mr. Tomlinson would bear him out in saying that they had very sharp curves to run round on that line, and

COMPOUND LOCOMOTIVES.

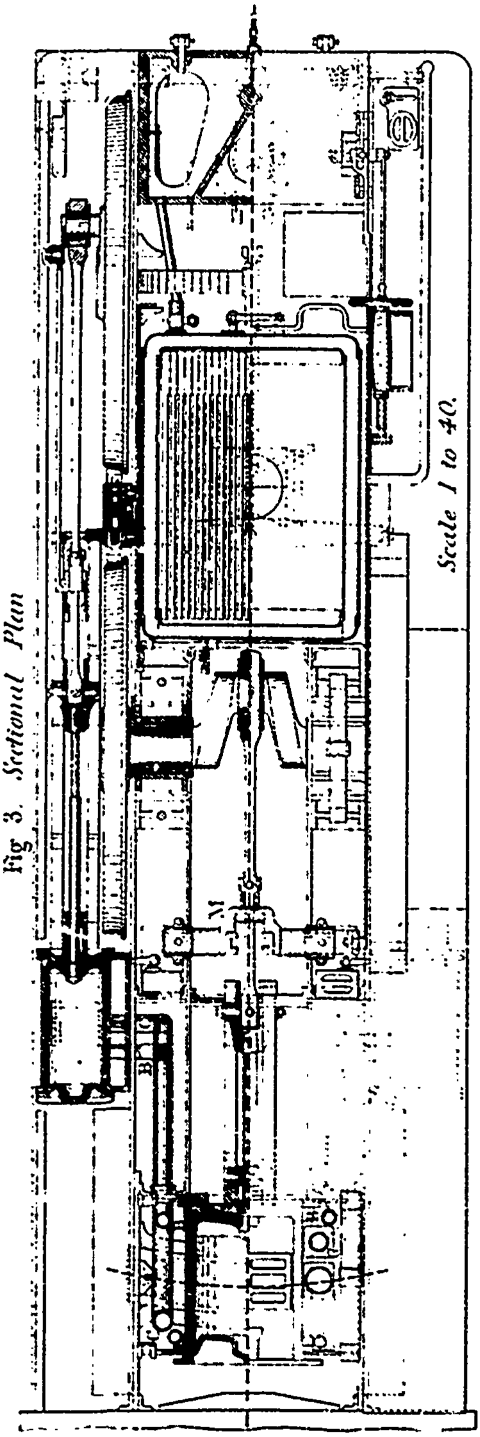


Fig 3. Sectional Plan

Scale 1 to 40.

Radial Axlebox.

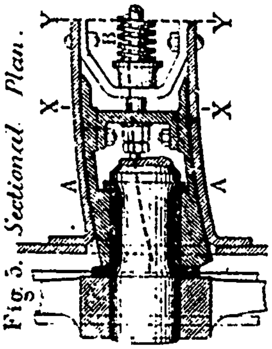


Fig. 5. Sectional Plan.

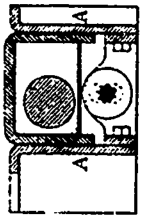


Fig. 7. Section at YY.

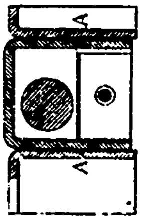


Fig. 6. Section at XX.

Scale 1 to 20.

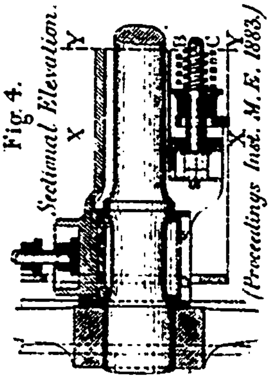


Fig. 4. Sectional Elevation.

(Proceedings Inst. M.E. 1883.)

COMPOUND LOCOMOTIVES.

Indicator Diagrams.

Fig. 8. *Speed. slow. Full gear:*

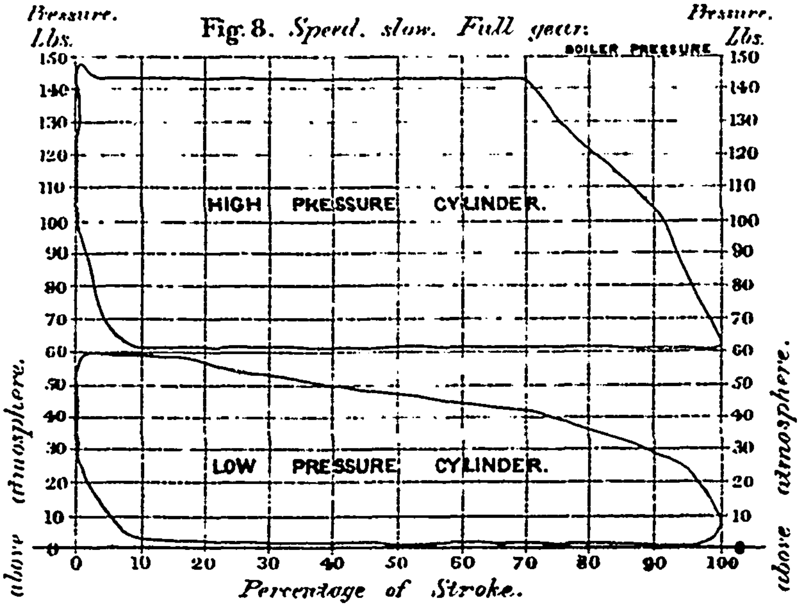
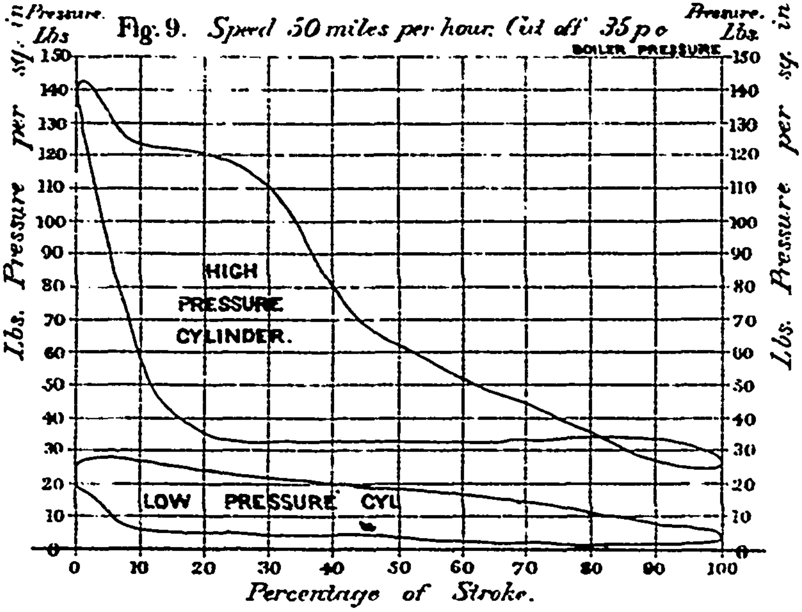


Fig. 9. *Speed 50 miles per hour. Cut off 35 p c*



that very great trouble had been experienced with coupling-rods. Five or six years was all the life that could be got out of a coupling-rod on that line. He believed he had answered all the questions that had been asked. He thanked the members very much for the favourable hearing they had given him; and he trusted that the result would be that the fuel of locomotives would last a little longer in the future, with the increased economy which he believed would be brought about by compounding them.—*A paper read before the Am. Soc. of Civil Engineers.*

ECONOMY IN HIGHWAY BRIDGES.[*]

By Prof. J. A. L. Waddell, C.E., B.A.Sc., Ma.E.

The object of these investigations is to determine the most economic number of panels and depth of truss for all ordinary highway bridges, also the lengths of span at which it is better to change from pony truss to through bridge, and from single to double intersection.

The calculations are made for iron bridges only, and deductions are made therefrom for combination bridges, but no notice has been taken of wooden bridges, for owing to the following reasons, there is no economy in building such structures.

1st. If both be properly designed a combination bridge will cost no more than a wooden one, and will last twice as long.

2nd. *Tension members of wood are objectionable, owing* to the difficulty and waste of material in making connections.

3rd. That, in a well built combination bridge, there is no part of the timber where water will lodge, while no wooden bridge can be built without such places.

4th. The iron of a combination bridge, after the wood has decayed is worth considerably more than the imperishable parts of a corresponding wooden structure.

The most common width of roadway, sixteen feet in the clear, has been chosen, and through bridges are alone considered, because highway deck bridges are very uncommon. however the results will apply also to deck bridges, except where they are affected by the consideration of necessary headway.

The Pratt truss has been chosen for two reasons: first, it is the truss most commonly employed in America; and second, the writer *has shown in a paper entitled* "*Economy in Struts and Ties*," published in this year's March number of the "Canadian Magazine of Science and the Industrial Arts," that although the most economic inclination of a strut to the vertical is about one in five or one in six, still practical considerations cause the vertical struts to be preferable, the actual difference in cost in the two cases being very slight. As seen by Table I, the spans for which calculations were made vary in length by ten feet up to spans one hundred and ninety feet long, and by twenty and thirty feet for longer spans.

The loads, working stresses, etc., are taken from "General Specifications for Ordinary Iron Highway Bridges," and the bridges are designed in accordance with the principles expressed in "Details in Ordinary Iron Bridges" and the writer's other papers pertaining to the subject. The bridges investigated *belong to* "*Class C*" *of the before mentioned* "*Specifications*," corresponding somewhat to those which used to be termed "factor four bridges."

The results, however, will apply, with only occasional and slight changes, to bridges of greater strength and wider or narrower roadways. Other specifications might cause some little difference in the economic depths, but for good designs the variations will be small.

The peculiar features of these specifications that may slightly affect the results are the use of C. Shaler Smith's formula for compression members with its varying factor of safety, and the exclusion of channels less than five inches in depth for chords, posts and batter braces, and of all webs less than one quarter of an inch thick. If three or four inch channels or I beams be used for posts, and Rankine's formula with its constant factor of safety be employed, as is not uncommonly the case, greater depths would probably be found, but no such consideration will at all affect the practical value of these results.

Much has already been written concerning the economic depths of trusses, the general conclusions being that they should be from one seventh to one tenth of the span.

Such investigations being purely mathematical and involving the use of the differential calculus are of little practical value, as they cannot take into account the number of variables that ought to be considered.

Not only do the stresses in a truss vary with the depth, but *also the intensities of working stress in the compression members*. These again vary in the top chords and batter braces with the number of panels; and this variation is according to a law or laws altogether too complicated to be dealt with by the calculus. Again the intensity of working stress varies or should vary according to the position and importance of the member considered.

That the results of previous investigations of economic depth are erroneous is proven by these calculations, for in no case is the economic depth as small as one seventh of the span.

At first the writer considered that it would be necessary to figure out the total actual cost for every case, but upon further investigation found that to determine the economic depth it would be sufficient to figure out the sections and weights per lineal foot required for the different members of one truss, *multiply these by the respective lengths and sum up the* products, neglecting all consideration of details; because the difference in the weights of the latter would balance each other. Thus, if we increase the depth of a truss by one foot, there would be a little increase in the weight of the lattice bars and rivets, and a decrease in that of the pins and eye bar heads. These may be taken as balancing each other, without making any appreciable error.

Again the economic number of panels for any span may be determined, without preparing complete bills of material, by considering only those portions of the structure which are affected by the variation in the number of panels,

Economy in pony trusses is an element which ought seldom to influence the design, for a good bridge of this kind will usually require more iron than the ordinary calculations demand.

Instead of trying to avoid a little expense, regard should be paid to obtaining a good distribution of plenty of material, in order to partly compensate for the lack of rigidity, which is characteristic of the pony truss.

In very wide pony truss bridges, especially when the length of span approaches its superior limit, it might be well to make a few calculations concerning the economic depth, but the number of panels should be regulated by the slope of the batter braces, which should never be less than two horizontal to one vertical.

This superior limit is not a fixed quantity, but decreases as the width of the bridge and the load increase, and as the intensities of working stresses diminish. For example, comparing a pony truss and a through bridge of sixty-five feet span in four panels, sixteen feet clear roadway designed according to "Class C" of the "Specifications," there is found a difference of three hundred pounds of iron in favor of the pony truss, while for the same span with twenty feet clear roadway and bridges designed according to "Class A" there is a difference of eleven hundred and fifty pounds of iron in favour of the through bridge.

For a clear roadway of twelve feet the superior limit of the pony truss would reach as high as seventy five feet, and for very wide bridges the inferior limit of the through bridge might reach as low as fifty feet, but on account of rigidity the superior limit of the former for all cases should be placed at sixty-five feet, and on account of appearance the inferior limit of the latter at fifty-five feet.

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[*] A paper presented to the Philadelphia Engineers' Club.

TABLE I.

Span.	No pans.	Interse.	Depth.	L.L.	D.L.	Chd. and BB. Ls.	Figured Length of Posts.	Wt. of Iron.
65'	5	S	7	1800	720	8"	W	•5,606
...	...	...	8	...	...	...	...	•5,233
...	...	...	9	...	...	...	...	•4,996
...	...	...	9	...	...	7"	...	•4,833
...	4	...	9	...	...	8"	...	4,854
80'	5	...	16 5	1280	460	5"	...	•4,531
...	...	...	17.	...	...	...	...	4,936
90	...	...	16.5	...	480	6"	...	5,683
...	...	...	17.	...	...	...	...	5,652
...	...	...	18	...	...	...	...	5,550
...	...	...	19	...	...	...		5 558
100	...	...	19	...	500	7"	...	6,754
...	...	...	20	...	...	...	...	6,714
...	...	...	21	...	...	...	...	6,768
110	6	...	20	...	530	...	...	8,313
...	...	...	21	...	...	...	...	8,269
...	...	...	22	...	...	...	...	8.296
120	...	...	21	...	560	8"	...	10,144
...	...	...	22	...	...	...		10,142
...	...	...	23	...	...	...	...	10,210
130	...	...	21	...	580	...	...	12,483
...	...	...	22	...	...	...	...	12,335
...	...	...	23	...	...	...	...	12,365
...	...	...	22	...	620		...	•12,574
...	7	...	20	...	580	...	...	12,662
...	...	...	21	...	...	...	...	12,409
...	...	...	22	...	...	...	...	12,476
...	8	...	20	...	...	...	...	12,[illegible]47
...	...	...	21	...	...			12,452
...	...	...	22	...	...	...	...	12,509
140	7	...	22	...	600	...	...	14,840
...	...	...	23	...	...	...	...	14,756
...	...	...	24	...	...	...	...	14,692
...	...	...	25	...	...	...	...	14,728
...	...	...	21	...	...	9"	...	14,634
...	...	...	22	...	...	...	...	14,571
...	...		23				...	14,734
...	...	D	25	...	...	8"	...	14,470
...	...	...	26	...	...	...	...	14,351
...	...	...	27	...	...	...	...	14,232
...	...	...	28	...	...	...	...	14,235
...	...	...	25	...	...	9"	...	•14,766
...	...	...	26	...	...	...	...	14,133
...	...	...	27	...	...	...	...	14,142
150	8	S	22	...	620	10"	...	16,830
...	...	...	23	...	...	...	...	16,792
...	...	...	24	...	...	...	...	16,808
...	...	D	24	...	...	...	...	16,161
...	...	...	25	...	...	...	...	16,125
...	...	...	26	...	...	...	...	16,141
160	...	S	24	1120	...	9"	...	17,200
...	...	...	25	...	...	...	...	17,222
...	...	...	23	...	...	10"	...	17,120
...	...	...	24	...	...	...	...	17.000
...	...	...	25	...	...	...	...	17,053
...	7	D	26	...	...	...	...	16,476
...	...	...	27	...	...	...	...	16,256
...	...	...	28	...	...	...	...	16,356
...	8	...	25	...	...	...	...	16,376
...	...	...	26	...	...	...	...	16,247
...	...	...	27	...	...	...	...	16,329
...	9	...	26	...	...	...	...	•16,932
170	...	S	25	...	650	...	...	20,249
...	...	...	26	...	...	...	...	20,158
...	...	...	27	...	...	...		20,443
...	...	D	27	...	...	...	...	19,229
...	...	...	28	...	...	...	...	19,162
...	...	...	29	...	...	...	...	19,149
...	...	...	30	...	...	...	H	•19,065
180	...	S	26	...	680	...	W	23,128
...	...	...	27	...	...	...	...	23,090
...	...	...	28	...	...	...	...	23,166
...	...	D	30	...	...	...	H	21,521
...	...	...	31	...	...	...	...	21,565
190	8	...	33	...	750	...	...	24,481
...	...	...	34	...	...	...	...	24,372
...	...	...	35	...	...	...	...	24,373
...	9	...	32	...	710	...	...	24,507
...	...	...	33	...	...	...	...	24,480
...	...	...	34	...	...	...	...	24,505
...	10	...	31	...	...	...	...	24,540
...	...	...	32	...	...	...	...	24,405
...	...	...	33	...	...	...	...	24,422
210	...	...	33	...	...	...	...	28,014
...	...	...	35	960	...	...	...	27,846
...	...	...	37	...	...	...	...	27,958
230	11	...	36	...	740	12"	...	33,953
...	...	...	38	...	...	...	...	33,957
...	...	...	40	...	...	...	...	34,365
260	13	...	38	...	780	...	...	46,290
...	...	...	40	...	...	...	...	46,129
...	...	...	42	...	...	...	...	46,248
300	15	...	42	900	900	...	...	‡65,424
...	...	...	44	...	...	...	...	65,219
...	...	...	46	...	...	...	...	65,550

• 20' clear Roadway Pony Trusses, Class A.
• 16' Clear Roadway, Class C, for this and following spans.

In designing the bridges from which Table I was prepared, the minimum depth was taken equal to sixteen and a half feet, which, because of the peculiar lower lateral system employed, corresponds to a clear headway of fourteen feet; the posts, when figured for either whole or half length, were considered to have both ends unhinged, and all sudden changes in cross-sections were avoided. For, instance, if, by decreasing the depth of a truss one foot, it were found advantageous to change to larger channels for chord and batter braces the change would not be made, as it would render the comparison useless: besides if the roadway or live load were slightly increased, the advisability of the change would no longer exist. For appearance the depths of channels in top chords and batter braces of the same structure are made equal, although sometimes a little material might be saved by making them different.

Comparison is made between bridges with sway bracing and those without; for when it is employed there is no need for brackets, unless light ones be put in for appearance, the total weight of iron not being affected to any extent by the change.

In double intersection bridges where the posts are figured for half length, light counters extend to the ends of the trusses, the least depth for this style of bridge being thirty feet. Spans below one hundred and sixty feet in length have stiffened bottom chords in the end panels, while those above do not.

As the actual differences in the total weight of iron were not affected thereby and in order to save time, no especial care was taken to see that the long spans were provided with proper stiffening; in fact, it is required by most of them. It has been shown lately in an editorial in the *American Engineer*, that, theoretically, most highway bridges require stiffened bottom chords throughout, but that practically they may be dispensed with in all but the first and second panels from the ends of the bridges, or even in the latter, as the joints, when properly laid, may be relied upon to take up the thrust after the dead load tension in the batter chords has been overcome by the wind pressure. The greatest length of span requiring stiffened end panels will decrease as the width and load increase, and increase as the ratio of depth of truss to panel length increases. It is not economical but usually necessary to stiffen end panels, so, if it be possible to legitimately do so and thus decrease the weight, the stiffening may be dispensed with, although it adds to the rigidity of the bridge when subjected to rapid travel.

The one case in which the economic depths found in this paper are liable to fail, is where, by decreasing the depth two or three feet, stiffened end panels may be avoided, thus making a less depth more economical; such cases, however, do not often occur. The writer hopes that after finishing his paper on "Dead Loads for American Highway Bridges" he will find time to write another upon "Lateral Systems for Iron Pratt Truss Highway Bridges," in which this subject of stiffened bottom chords will, among other things, be satisfactorily settled.

In Table I the first column gives the length of span, the second the number of panels, the third the style of intersection, *S denoting single and D double, the fourth the depth of truss* from centre to centre of chords, the fifth the live load, the sixth the dead load, the seventh the depth of channels used in top chords and batter braces, the eighth the figured length of

---

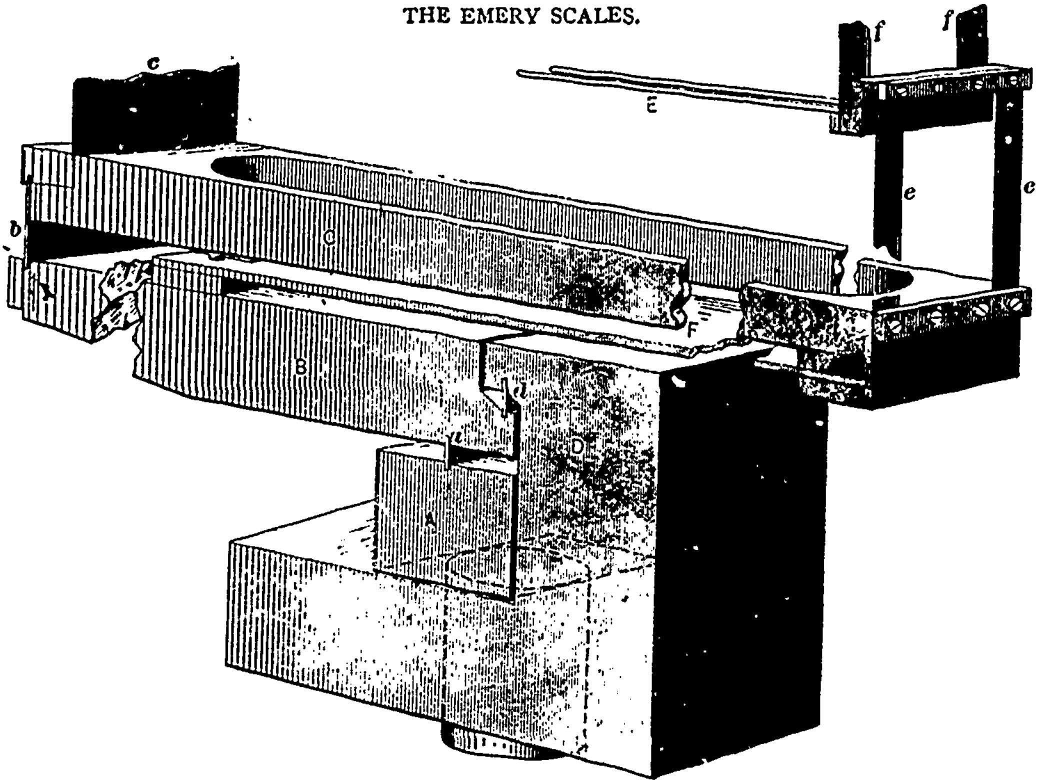
• Increased wt. for heavy joists.

• Light 9" Ls too small, therefore necessary to employ extra heavy ones.

•The non-economy in using 9 panels is apparent without further investigation.

‡Add 130 in. for extra details at centres of posts making total weight = 19,195.

THE EMERY SCALES.



Emery Scales and Testing Machines.—Fig. 1.—Levers and Plate Fulcrums.

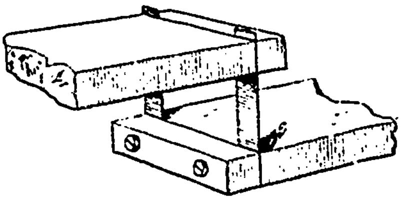


Fig. 2.—Clamping Suspension Fulcrums.

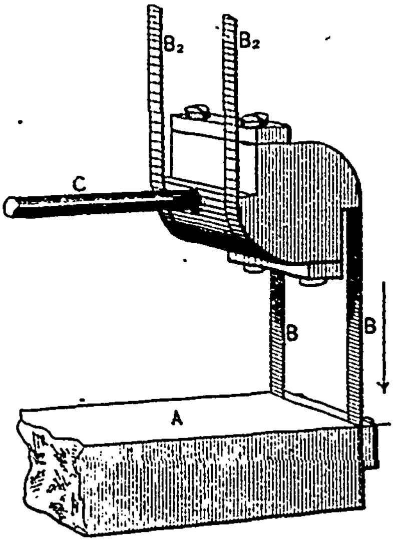
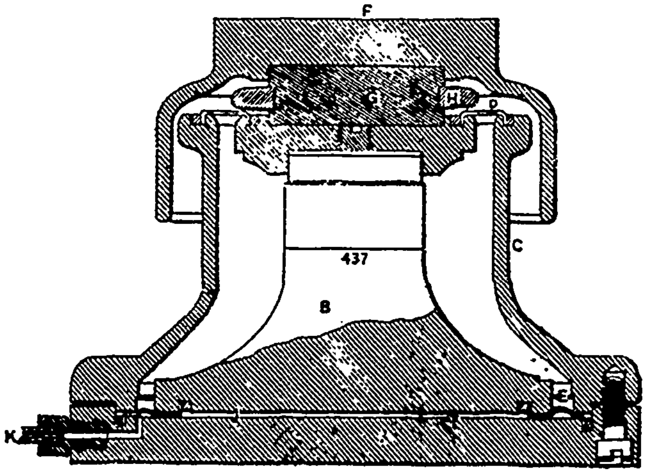
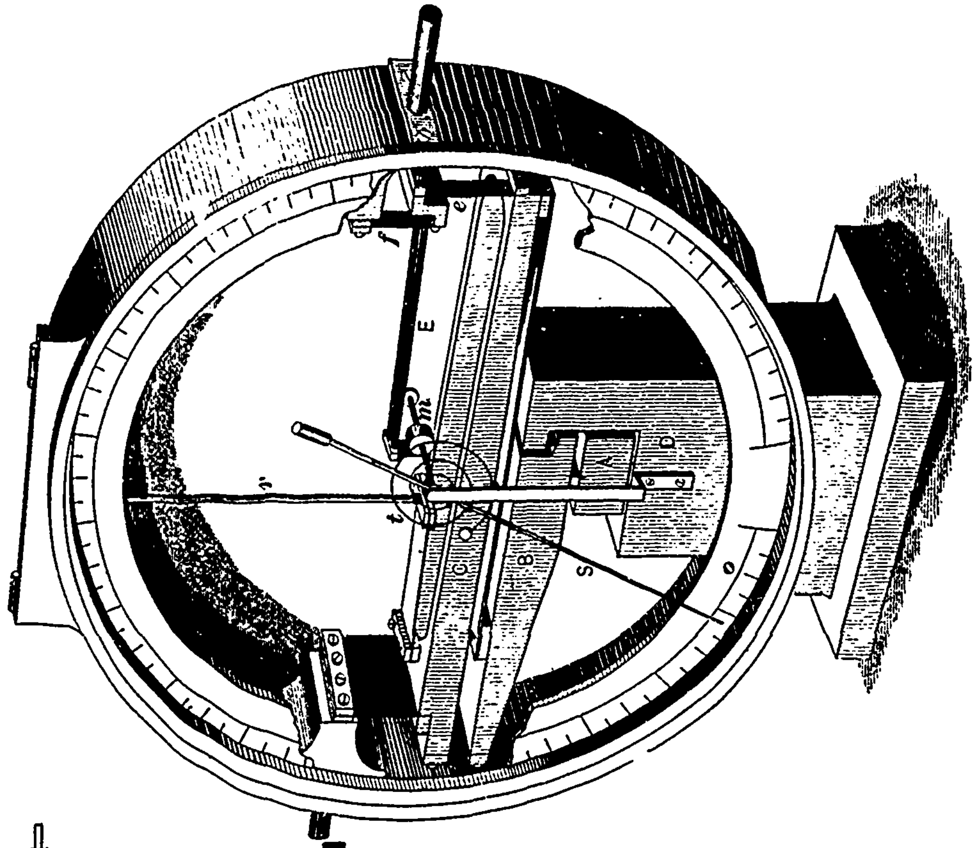


Fig. 3.—An Indicator-Rod and Fulcrums.

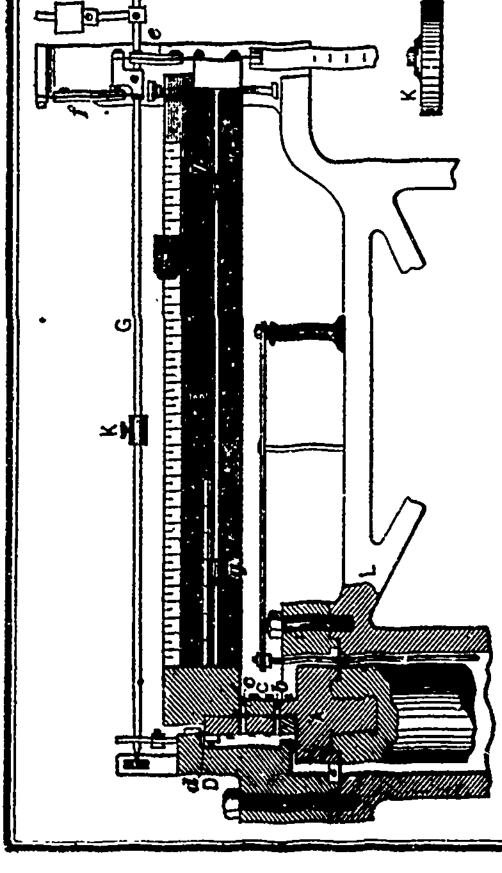


Emery Scales and Testing Machines.—Fig. 6.—Hydraulic Support.

THE EMERY SCALES.



Emery Scales and Testing Machines.—Fig. 4.—Hydraulic Gauge.



The Emery Testing Machine.—Fig. 5.—Beam for Platform Scale.

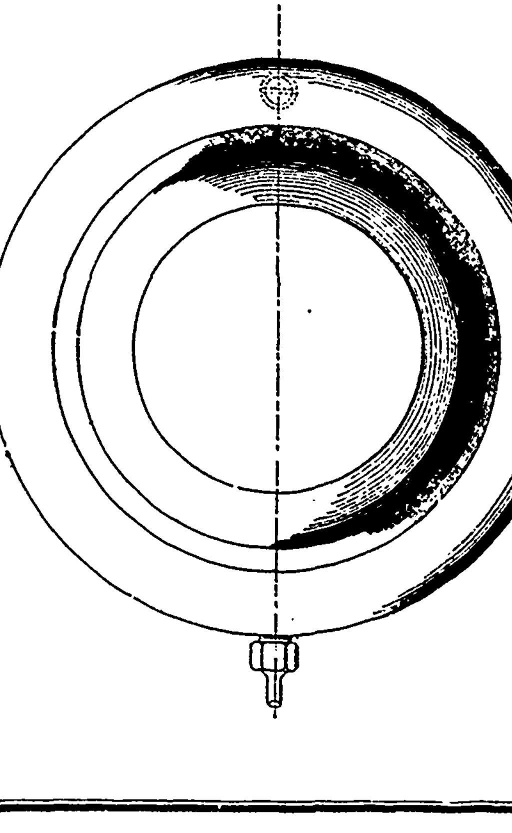


Fig. 7.—Top View of Hydraulic Support.

posts, *W* denoting whole and *H* half, the ninth the comparing weight for one truss, and the tenth, accompanying remarks.

An examination of the Table shows a reasonable regularity in the increase in economic depth , any variations that there may be, can be accounted for by some peculiar circumstances affecting the cases where they occur, so it will not be well to adhere to these depths in all cases with cast iron rigidity.

Thus in the case of the one hundred and forth foot span the economic depth, when eight inch channels are used, is twenty-four feet , and, when nine inch channels are used it is twenty-two feet, the actual weights of iron in both cases, taking into account the increased weight of details when nine-inch channels are used, being almost the same.

For the general case twenty-three feet would probably be the economic depth for the one hundred and forty foot span.

Again, in the case of the double intersection one hundred and fifty foot span, it was necessary to use exactly the same chord channels for a depth of twenty-six feet as for a depth of twenty-five feet, so the latter appears to be the economic depth, while, if the required channels could have been obtained, twenty-six feet would have been more economical. In preparing Tables III. and IV all these variations are corrected. It can be seen seen in general from Table I that, if the economic depth be calculated for any span, where the panel length is twenty feet or the nearest length below twenty feet, and is the economic depth for the same span but with one panel less be calculated, the latter will be found to exceed the former depth by one foot.

To ascertain in general the economic panel length, it will be sufficient to take a few cases and assume that what is proven for these will hold true for all the rest. The result may be easily predicted, viz . that long panels within reasonable limits are more economical than short ones. For instance, taking the cases of the one hundred and thirty and the one hundred and ninety foot spans, the former of which has been figured for six, seven and eight panels, and the latter for eight, nine and ten panels, there can be found, approximately the differences in the total weights of iron, without ascertaining these totals, by looking over the list of members given in "A System of Designing Highway Bridges," choosing those in which there will be variations in the weights, and calculating these variations.

There is thus found for the one hundred and thirty foot spans that 1,100 pound more iron are required for the seven than for the six panels, and about 1420 pounds more for the eight than for the seven panel. On the other hand there are about 2,400 more ft. b.m., of pine required for the six than for the seven panel, and about 500 ft. more for the seven than for the eight panel.

Now as 1,100 pounds of iron are usually worth more than 2,400 ft. of pine, and 1,420 pounds of iron more than 500 ft. of pine, it is evident, that for this case, the long panels are the most economical. Again in the case of the one hundred and ninety foot spans, there are about 2,500 pounds more iron required for the nine than for the eight panel, and about 1,430 pounds more for the ten than for the nine panel.

On the other hand the eight panel requires about 3,100 ft. more lumber than the nine panel, and the nine panel about 3,200 feet more than the ten panel. As before the total difference in cost is in favour of the long panels.

Again in the case of the double intersection one hundred and sixty foot spans, the great increase in truss iron, as indicated by the Table, for the nine panel bridge will alone show the want of economy in using panels less than twenty feet long.

There is another point to be considered, though, viz., that long joists cost a little more per M. than short ones ; so that, if in any particular case lumber were expensive and long pieces especially so, the shorter panels might be more economical. But it would in no case be advantageous to make the panel length less than eighteen feet, for, ordinarily, all lumber not exceeding this length costs the same per M.

It may then be concluded that in places where lumber is expensive it will not be well to make panels over twenty feet long, or in places where it is cheap to make them over twenty-four feet long, because timbers exceeding the latter length are not always easily procured. Then, too, in designing iron bridges, which are supposed to last indefinitely, or combination bridges, of which the iron-work will be used again after the timber will have decayed, it must be remembered that, as time goes on long timbers will become more and more expensive and less easily procured, even in timber districts ; so that panels exceeeding twenty feet should be employed very cautiously. For spans less than one hundred feet in length it is well for appearance not to use panels twenty feet long ; besides a four panel through bridge nearly always requires a stiffened bottom chord throughout, while a five panel one does not. From Table I. can be determined, by doubling the differences of the comparing weights, the saving of iron in using the double instead of the single intersection. Thus in the one hundred and forty foot span there is a saving of about 920 pounds of iron, in the one hundred and fifty foot about 1,330 pounds, in the one hundred and sixty foot about 1,500 pounds, in the one hundred and seventy foot about 2,020 pounds, and in the one hundred and eighty foot about 3,140 pounds.

The principal objections to the use of the double intersection for short spans are, that as the rods are long and slender they will vibrate more than the shorter and larger ones of the single intersection ; any flaw in a small rod will have a proportionally greater injurious effect than the same sized flaw in a larger one ; long and slender rods are difficult to transport and are liable to become twisted and bent (this objection can be partially removed by halving them and attaching to a central pin passing through the post) , and as the posts are lighter they will spring more under the shock of rapidly-moving loads.

For these reasons the double intersection one hundred and forty foot span is decidedly inferior to the single intersection, while in the one hundred and eighty foot span, these objections applying with a great deal less force, the increased weight of the single intersection would render it so much more expansive (about $1.00 per foot) that the double intersection would be preferable. Now between these two lengths there is one at which it would be advisable to begin to use the double intersection.

In the writer's opinion it is for this case one hundred and seventy feet.

As the width of roadway and the live load increase and as the intensities of working stresses decrease, this limit will be lowered. Table II. gives the limiting lengths which the writer would recommend.

Table II.—Limiting Lengths

Clear Roadway.	*Class A.*	*Class B.*	*Class C.*
14 in	165 in	175 in.	180 in.
16 "	155 "	165 "	170 "
18 "	150 "	160 "	165 "
20 "	145 "	155 "	160 "
22 "	140 "	150 "	155 "
24 "	140 "	145 "	150 "

It is to be noticed that the common idea among highway bridge builders, that a double intersection bridge should for economy's sake have more panels than a single intersection bridge of the same span and loading, is incorrect.

In view of the previous considerations, Tables III and IV have been prepared, the former for districts where lumber is comparatively expensive, the latter for those in which it is very cheap. They treat of through bridges only, commencing with eighty foot spans, for which the economic depth is the least allowable.

(*To be Continued.*)

◆

BLOWING OUT BOILERS.—Blowing out boilers should be done at least once a month, except in the very rare instances in which water is used that will not form a scale. The boiler should not be blown out until the furnace is quite cold, as the heat retained in the walls is likely to injure an empty boiler directly by overheating the plates, and indirectly by hardening the scale within the boiler. Bad effects are likely to follow when a boiler is emptied of its water before the side walls have become cool; but great injury is likely to result when cold water is pumped into an empty boiler heated in this manner. The unequal construction of the boiler is likely to produce leaky seams in the shell and to loosen the tubes and stays. It is a better plan to allow the boiler to remain empty until it is quite cold, or sufficiently reduced in temperature to permit its being filled without injury. Many boilers of good material and workmanship have been ruined by the neglect of this simple precaution.

EMERY SCALES AND TESTING MACHINES.

For illustrations see pages 364, 366, 368, 369 and 372.

There are few of our readers, and, in fact, few professional men generally in the country, who are not familiar with the remarkable work performed by the Watertown testing machine. That after recording hundreds of thousands of pounds it will show the strain which breaks a horse-hair, or, when testing to hundreds of thousands of pounds, read to a fraction of its load as small as that of an analytical balance, are facts which have caused the greatest wonderment and curiosity in regard to the remarkable mechanism by which these results have been accomplished. It is evident to those who are familiar with the apparatus and the way it has been developed that a revolution in machinery for weighing is at hand. Abandoning as utterly useless the knife edge, Mr. Emery struck out upon what is an entirely new line. From the weight to the recording index he undertook the problem of transferring the pressure by itself, and practically without motion. He undertook to do this without introducing back lash or the wear of pivots or knife edges. The importance of this we can the better understand when we refer to the work of some of the best *analytical balances of the country. One of these, exhibited at* the Centennial, with one pound in each scale will turn with 1-500,000 of its load. The finest assay scales by the same maker with one gram in the pan will turn with 1-10 milligram. or 1-10,000 of the load. Such a scale, on account of the great amount of motion and the fact that a considerable mass must be put into motion by an exceedingly small force, is excessively slow in coming to rest. On one occasion a gentleman used a whole day in weighing a single pound seven times. The maximum difference between the greatest and the least weight obtained was 1-150,000 part of the load. When on the same *scale the attempt was made to weigh two pounds, nine weighings* required more than a day for their accomplishment, on account of the great length of time necessary for balancing the scale with such a load.

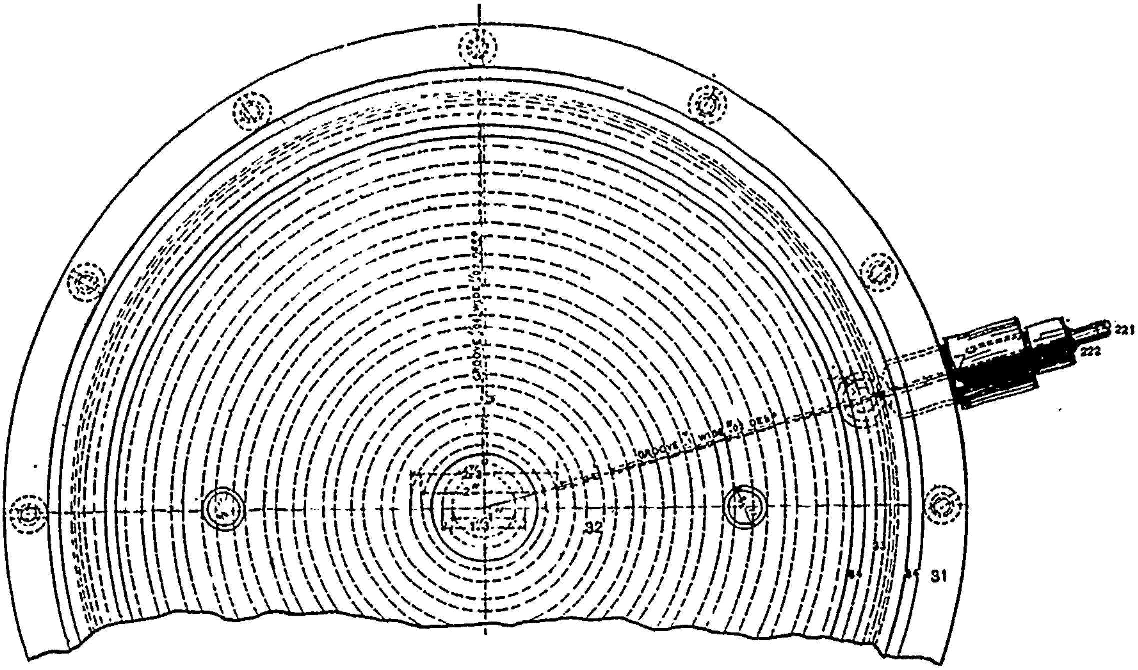
Scales of this sort may be said to be excessively impatient, if we may be permitted the term, of overweight, or a weight which exceeds that for which it was intended by the makers, and are always injured by any excess of this weight becoming sluggish when it is placed in the pan and having their knife edges ruined. In fact, the ordinary load soon destroys, by wear and crushing, the sharpness of the knife edge, and the scales deteriorate sensibly and rapidly by ordinary use. They are also sensitive to dirt and to rusting. If one of these delicate scales be overloaded the knife edges lose their shape and are crushed into forms approaching circles. Not only, then are the edges crushed and worn into rounded forms, but the fulcrum distances are by this means changed, and consequently the accuracy of the scale is lost. The fine scales for weighing silk are intended to take 1 pound, and are sensitive to one seven thousandths part of the load — that is, with 1 pound in the pan — and they will indicate 1 grain. Disbelieving the manufacturer's statement that 5 pounds would ruin this scale, a friend of ours bought one, and after testing it well within its capacity attempted to weigh 5 pounds with it. After this weight had been put on he found that although the scale still moved with a single gram, yet it would not weigh a pound twice alike to within a gram. In other words, the overloading had not only destroyed its sensitiveness, but had ruined it for accuracy by changing the fulcrum distance.

In contrast with this we take the scale beam of the testing machine at the Watertown Arsenal, which was used before the machine was finished as an ordinary beam scale by the prolongation of its weight beam. When rigged as a balance 100 pounds was put in the pan and weighed seven times, and the greatest difference between the maximum and minimum weights obtained was one part in 1,750,000. A 200-pound standard was afterward weighed nine times in succession. Here the greatest difference between the maximum and minimum weighings was one part in 2,350,000. The sensitiveness of the scale when thus used with the 200 pound load, stated according to the ordinary method, was equivalent to the scale turning with one fourteen-millionths part of its load. In other words, a scale beam with its fulcrum capable of sustaining without injury a load of 4000 pounds has been made more sensitive than the finest analytical balances yet made in this or any other country. Indeed, the same beam, if we understand Mr. Emery's statement correctly, might be used for analytical work with a far greater perfection than is attainable with the ordinary balances inside of their range of accuracy.

To understand how such accuracy is possible, we must first get an idea of the nature of the fulcrums used and the levers employed in Mr. Emery's scales, gauges and dynamometers. The second step will be the means used for transmitting enormous loads on heavy scales or the strains of large testing machines to the weighing apparatus. Lastly will follow a description of the methods of balancing the beams and reading the loads. Figs. 1, 2 and 3 illustrate the arrangement of these fulcrums and levers as applied to a pressure gauge or weighing dynamometer. They consist of thin, flat pieces of steel of suitable widths and lengths, forced into grooves or held between columns. In Fig. 1, *a*, *d*, *b*, *c* represent these fulcrums made of flat pieces of steel, and *e* and *f* show similar fulcrums where two flat strips of steel take the place of a wide one. The method of connection and the variations of the bearing are shown in Figs. 2 and 3, which are enlarged details of certain parts of special scales or gauges. In the case of the gauge or weighing dynamometer, A (Fig. 1) shows the pressure column, consisting of a cylinder widening into the rectangular head A, in which is planed a groove to receive the first fulcrum *a*, into which it is pressed, and which is also pressed into similar grooves at its upper end in the first lever B. A fixed fulcrum, *d*, is pressed at its lower end into the lever B, and its upper *end into a groove* in the fulcrum block D. The third fulcrum *b* is shown clamped at the outer end by a clamping-plate, and its upper end is pressed into the lever C, or into a block attached to the lever C. The same block clamps the fourth fulcrum *c* to its lever C. The fulcrums *d* and *c* are both fixed, which causes the lever B to move upward at its upper outer end, as shown by the arrow, and the lever C to move downward at the same time. The strain on the first four fulcrums *a*, *d*, *b*, *c*, is compression, while that on the fulcrum *e* and *f* is tension. These fulcrums are all of tempered plate steel, and are often gold plated, to prevent rusting. In the illustration *shown, the pressure on the block A may amount to 4000 or* 5000 pounds, and the thickness of the first and second fulcrums is from .04 to 05 inch and the third and fourth fulcrums *b* and *c*, .02 inch. The width of these is 4 inches, and the exposure or portion left free between the different levers is about .2 inch for *a* and *d* and .8 inch for *b* and 2 inches for *c*, the loads on the latter being reduced to about 400 pounds through the lever B. Fig. 1 is an enlarged view of the pressure gauge shown in Fig. 4. This hydraulic gauge is for measuring loads of 7500 pounds to the square inch. Surprising as it seems at first sight, the motion of these levers, though firmly connected in this way and transmitting strain without the possibility of backlash, is practically frictionless.

A further application of this form of fulcrum is shown in Fig. 5, where the heavy lines *b*, *c* and *d* represent pieces which, as we have said, take the place of the ordinary knife edges. Here the beam B receives its load from the pressure column A through the fulcrums *b* and *c*. These are connected together by the block *c*, for the purpose of introducing or allowing for a certain amount of lateral motion around the center of motion in the fulcrum *b*. The beam is prevented from yielding bodily to the stress by the fulcrum *d*, held in the fulcrum block D.

THE EMERY SCALES.



Emery Scales and Testing Machines.—Fig. 8.—Plan of Diaphragm.

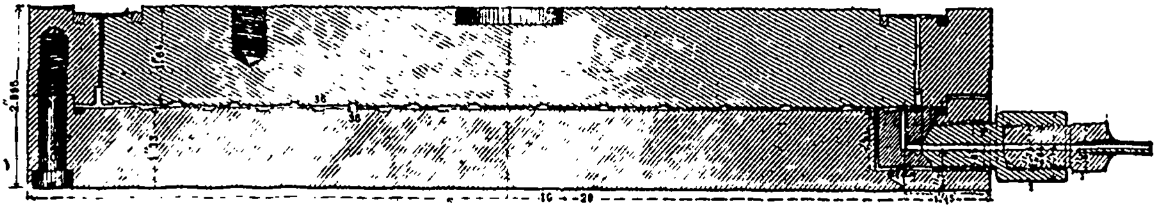


Fig. 9.—Section of Diaphragm and Plates.

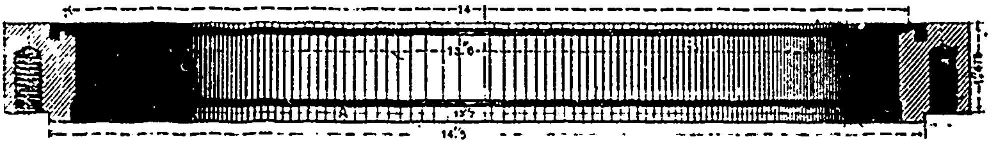


Fig. 10.—Section of Surrounding Ring.

Fig. 11.—Supporting Plate for Diaphragm.

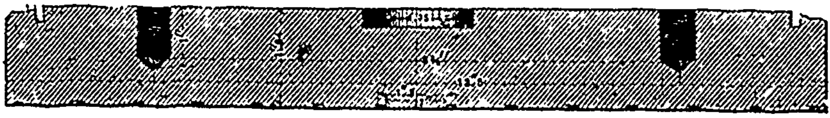


Fig. 12.—Plate Resting on Top of Diaphragm.

THE EMERY SCALES.

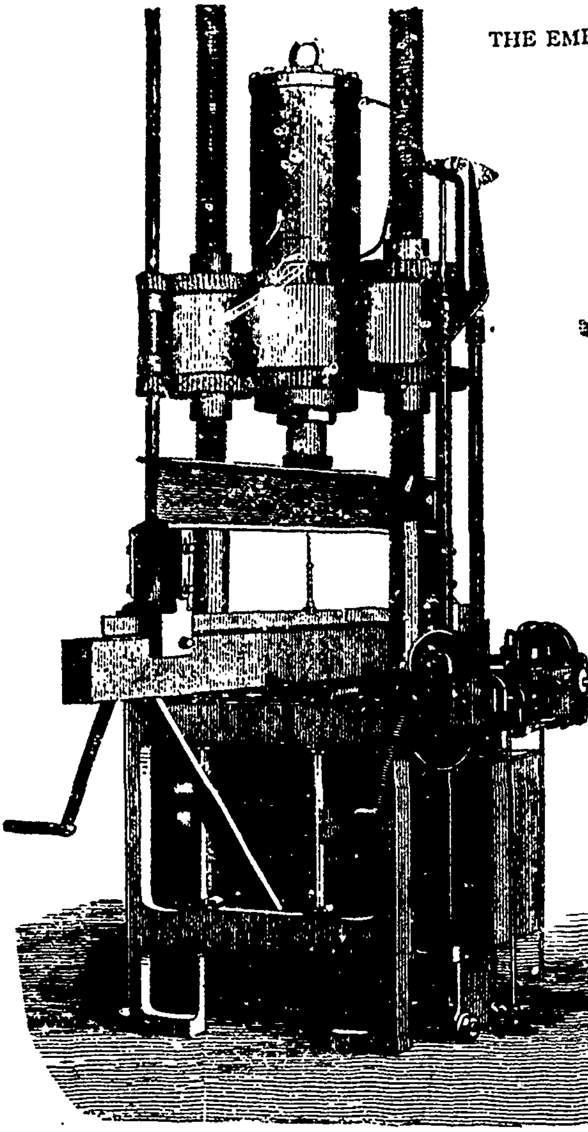


Fig.14.—Elevation of the Machine.

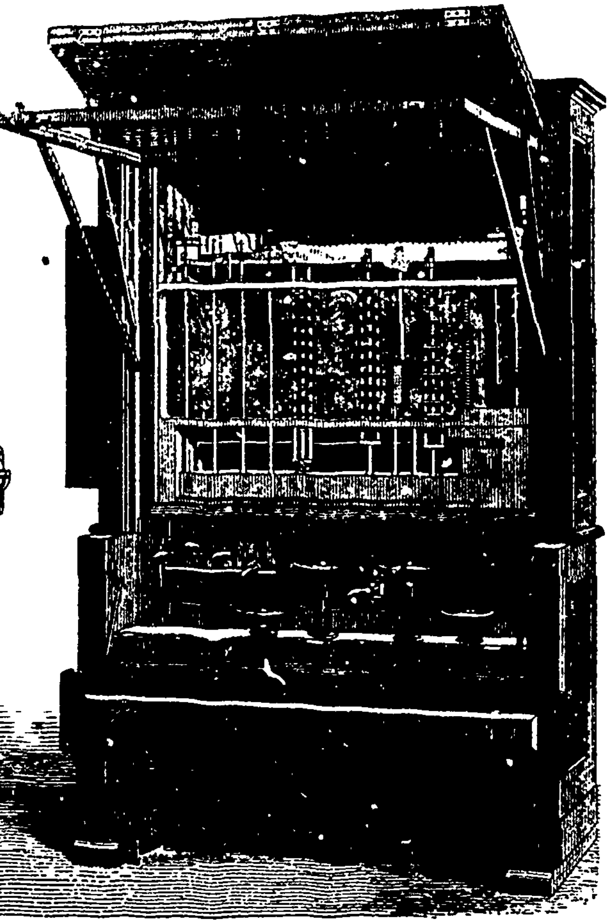


Fig.15.—Scale Beam and Case.

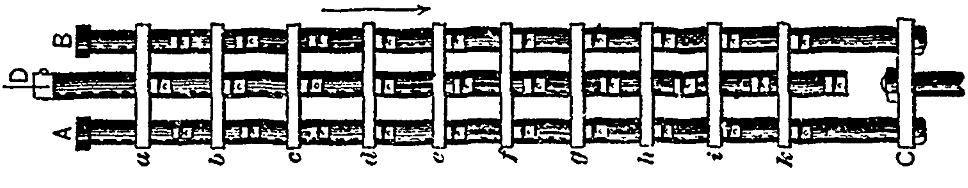


FIG. 17.

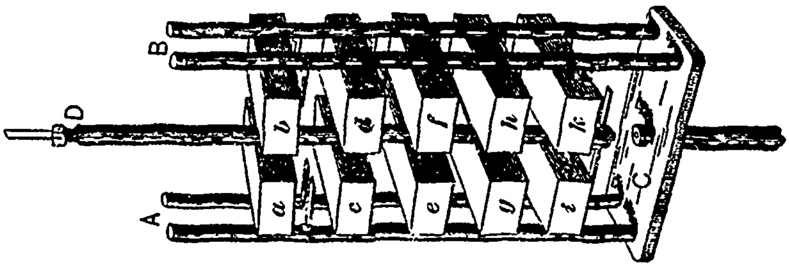


FIG. 18.

At its outward end moves up or down, motion is transmitted to the indicator rod G by means of the two suspension fulcrums E and F. Their action on the point of support of the indicator rod G is similar to what is shown in Fig. 3, which is, however, from another piece of apparatus, and this construction is intended to permit a large range of motion. We may here point out a decided difference in the two constructions. In Fig. 5 the bending of the fulcrums c and *f* is directly as the angular motion of the indicator rod G, while in Fig. 3 the bending of the fulcrums B2 and B2 is constant, no matter what the angular motion of the indicator rod C may be. This construction is often employed by Mr. Emery where it is necessary to hang one beam from another, and where it is desirable to obtain great angular motion. Fig. 2 illustrates the method of clamping suspension fulcrums similar to E or F in Fig. 5. It must be observed, however, that in Fig. 5, the fulcrums being very long and delicate, it is found desirable to protect the central portions, and this is done by a pair of clamping plates. From the end of the beam B a poise rod I and weight plate K are hung by a pair of thin plates, which illustrate another application of this kind of fulcrum, giving all the lateral motion and flexibility which is needed, and preserving the exact fulcrum distance without wear or friction. The thickness of metal used for supporting the beam is very slight, and it would surprise most engineers to know that a piece of metal one twentieth inch thick and 5 or 6 inches long, and perhaps 2 inches "exposure," or portion not in, but between, the groove, will carry many thousand pounds without suspicion of buckling or springing. For those bearings or primary fulcrums which are to take the *heaviest pressures in the large gauge, the strips of metal are of* the finest spring steel, one twentieth inch in thickness and 4 inches in width, and are pressed into their grooves with a load of 18,000 pounds, though in use they would receive 4000 or 5000 pounds only. The greater portion of this metal is, as the reader will see from the different drawings, firmly fixed in slots cuting the beams. When tensile strain is to come upon these fulcrums, of course a much thinner spring and a longer one is possible, and, with the construction shown in Fig. 3, the angular motion can then be made as great as may be desired, and with the other construction it can usually be made as great as is necessary. In many constructions the thickness of these fulcrums for compression is reduced to as little as one five-thousandth inch, and for tension to as little as fifteen ten-thousandths inch. By increasing the width, the amount of strength obtained can be raised indefinitely and any load whatever supported.

Fig 1 shows the system of levers adopted for the pressure guage in Fig. 4, where the motion between the pressure column A and the point of the indicator S is multiplied more than 60,000 times, so that a movement of the column of less than 1-1000th inch will give the 60 inches reading at the point of the needle where the arc is graduated and divided into a thousand parts, each graduation being made by actual test. This, we think, is the greatest multiplication by levers in so small a space of which we have any knowledge. The graduation of the dial by actual test eliminates several sources of error which would theoretically be found in employing the usual methods for graduation. The method of operation of these levers and fulcrums may be understood by reference to Fig. 1, where the pressure communicated to the fulcrum block A is transmitted by the fulcrum to the lever B; about 1-12th of this is transferred to the outer end of the beam and to the fulcrum B. This in turn is communicated to the lever C, which at its outer end transmits in a downward direction to the resisting spring F about 1-30th of the load which it receives. The spring F uses up by bending the entire force transmitted to it. The motion through the fulcrums *e e* and *f f* is then transmitted through the rods E (see Fig. 4) to the indicator-rod S, and thus indicates the entire amount of bending which has taken place when the bending of the spring has brought it into equilibrium.

Briefly stated, the method of measuring the load in large platform scales is to transmit a portion of the downward pressure of the load to the weighing mechanism. The load may be supposed to be supported on a series of diaphragms, which, through a system of pipes, by hydraulic pressure transmit a portion of this pressure to other similar diaphragms, where the resultant pressure is measured by suitable apparatus. In other words, the principle of the hydraulic press is introduced into the weighing apparatus as a transmitting mechanism, but the construction is such as to make the apparatus frictionless.

Fig. 6 shows what is called a hydraulic support, and is one of the members which primarily receive the load on a large platform scale. It consists of a base A, in which is a circular chamber, usually 25-1000th inch depth, which is filled with a liquid on which sits the pressure column B contained in the protecting case C, to which it is secured against vertical motion at the top by the diaphragm D, end at the bottom by the diaphragm E, the latter being the pressure diaphragm, which prevents the liquid from flowing out of its chamber when pressed by the load put upon the pressure support. The diaphragm D not only centers and retains the upper end of the column B in the support but seals the chamber around it from dirt, &c., this chamber being merely filled with air. A bell-shaped cap F, receives the load from the platform and protects the diaphragm D from injury. It transmits the load from the platform to the pressure column B through the rubber block G, which does not act like a spring, as it is confined by the ring H, but serves to transmit the load to the column B, and at the same time permit lateral movement and tipping of the cap F caused by any bending of the platform. The liquid contained in the chamber I communicates through the pipe K, usually 5 100ths or 6-100ths inch in diameter, to a small sealed pressure chamber within the weighing mechanism.

This diaphragm is of large size, held firmly between surfaces, and has a total motion in, for example, a 50 ton testing machine of 1-400 000th inch. For 1 pound the change or motion is 1-40,000,000th inch. The whole range of the first diaphragm is 1-1,00,000 inch. The indicating arm, equivalent to B in Fig 5, moves 1-100th inch for each pound, and has a total motion in that particular case above and below zero *amounting to 1 6 10th inches. The main diaphragm, in mov*ing displaces a column of water, which acts upon another or secondary diaphragm receiving only a small fraction of the pressure upon the primary one. In this way very intense strains are, by the simple difference in the size of the diaphragms, reduced to come easily within the range of the scale beams to manage. In track scales and other scales where large platforms have to be supported there are usually a number of primary diaphragms, which are connected and transmit pressure to a series of smaller ones, which in turn act as a unit of the real secondary diaphragm which actuates the beam. The possibility, then, of reducing the weight to be measured at one or two steps to an amount which can easily be handled is an immense advantage, and the fact that this reduction, instead of being made by means of beams, is accomplished by a fluid in small pipes, is a very great advantage. Practically, it seems that there would be no difficulty in placing the platform 5, 10 or 50,000 yards away from the beam.

To give an idea of the actual mechanism of the diaphragms upon which the pressure comes and the peculiar arrangements necessary in order to eliminate friction, the reader will refer to Figs. 8 to 12. Fig. 8 is a top view of a diaphragm and the plates which support it. The diaphragm as used here may be described as essentially a flat metallic bag of circular form. In Fig. 9 it is seen in section beneath the part No. 32. The circular grooves are formed in the plate and in the diaphragm itself, or, rather, we should say the two diaphragms, and are essential features. The plate 32 takes the weight which is resisted by the liquid inclosed between the diaphragms. There is a tendency to force it out through the connection 221, shown on a larger scale in Fig. 13, this tendency to displacement varying with the load. Fig. 12 is the plate uncovered to show its form. In order to hold this plate in place and prevent it from having any side motion, and consequent friction, a thin annular diaphragm connects it with the ring 31, which is also shown in Fig. 10. This diaphragm 33 is shown on a large scale in Fig. 13, 34, 34 are the rings of solder which hold it in place. Any pressure which is brought to bear upon the plate 32 will, of course, be transmitted to the fluid inclosed beneath it, and this pressure will at once be transmitted through the connecting-pipes. By using a diaphragm of a smaller diameter, the pressure may be reduced to practically any desired extent. Though there may be 100,000 pounds on the large diaphragm, it is not necessary to have on the receiving diaphragm a load any larger than can be conveniently handled. The amount of reduction is, of course, determined by the ratio of area of the primary and secondary diaphragms. If, as in the case illustrated, the first diaphragm has a diameter of 13 inches, the area will be, say, 132 square inches, and if the receiving or secondary diaphragm be 4 inches in diameter, the pressure will be reduced approximately to one-tenth of the original amount; hence, by choosing proper ratio of areas, the pressure to be dealt with is entirely within control. The importance of this point can hardly be overestimated. In Fig. 13 one of the minor details of the system is shown, which, from its wide application in hydraulic work, is worth careful attention. In order to make tight joints, it is necessary to exercise a great deal of care, and one of the greatest difficulties in hydraulic work has been the difficulty of having perfect fittings. Here the trouble with joints, &c., is avoided by a simple form of plug or nozzle. A very small portion of the extreme point of a hemispherical plug is flattened into a conical form, and this takes a bearing at the extreme point on a conical seat. Of course, the pressure within the tube tends to expand the metal and increase the tightness of the joint. The metal is here condensed to the greatest possible degree by hammering. The area of the pipe being very small, the pressure to be resisted by the screw thread is light, and there is no necessity for accurate fitting. Fig. 13 shows this part of the apparatus the full size. The actual pressure to be reduced by the screw threads is merely nominal, and tight joints are obtainable with very small wrenches and a merely nominal pressure.

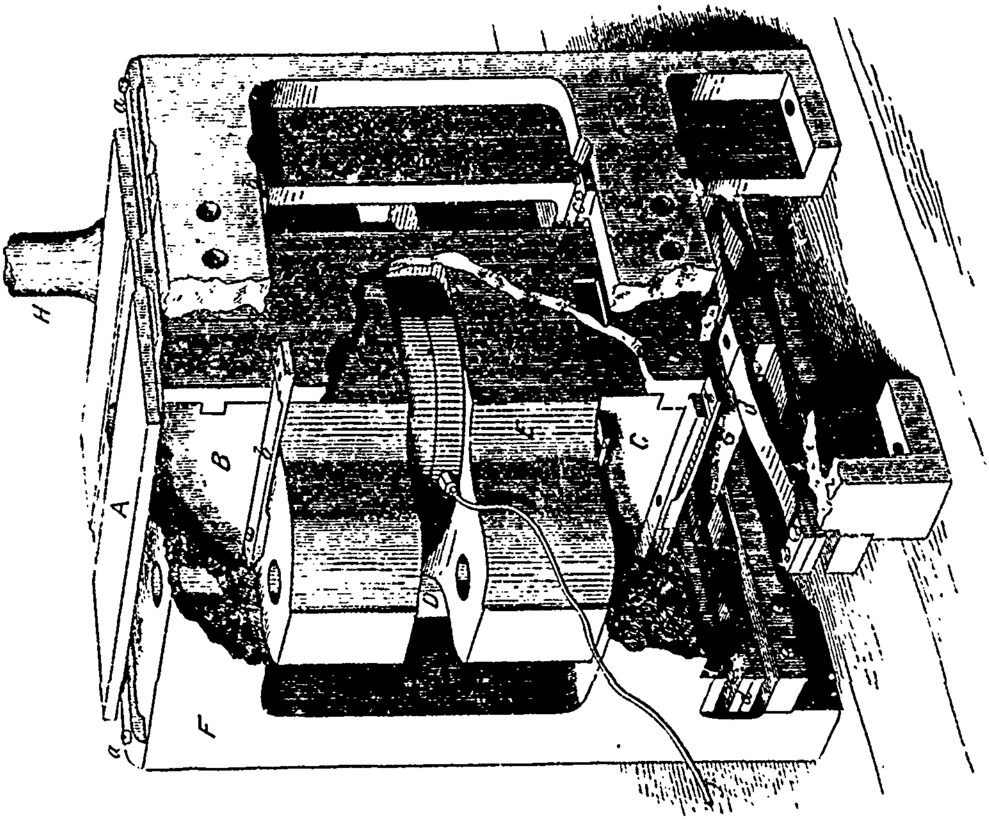
We shall now attempt to shew how a system of diaphragms can be applied to the weighing of the work of a testing machine, what means the designer has adopted to obtain a machine entirely free from back-lash when the specimen breaks. As shown in Fig. 14, it will be seen that the apparatus consists *of two parts. The first is the machinery for putting strain* upon the specimen, whether of compression or tension. In the engraving the machine is shown exerting a transverse strain on an I beam. In its essential features this apparatus consists of two screws carrying a straining beam, to which an hydraulic cylinder is attached. This cylinder furnishes the power for compression or extension. These screws are attached to a frame in which a pair of beams are placed to furnish the abutments for resisting the power. Whether the strain is tensile or compressive, it results in compressing the liquid in the hydraulic support between these beams, which constitute alternately the platform and bed of the scale. The second part of the apparatus of the weighing mechanism comprises a system of levers and a scale beam with suitable weights, and a pressure column with its diaphragms, to which the pressure exerted in the testing machine is transferred by a suitable tube. The liquid in the support between the beams, being compressed, is forced against the pressure diaphragm of the pressure column. The amount of force exerted here is then weighed, and the indication read from the scale beam and the pointer which is attached to it. The reader should bear in mind carefully the distinction between the two pieces of apparatus. One is in and of itself essentially for testing. It gives no indications of the amount of strain applied, and is a perfectly independent and disconnected apparatus. The other is an indicating mechanism, and might be adjusted to a *platform* scale, a *weighing* lock, a track scale, or, in fact, to a thousand and one other uses if necessary, its office being solely to register or indicate the amount of force exerted upon the system of levers which it contains. Although resembling to a certain extent the ordinary scale beam, it differs not only in the nature of its connections, but also in the method of putting on and taking off its weights. This feature alone is entirely different from anything of which we have any account, and adds very materially to the ease and speed of weighing. One of the features which not only in chemical, but also in large balances, is inherent in Mr. Emery's system of weighing, is the fact that the motion of the load is so small and the consequent momentum so insignificant that the beam or pointer can come to rest quickly without a long series of vibrations on each side of the zero.

In order to enable the reader to understand the construction of the apparatus, we have had a drawing made of the base of the machine and framework, with portions broken away to show the more important features. Bearing in mind that whether the strains be those of tension or compression — that is, whether in an upward or downward direction — they must result in compressing the liquid in the pressure support, the reader is prepared to understand the method of operation. The resistance, or the final abutment, is found in the frame F, which is of cast iron and very heavy. This frame surrounds the two beams E E, which constitute the bed and platform of the scale, and between which is placed the hydraulic pressure support. When the strain takes an upward direction these pieces are forced against the upper member of the frame. When the pressure is downward they rest on the lower portion of this frame. They have between them, in the pressure support, a pair of diaphragms inclosing a quantity of fluid, which, by means of the slender tube *f*, communicates with the pressure column of the weighing apparatus. These pieces E E are surrounded by a yoke, B D C D, in which they are perfectly free and with which they have no rigid connection. The strain of the load is taken by this outside yoke entirely, and through it communicated to the abutment pieces E E. These two pieces, with the diaphragm between them and its inclosing rings, are finished to such a thickness that they just fill the space between the two members of the frame to within, say, 5/1000 inch. This is the maximum amount of motion which is permitted. Having this arrangement of yoke and abutment pieces, it becomes necessary to hold it in position and prevent it from any lateral motion, and at the same time allow it perfect freedom in a vertical direction. This is accomplished by a most ingenious modification of the flexible plate or metal fulcrums. For example, the upper beam E is held and supported in position and prevented from side motion by the thin bars *b b*. The vertical motion is so small that the elasticity of these spring bars *b b* allows it to rise and fall with practically no friction.

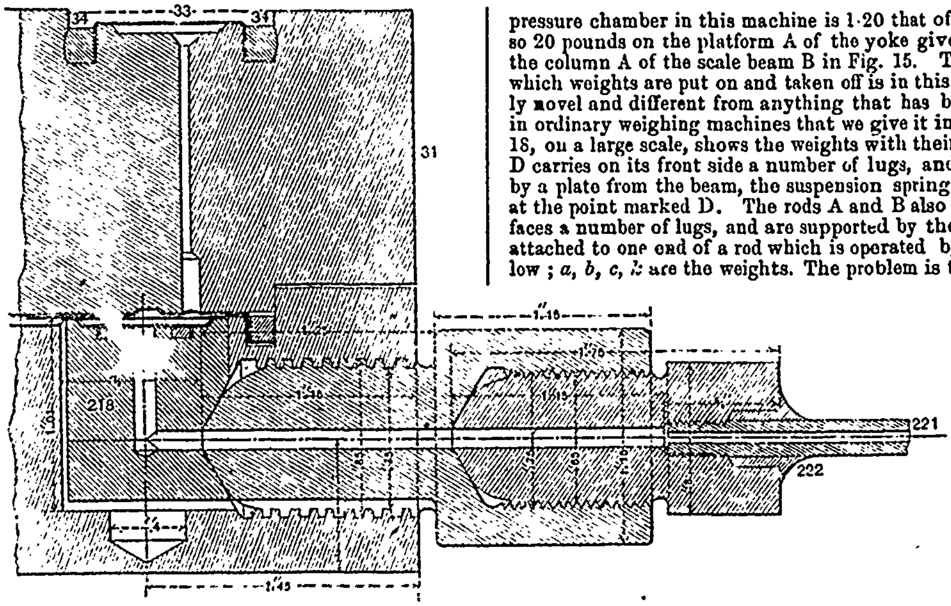
Similar flexible bars *c c*, support and fix in position the lower scale beam E against horizontal motion and allow freedom of motion vertically. The yoke is in like manner firmly fixed against horizontal motion at its top and bottom by four pairs of spring plates, two of which, *a a* and *a' a'*, at the top, are attached at right angles to each other to the upper beam *A B of the yoke and to the frame F, while the other two pairs* at the bottom *e e* and *e' e'*, also at right angles to each other, are [illegible] to the lower beam C of the yoke, and to the frame F. They allow perfect freedom in a vertical direction, while compelling the whole movable portion to work in a vertical line. A beam, G, is bolted to the bottom beam C of the yoke, and has its two ends extended between two pairs of initial load springs marked *d d*. The yoke B C D D and its contained scale beams E E being suspended in the air by the six pairs of fixing springs, as before mentioned, is now carried firmly against the beam E E by the full pressure of the load springs *d d* by means of two pairs of screws not here shown, one pair of screws acting to apply the load of these springs *d d* in an upward direction, and the other in a downward direction. When these springs are made to bear upward against G, the yoke is resting against the lower scale beam E, transmitting the load of the springs *d d* through the pressure support to the upper beam E, which now becomes the bed of the scale, with its outer ends resting against the frame F at the top, while the lower beam E acts as a free platform, and the scale is then balanced ready for use with strains or tension. If strains of compression or transverse loads are desired, the load springs *d d* are made to act downward on the beam G, the upper beam E now acting as the free platform, and the lower beam E as the bed of the scale. The acting area of the diaphragm in this *apparatus*, where a strain of 75 tons is to be exerted, is 13.6 inches in diameter.

As shown in Fig. 14, the testing machine is arranged for transverse strains. This is accomplished by putting a heavy bar across the table A, which carries at its two ends suitable supports with hemispherical bearings on which the specimen rests. The outer ends of these bars are supported by braces, one of which is shown in Fig. 14. The lower ends of these braces enter the slot shown near the base of D in Fig. 16. Immediately under the ram is shown a gauge for reading the deflection. The cross-head which carries the hydraulic ram is arranged in a very neat, but somewhat peculiar, manner. It is carried by two screws, the nuts of which have, both above and below, a pair of gear-wheels. A pair of intermediate gears transmit the motion from one to the other, and the whole is moved up and down by means of a crank at the left hand of the machine. This crank, through a pair of bevels gears, works the vertical shaft on the left hand side with its two pinions, thus revolving the nuts. The shaft is provided with the usual slot and feather. This makes the matter of adjustment for different length of specimens comparatively easy, and, at the same time, simple. The cylinder is a double-acting one, and is connected with the force pump by means of two telescopic tubes, shown at the right hand side, and connecting with the cylinder itself by small bent copper pipes. These telescopic tubes are arranged in such a way that no changes in the connections are needed in any part of the stroke. For extension a peculiar form of jaw screws into the bottom of the piston rod or ram, and also into a hole in the beam A B, Fig. 16. The weighing mechanism itself consists of a weight beam, somewhat similar to that shown in Fig. 4, with its indicator rod and a series of suspension rods for carrying weights. This beam in the scale shown is not connected directly to a

THE EMERY SCALES.



The Emery Testing Machine.—Fig. 16.—The Base Frame and Abutments.



Emery Scales and Testing Machines.—Fig. 13.—Details of Diaphragm and Connections.

pressure column, but is moved by a large steel beam 2.5 inches deep by 10 inches in width, pivoted with plate fulcrums and moved by a pressure column shown at A in Fig. 15. Just above the block A is shown the case containing the small pressure chamber which is connected with that in the support between the scale beams E E. The acting area of this small pressure chamber in this machine is 1·20 that of the large one, so 20 pounds on the platform A of the yoke gives 1 pound on the column A of the scale beam B in Fig. 15. The method by which weights are put on and taken off is in this case so entirely novel and different from anything that has been employed in ordinary weighing machines that we give it in detail. Fig. 18, on a large scale, shows the weights with their rod. The rod D carries on its front side a number of lugs, and is supported by a plate from the beam, the suspension spring being shown at the point marked D. The rods A and B also carry on their faces a number of lugs, and are supported by the cross-head C attached to one end of a rod which is operated by a lever below; *a*, *b*, *c*, *k* are the weights. The problem is to successively throw these weights upon the beam. This is accomplished by a downward movement of the rods A B. The lugs not being evenly spaced, this downward motion brings the top weight A in contact with the uppermost lug on the rod D. If the motion is continued, B is next dropped on the rod, and C follows. In the engraving, *a*, *b*, *c* have already been left by the down-

FIG. 12—1. Diagram showing path of rays when viewing an object at an easy distance.
2. Object brought close to eye when the lens L is required to assist the eye-lens to observe the image when the object is magnified.

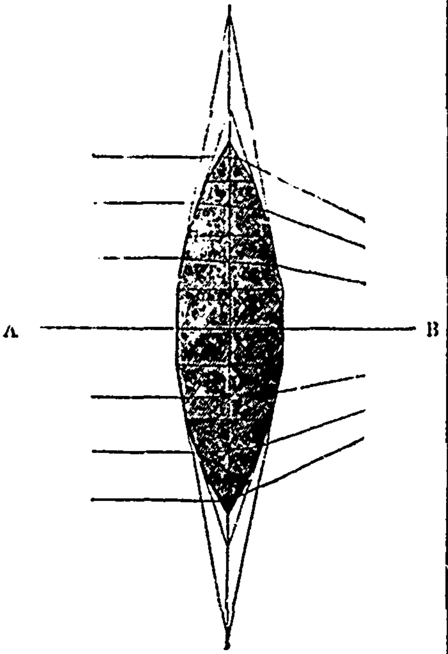


FIG. 13.—Formation of a lens from sections of prisms.

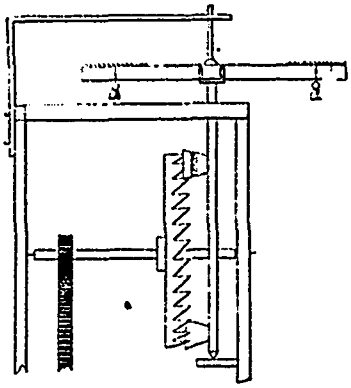


FIG. 18.—Ancient Clock Escapement.

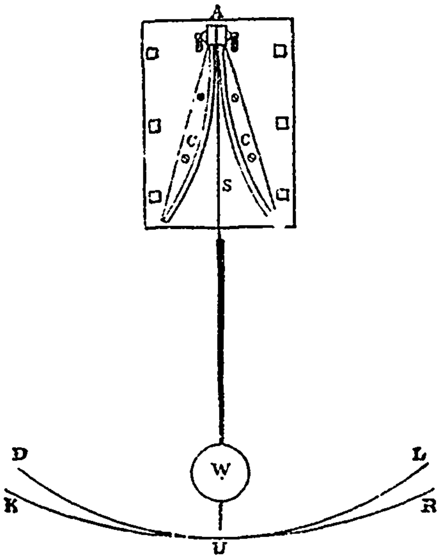


FIG. 19.—Cycloidal Pendulum.

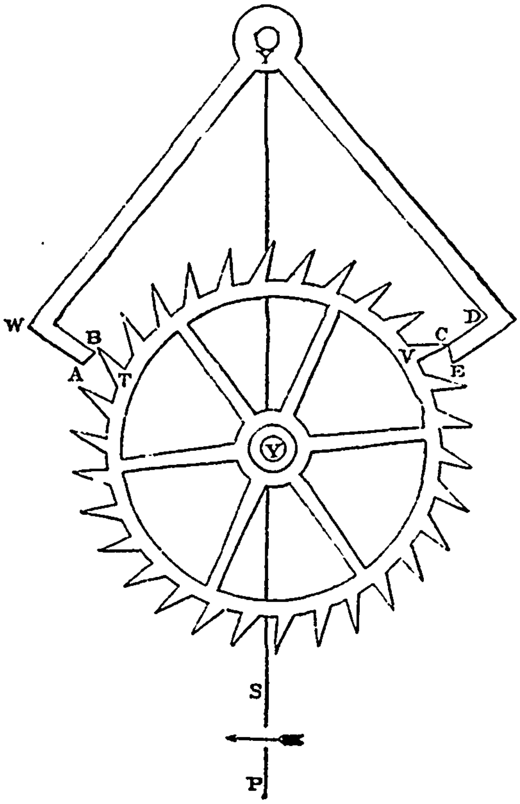


FIG. 20.—Dead-beat Escapement.

ward motion of A B on the rod D. The weight *d* is bearing not only on the center, but also on the side rods, and any further downward motion of A B would allow it to rest upon D. The other weights would be in succession deposited on the central rod by a continuance of the downward motion. On the front of the beam there are three sets of these rods, each one of them carrying a carefully adjusted set of weights, 10 in number. When all of one set are upon the beam the next set is added, and so on, gradually increasing the weights until the limit of capacity is reached. The weights are arranged to add tens, hundreds and thousands of pounds to the balancing load. At the outward end of the beam, however, it is desirable to put on still greater weights, and Fig. 17 shows how these large weights are arranged. As in the previous case, there are 10 of them, but they are carried by two sets of rods fastened to the cross head C. The rod D has arms projecting from it. One pair of these arms is shown at its bottom just below the weights *i* and *k*. By the lowering of A B, the weight *a* is first picked up by the rod D, then B follows, and so on until all are carried by D. When the cross head C is raised the weights are lifted from D in a reverse order. In the front of the case which covers the beam four handles are seen. These handles, by motion up and down, move, by means of levers, the weight frames and put on or take off the weights. At the same time they raise or lower a series of pointers, and thus indicate just how many weights have been placed on the beam. In starting to weigh, all the handles are moved so as to bring the pointers at zero.—*Mechanics.*

Scientific.

ELECTRICITY AND MAGNETISM.

BY PROF. W. GARNETT.

DEF. A surface is said to be *level* when a heavy body has no tendency to pass from any one point to any other upon the surface.

A horizontal plane is practically, a level surface if its dimensions are small. Over an extended area a level surface conforms to the general form of the earth. Thus a complete level surface, drawn through any point, is approximately a spheroid whose centre is coincident with that of the earth.

The test practically employed in order to determine whether a surface is level or not consists in observing whether a mobile liquid has any tendency to flow from one point to another of the surface. For this purpose a spirit level is employed. A spirit level consists of a glass tube very slightly curved, and mounted with its convexity upwards. The tube is nearly filled with spirit, leaving only a small bubble. The bubble always occupies the highest point of the tube, that is, the centre of the bubble lies at that point of the tube where the tangent is horizontal. If the instrument is properly mounted the centre of the bubble will coincide with the middle of the tube, however the instrument may be turned in azimuth, so long as it lies on a horizontal plane; but if the level is placed on a plane which is not horizontal, the spirit will flow towards the lower end of the instrument, and the bubble occupy the highest portion. Thus the tendency of a heavy fluid to pass from points at a higher level to those at a lower level is practically utilized to test whether or not a surface is a *level* surface.

Spirit levels, as employed by carpenters, builders, &c., determine whether small plane surfaces are horizontal. As employed in the survey of a large tract of country the spirit level enables the surveyor to follow a curved surface which coincides with that which would be the surface of still water—if water were present—but which cannot be regarded as a plane surface except over a very small area, and then only approximately so.

If a vertical straight line were erected in London, and points marked off upon the line at successive distances of one foot, and if level surfaces were drawn through these points their form would agree generally with the surface of the ocean supposed smooth, and they would cut the more elevated portion of the earth's surface in *contour* lines. But though the vertical distance between successive surfaces in London was exactly one foot, it would be found that the distance did not remain the same in other latitudes. At the poles it would be less than one foot, and at the equator more than one foot, just as the earth's polar radius is less than the radius through London, while the equatorial radius is greater.

The law by which the distances between successive surfaces would be regulated is the following:—*The work done on a given portion of matter in falling from any surface to the next would be the same at all points, and therefore equal to that done in fallng between the same two surfaces in London.*

Hence, where gravity is strong, as at the poles, the distance between the successive surfaces will be small, but where gravity is weak, as at the equator, the distance will be proportionally great. As we recede from the earth's surface, these local differences will diminish, and the general form of the surfaces will approach more nearly to that of a sphere.

If we define a foot pound as the work done by gravity on a pound in falling vertically through one foot to the sea level (Trinity high-water mark) in the latitude of London, thus making it an absolutely constant unit of work, instead of a variable unit as it is generally defined to be, then the work done on a pound in falling from one of our hyothetical level surfaces to the next will be everywhere a foot-pound, provided the surface to which the pound falls be that which passes through the Trinity high-water mark in London.

But if the distance between successive surfaces in London be in all cases a foot, the work done on a pound in falling from one surface to the next will diminish as we ascend, in consequence of the diminution of gravity. We may, however, so regulate the distances between successive surfaces in London that the work done may, in all cases, be a foot-pound. The distance between successive surfaces will then increase as the intensity of gravity diminishes with increased altitude, but the system of surfaces will possess the simple property that a foot-pound of work will be done on a pound in falling from each surface to the next in succession, whatever be the locality in which the fall takes place, and whatever be the elevation in which the fall takes place, and whatever be the elevation above the sea.

These surfaces may be numbered consecutively from the sea level, which may be regarded as zero. Surfaces below the sea level may have negative numbers assigned to them. The level of a point lying on one of these surfaces will then be represented by the number assigned to the surface, and the level of a point lying between consecutive surfaces will be represented by a fractional quantity. On this system the level of a point is represented by the number of foot-pounds of work done on a pound of work done in falling from the point to the sea-level, that is the surface whose level is zero. Levels thus determined may be said to be measured with the *foot-pound rule.* They differ from levels measured with the *foot rule* on account of the variation of gravity. On the foot-pound system the the difference of level between two points is equal to the number of foot pounds of work done by gravity on a pound in falling from the first point to the second, whether the points lay in the same vertical or not.

It should be noticed that the *foot pound* as above employed is not the foot-pound as ordinarily defined, but is a constant unit not varying with the intensity of gravity in different localities. We might have drawn our surfaces so that the work done on a gramme in descending from each surface to the next was always equal to one erg, and the set of surfaces would then have corresponded to the C.-G.-S. absolute system of units.

If it is desired to measure the depth of a mine for the purpose of estimating the cost of pumping water from it or the height of a mountain lake, for the purpose of estimating its value as a source of power, it is clear that the intensity of gravity ought to be taken into account, and thus it is the *foot-pound rule* and not the *foot rule* which ought, theoretically, to be employed in the measurement.

A method (which is practically possible) of employing the foot-pound rule for the measurement of the difference of level between two points is the following: Connect the two points by a tube filled with water, and attach a pressure guage, which registers in *absolute* measure, to the lower end of the tube. The registration of the gauge will indicate the difference of level between the ends of the tube on the *foot-pound* system.

Henry Cavendish pointed out that electricity, in many of its properties, resembles an incompressible fluid, so that there are many analogies between the behaviour of electricity in conductors and of water in tubes or other vessels.

If a heavy fluid tend to pass from a point A to a point B, then A is said to be at a higher level than B. If positive electricity tend to pass from one point to another, the first is said to be at a higher *potential* [or electric level] than the second.

Electric *potential* is the theory of electricity what level is in the theory of gravitation.

DEF. The *potential* of a conductor is its electric condition with reference to its power of communicating electricity to, or of receiving electricity, from other conductors.

As thus stated, the definition of electric potential is similar to that of temperature in the theory of heat. But, in the case of electric potential, we can do what we cannot do in the case of temperature, that is, explain at once how electric potential may be estimated *quantitatively.* In this respect electric potential resembles level in gravitation; we have only to replace the unit of mass by the unit of electricity.

If, when two bodies, A and B, are placed in communication, positive electricity tends to go from A to B, then A is said to have a higher potential than B. If electricity does not tend to pass from either to the other the bodies are said to be at the same potential. Hence when a conductor is in electrical equilibrium it must be at the same potential all over.

It is not usual to speak of the temperature of a point in space, though a meaning may be assigned to the phrase. A point in space may, however, have a definite electrical potential, whether there is any matter there or not.

DEF. The difference of potential between two points is the number of units of work (*ergs*) done by electric forces on the unit of (positive) electricity in passing from the first point to the second.

DEF. An *equipotential* [or *level*] surface is a surface such that electricity has no tendency to pass from any one point to any other point upon the surface.

(To be continued.)

THE MOVEMENTS OF THE EARTH.—(*Nature.*)

Another diagram (Fig. 12) will perhaps make it a little clearer how this range on the retina is formed. At *A B* is an arrow, from it ray of light are marked going to the three different points on the retina. But it will be seen that those rays of light which come from the top of the arrow are, by the action of these three media, twisted downwards, and form an image of the top portion of the arrow on a low part of the retina. The rays of light proceeding from the bottom of the arrow are bent up, so that its image is formed on an upper part of the retina. The light coming from the middle of the arrow is not bent at all, and thereby forms its image on a middle portion of the retina. This is the way in which the eye deals with rays of light entering it. With this knowledge of the optics of the eye, it will be very easily seen how very wonderfully the construction of the eye has been imitated in a photographic camera. The front lens is practically the equivalent of those three refractive media of the eye, the aqueous and vitreous humours, and the crystalline lens; whilst the iris, which in the eye serves to limit the amount of light entering it, has its exact representative in the "stop," which serves the same end in the camera. The photographic plate is, it need hardly be said the counterpart of the retina, and has consequently been beautifully described as "a retina which does not forget." Similarly there is just such an arrangement for focusing the light as exists in the eye. In fact a camera is a rather better machine altogether than the eye, because the range is greater, and the focusing power is not lost as age increases. Therefore the artificial eyes of our camera are never in need of spectacles.

1. *How Optics enables us to Read Fine Verniers.*—This knowledge, then, having been acquired, how is it to be utilised for the purpose of the measurement of angular space? It may be utilised in this way. The reason that we cannot clearly distinguish objects placed very close to the eye is, that the rays of light which flow from them are so extremely divergent that the crystalline lens cannot focus them on the retina. But by placing between the eye and the object a double convex lens of the eye, this extreme divergence is corrected; the crystalline lens is thus aided, and the rays of light are brought to a focus, as shown in the lower part of Fig 12. Take the case of a vernier whose divisions are so fine that they are not visible at the distance of distinct visions, say about ten inches. If we attempt to correct this by making the divisions appear larger, by bringing the vernier close to the eye, we lose the power of focusing the rays which flow from it. But the introduction of a convex lens between the vernier and the eye enables the eye to see the division quite distinctly.

Of course the more nearer an object approaches the eye, the more powerful must by the lens, in order that the eye may clearly see it. In this way we see that the simple addition of a convex lens has enormously increased our power of observing and measuring small angles.

2. One can, however, go further than this, and use not one simple lens, but a combination of lenses. But before discussing the various combination of lenses which are employed in various instruments, it is necessary to look a little more closely than we have yet done at the structure and action of our convex lens. Let us use a glass lens in conjunction with an electric lamp. Then we may get an image of the carbon poles thrown on the screen, in exactly the same way that the crystalline lens forms its image on the retina. But there would be this important difference, that while the image formed by the crystalline lens would

be a clear and distinct one, that formed by our glass lens would be a very bad one; instead of the poles of the electric arc being clearly and sharply defined, they would appear as if seen in a haze, and would be surrounded by coloured fringes of light, and not much could be made of them. Why is this? We find by experiment that this attempt to imitate the action of the eye by means of such a simple glass lens is an incorrect way of proceeding, the eye possessing certain qualities which the simple glass lens does not. Although a lens seems to be a very simple matter, its structure is really based upon some very complicated considerations. If a section of it be taken it will be seen that its surface is built up of sections of triangular pieces of glass, these triangular pieces of glass being called prisms, and how they deal with the light it is very important for us to know. If in front of the beam of light issuing from the lantern a prism be interposed, it will be found that whilst part of the light is reflected from its first surface another portion is refracted as it is termed, that is, bent out of its original course by the prism. Further, it not only suffers this deviation due to refraction, but it undergoes also what is called dispersion. In fact, where the light falls on the screen an infinite number of different colours are seen, these forming what is called a spectrum. This is one of the reasons why such a glass lens as we have used will not perform the finer work of the eye; the images of the poles are surrounded by a false glow, because it is difficult to give the lens the proper curvature, and there is this power of dispersion which breaks the compound white light up into a number of its different elementary colours. It is this power of deviation which the lens possesses which enables it to bend the rays differently according to their different distances from its centre, and causes them to form an image at what is termed the focus of the lens. The rays of light passing through the outer part of the lens undergo more deviation in order that they may be brought to a focus at the same point as the other rays. Now prisms which are made of different material, although they be of the same size and of the same angle, produce different deviations and different dispersions of the light which falls upon them. This fact has been taken advantage of in the construction of lenses. Let us take an illustration of the way in which this has been done. Imagine glass which gives a high dispersion and but slight deviation, set to work against glass giving great deviation with but little dispersion. It is obvious that it is quite possible by a combination of that character to keep the deviation and get rid of the dispersion, or to keep the dispersion and get rid of the deviation, as may be desired. By doing this an artificial eye of great excellence may be made. Suppose two different kinds of glass so combined as to form a prism, which should give a perfectly white image. Then the

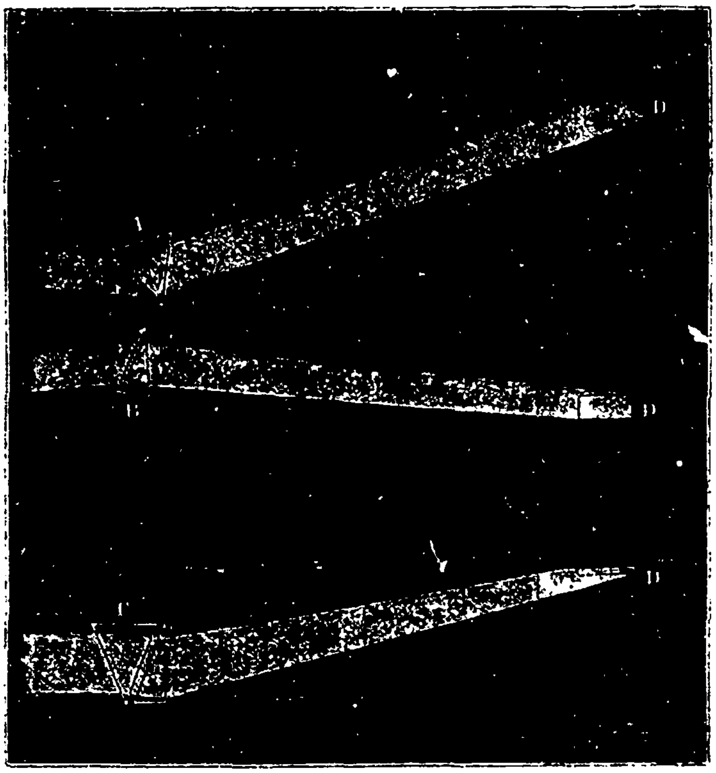


FIG. 14.—Diagram explaining the formation of an achromatic lens. A, crown-glass prism. B, flint-glass prism of less angle, but giving the same amount of colour; C, the two prisms combined, giving a colourless yet deviated band of light at D".

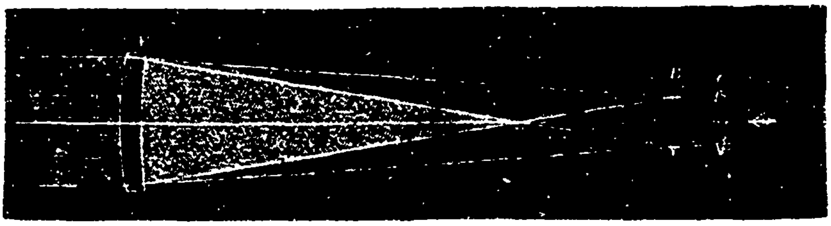


FIG. 15.—Telescope. A, object-glass, giving an image at B; C, lens for magnifying image B.

dispersion will have been got rid of, and the deviation will have been retained, and this is exactly what takes place in the modern compound, or, as it is called, achromatic lens. By building up a lens in this way we can get a much better image of the carbon poles of the lamp than before. This compound, achromatic lens, when used in a combination, is called the object-glass, because it is pointed to the object. But when it is a question of the combination of lenses, there is something else to be considered besides the mere formation of images. It is not enough to consider merely this, because when we spoke of the action of a convex lens in aiding us to read the vernier, we found that if an image was to be obtained the rays entering the eye must be practically parallel. In that case the rays always come to a focus at the same point. If the rays are not parallel, but divergent rays, then their focus will vary with the varying distance of the source of light.

In combining lenses together, then, it is important to bear in mind the fact that the rays of light which, after passing through the lenses ultimately reach the eye, must be parallel ones. Let us consider that arrangement which obtains in the telescope. In the simple form of this instrument, A (Fig. 13), representing the object-glass, receives the rays of light and forms an image of the distant arrow, from which they are supposed to flow, in exactly the same way that the lens we used just now formed an image of the carbon poles on the screen.

This image, then, having been observed, the eye views the distant object as if the object itself were placed at B: Remember now the way in which the eye was enabled to read the vernier placed close to it, and the action of the convex eyepiece of the telescope will be very obvious. In just the same way as the divergent rays coming from the vernier were grasped by the convex lens, and rendered parallel, so in this case the convex eyepiece of the telescope grasps the divergent rays from the image, reduces them to the necessary condition of parallelism, and thus enables the image of the object to be clearly formed upon the retina of the observer's eye.

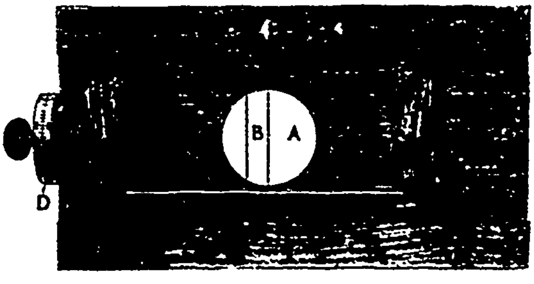


Fig. 16.—Model of Micrometer.

We have, then, got so far that by means of an object-glass we produce an aërial image, and by means of a convex lens we can view this image under conditions which enable another image of it to be formed on the retina. It is at once obvious that we can do something more than this, for if we place a concrete thing such as a cross wire at the same distance in front of the convex lens as the aërial image, or, in other words, at the focal distance of the object-glass, we shall see both the aërial image and the concrete thing, be it a cross wire or what not, both together. Now imagine that we can obtain an aërial image in this way of a star, and that side by side with this image of the star we observe the cross wire. It is quite clear that if we have any means of getting the cross wire to bisect the image of the star we shall have a much more accurate method of pointing at the celestial body, and therefore of measuring the angle between two celestial bodies, than was possible on the old system of sight without telescopes.

Suppose this telescope of ours to supplant the pointer of the old instrument of Tycho Brahe, consider the extreme accuracy of its observation as compared with that of the pointer in Tycho's quadrant, and it will be seen how vastly the application of these optical principles has added to the instrumental powers of the astronomer.

3. *How Optics enables us to Replace the Vernier by a Micrometer.*—But we have not yet done with optics. Its principles have been applied in yet another manner, but still, like these two applications which we have considered, tending to increase the power of accurately measuring minute angular distances of space.

Fig. 14 shows a simple model which has been designed to illustrate the principle of the instrument called the micrometer. This instrument places in the hands of the astronomer the power of measuring with extreme accuracy the most minute distances. It consists of two vertical wires, one, A, fixed, the other, B, movable by the rotation of a very perfectly cut screw, seen at C. The head of the screw, D, is divided into 100 parts, and read by means of a vernier to 1/1000ths.

This system of threads moving over certain small distances which can be accurately measured by means of a micrometer screw, can replace the cross wires to which we have just referred, and there are two very notable applications of this principle to which reference must now be made. When the object-glass is used for astronomical purposes, it is naturally arranged to bring the rays which fall upon it from a celestial body, and which are practically parallel, to a focus which represents the actual focus of the lens for such rays, and which is called the principal focus. But it is not necessary that the rays which fall upon such a lens should be parallel. The lens acts under other conditions with this proviso, that the more the rays diverge from the body in front of it, or, in other words, the nearer the object is to it, the greater will be the distance behind the lens of the point at which the aërial image is formed.

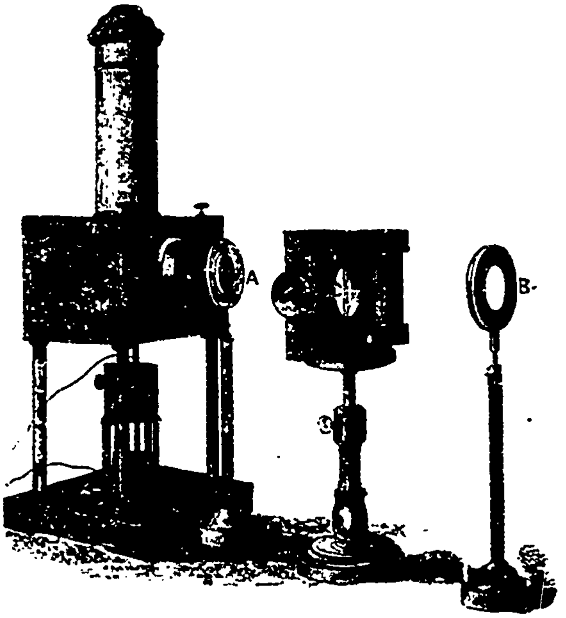


Fig. 17.—Micrometer arranged for demonstration with the electric light.

Here in a few words we have a statement of the arrangement used in the microscope, and a moment's thought will show that such an arrangement may be applied to the vernier instead of the small lens, to which reference has already been made. Nay, we can go further than this, it may be applied to the circle itself, and help us to measure small fractional divisions of its parts with yet greater accuracy than is possible by the aid of the vernier. The way in which this is managed is as follows:—The microscope is turned towards the circle, so that its divisions may be plainly seen in the field of view, and the position of the wire, on, or between any division may represent a certain position which is to be measured by means of the circle. The micrometer head may now be used to tell us the exact distance in 1/1000ths of a revolution between the position occupied by the wire in the first instance, and the position of the wire when it exactly lies on the next division. By determining, according to the graduation of the circle, the number of thousandths of parts as indicated by the micrometer which lie between each division, it is obvious that the exact angular distance between such a position and the next division of the circle can be accurately determined. Such an operation as this is called a "run," and practically such a system as this is adopted in reading all large circles. But when it is a question of measuring smaller arcs, the micrometer *may be used with the telescope itself*, its wires appearing with the image of the object in the field of view.

A description of an experiment will perhaps convey a better idea of what can be done in this way. Fig. 15 represents the arrangement The condensing lens of the lantern having been removed, the light is allowed to impinge upon a lens, A, placed at a slight distance from the lantern. Its action on the light causes a reversed image of the poles to be produced in the air. The light coming from this image is then made to pass through another lens, B; the reversal is corrected, and a magnificed image of the poles of the electric arc is thrown upon the screen. The first lens which forms the image may be regarded as the object glass of a telescope, whilst the other lens which throws the magnified image upon the screen in the counterpart of the telescope's eyepiece. Now if at C, where the image is formed in air, the micrometer wires are placed, they, with the image of the poles, will appear magnified on the screen.

In this manner bodies appear with the wires in the field of vision of the telescope, and their diameters and the dimensions of *different parts of them* may be most accurately determined. Up to the present time we have been concerned simply with accurately determining the positions occupied by the various bodies which people space. But with this micrometer in the field of view of the telescope something more than this may be done. We may now determine some measurements upon the bodies whose positions alone we have been considering up to now. *For instance, the image of a planet may be grasped by* the wires, one wire bounding one limb of the planet, the other wire lying along the other limb. Then, knowing how many complete turns, and 1 100th, and 1 1000th parts of a turn have been given to the head of a screw in order that the wires may be separated through such a distance, and knowing also the value of these divisions in seconds of arc, the diameter of the planet may be measured. In like manner, the heights of lunar mountains may be ascertained by measuring the lengths of the shadows thrown by them. Or it may be a question of the distance between two stars close together. The method is still the same. One star is made to lie along the movable wire, the other is seen on the fixed one, and the distance through which the wires are separated ascertained. Having attained to this, let us bring our inquiry into angular measurement to a close.

In passing, as we shall in the sequel, from the measurement of space to the measurement of time, it will be found that the difficulties have been grappled with very much in the same way. In this measurement of space we began with simple instruments, *and only by a slow growth has the modern instrument* been arrived at; yet notwithstanding the immense changes that have taken place, the pointer and circle of the old instrument are still represented in the new, whilst the vernier and micrometer, still prominent, enable a degree of fineness to be attained quite unparalleled in the old days. But in *passing from these older instruments*, in which the circle was so prominent a feature, and the pointer so small, to the more modern instruments, it will be seen that, although both are still preserved, a great change has taken place. The pointer, represented by the telescope, is the prominent part of the instrument, whilst the circle is hidden away almost out of sight.

II. Measurement of Time.

It has been shown how, by the application of geometrical and optical principles, the measurement of angular space has been carried down to the 1-100th of a second of arc, such a quantity being 1-129,600,000th part of an entire circumference, and when such an accuracy as this has been attained, and the altitude or the azimuth of the sun, or moon, or any other heavenly body can be correctly stated with this exactitude, it will be seen how much better off in the way of defining positions is the modern astronomer than was Hipparchus with his 1 3rd, and Tycho Brahe with his 1 4th of a degree. To do this, *however, is not enough.* It is not only necessary accurately to define the position of a heavenly body, it is necessary also to know at what particular time it occupied that position. The next thing to be done, then, is to see how far we moderns have got in another kind of measurement, no longer the measurement of arc—the measurement of angular distance—but the measurement of *time*.

The measurement of time, however, is not quite so simple a matter as was the measurement of space. A certain angular measurement of space, or the angular distance between two bodies, whether that distance be a degree, or a minute, or a second, is a very definite thing, having a beginning and an end; but time, so far as we can conceive, has neither beginning nor end; so that the problem of the measurement of time has to be attacked rather in a different way. Here again it will be as well that the matter should be studied historically.

What more natural than that man having got the idea of the flow of time, should have begun to measure it by the flow of water, or the flow of sand? The earliest time measurers were *really made in this way; water or sand being allowed to drop* from one receptacle to another. There were difficulties, however, in thus determining the flow of time. In the first place the thing was always wanting to be wound up, so to speak, something was wanted to continue the action, and to prolong it; and the first appeal to mechanical principles was made with that view.

The first real clock put up in England was put up in Old Palace Yard, in the year 1288, by the Lord Chief Justice of that time, who had to pay the expense of it as a fine for some fault he had committed. Its construction was somewhat after this wise. One method of dealing with the flow of time was to call in the aid of wheelwork; but, as it well known, if a weight acts upon a train of wheels the velocity increases as the rotation goes on. Therefore the science of mechanics was called in to supply some principle which could be applied to prevent this unequal velocity of a train of wheels. Consider the arrangement shown in Fig. 18.

The wheelwork train is capable of being driven by a falling weight. *On the same axis as the smallest wheel, and therefore* the one which turns most rapidly, will be seen another wheel provided with saw-like teeth. Then at the top is a weighted cross bar, from the centre of which a perpendicular rod, provided with pallets, comes down to engage the teeth of the pallet-wheel. Now suppose the clock to be started. The weight is allowed to fall, and the wheels, including the pallet wheel, begin to revolve; then begins a reciprocating action between the swinging bar and the wheel with which it acts, because the pallets which act on the bar as they are on either side of the centre of motion really drive the bar first in one direction and then in the other. The teeth of the pallet wheel are continually coming into contact with the pallets of the swinging bar. First suppose that one of the teeth has encountered the upper pallet; it pushes this aside, and swings the bar in one direction. No sooner, however, has this been done than another tooth in the wheel at the bottom of the bar encounters the pallet and swings it in the opposite direction. In this way it is obvious that the bar is continually meeting and being met *by the teeth of the rotating wheel, swinging first in one direc*tion, and then in the other, the result of this reciprocal action being to prevent the increase in the velocity of the wheels which would otherwise take place.

It is in this way, then, by the performance at constant definite intervals of an equally constant definite amount of work, that the regularity of action of the clock is produced. The greater the distance of the weights on the cross-bar from its centre of motion, the longer will the bar take in swinging, the slower will be the action of the clock; so that the clock may be regulated by altering the position of these weights, bringing them nearer to, or removing them further from the centre of motion of the bar, according as it is desired to hasten or retard the action of the clock's mechanism. Yet at whatever distance from the centre of motion the two weights be placed, assuming always that they are both at the same distance from it, there is still this constantly recurring performance, at equal intervals, of an equal amount of work which produces the regular action of the clock. This was the kind of clock then which was *put up in Old Palace Yard.* But that did not go well enough, giving such inaccurate results that Tycho Brahe had to discontinue its use. Fortunately some few years later two most eminent men, Galileo and Huyghens, had their attention drawn to this very problem. The first of these, Galileo, was at that time studying medicine. He happened one day to be in the Cathedral at Pisa, where, it will be remembered, they have a most beautiful lamp which swings from a great height in the cathedral. Galileo was at this time working at that branch of his medical studies which deals with the pulse, and he looked at this lamp and found that its swinging was perfectly regular. To-day perhaps it may seem very natural that this should be so, but Galileo had the advantage of being *before us, and that is why it did not seem quite so natural* to him. There was at that time no known reason why it should swing in perfect regular rhythm. He found that the lamp when swinging, no matter with what amplitude, took practically the same time for each swing, timing it by his pulse. His idea was that this would be an admirable method of determining the rate of a man's pulse, and the first clock on this principle was constructed from that medical point of view, being called a Pulsilogium. Some years afterwards, however, the extreme importance of such an arrangement from an astronomical standpoint became obvious, and very much attention was given to it. It is unnecessary to add that this swinging body is nowadays called a pendulum. The most perfect pendulum made in those early days is represented in Fig. 19.

The fundamental difference between that and the modern pendulum is that part of the pendulum between S and A was elastic. It was made elastic for the reason that although Galileo could not find any difference between the times of the oscillations of the lamp in Pisa Cathedral, according as its amplitude of swing was large or small, yet such a difference did exist, although it was only a slight one; and the only method of getting a perfect pendulum which should make its swing in exactly equal times, independent of its arc of oscillation, was to construct this so-called cycloidal pendulum. It was so named because in its swing its elastic portion was held by the curved guides seen in the figure, and made to bend in that particular curve. By this means the pendulum instead of swinging through the arc, K U R, was made to oscillate through D U L. But when the pendulum was at the points D and L, it was practically a shorter pendulum than when at rest. In other words, whilst the pendulum was swinging from U to D and from U to L, its curvature, and consequently its vibrating length was continually changing. In that way, by continually varying the length of the swinging part, it was found possible to make a pendulum which, independent of the length of its arc of oscillation, would make its swing in times which for all practical purposes were absolutely equal in length. That was the most perfect pendulum of that time. Nowadays, the cycloidal pendulum has been replaced by one which swings through a very small arc, and the continual shortening during the oscillation in the cycloidal pendulum is by this means dispensed with, whilst the friction also being much reduced, there is less interference from that source. With this very small swing the difference between the arc of the circle described and the cycloid in which the cycloidal pendulum swung is practically indistinguishable.

The great difference between the modern clock and the ancient one is that in the former the pendulum is interfered with as little as possible whilst swinging, and makes each swing under precisely similar conditions. To attain this is to have done much. In the first place, if the clock has a heavy weight, that weight will probably interfere a good deal with the swinging of the pendulum. The clock weight, therefore, must be as light as possible. Secondly, if the wheelwork is always in contact with the pendulum, this also will interfere with its free and natural movement. There must be, then, such an arrangement that the wheelwork shall be brought into contact with the pendulum only for the shortest possible time. Thirdly, it must be remembered that the different substances which it is most convenient to use in the construction of pendulums, vary their dimensions with the variations of the temperature and moisture of the air in which they are placed, and great care must be taken to eliminate any errors which might arise from such a source. How are these various conditions complied with? The first, that the clockweight must be small, is not difficult to adhere to; but it will be well to consider the way in which the second condition, that the action between wheelwork and pendulum shall be the least possible, is met. This is done by employing what is called an escapement. It is so named because the pendulum in its swing is allowed to escape from the wheelwork, and thus retain a perfect freedom. The particular form of escapement about to be described is that which, for a reason that will appear immediately, is called the dead-beat escapement (see Fig. 20).

The escape wheel is the modern representative of the toothed wheel of the old clock, whilst the projections W and D are modifications of the pallets on the swinging bar in that instrument. Let the pendulum move in the direction of the arrow. The tooth T has just been released, thus permitting the tooth V to engage the other pallet D. Now whilst the tooth remains on the pallet, the escape wheel remains locked, while the pendulum is quite free to swing, there being nothing to retard it save the very slight friction between the tooth and the surface of the pallet. The rotation of the escape wheels, however, brings the tooth on to the oblique edge of the pallet, and with it in this position the pendulum is aided in its forward swing. Then the pallet escapes, receiving an impulse, but since this is received almost as much before the pendulum has reached its vertical position as after it has passed that point, no increase or diminution in the time of its oscillation takes place. It is in this way that the second of our conditions is complied with, the wheelwork being effectually prevented from interfering with the regularity of the pendulum's swing. It is called the dead-beat escapement, because when the tooth falls on the circular portion of the pallet and locks the escape wheel, the second hand fitted to it stops dead without recoil, because the arc of the surface of the pallet is struck from the centre of motion. In an astronomical clock a still more modern form of escapement, called the gravity escapement, is sometimes employed.

(To be continued.)

THE GENERAL THEORY OF THERMODYNAMICS.

The first of six lectures on HEAT IN ITS MECHANICAL APPLICATIONS, was delivered on Thursday evening, the 15th of November, before the Institution of Civil Engineers, (Eng.), by Professor OSBORNE REYNOLDS, M.A., F.R.S., the subject being "The General Theory of Thermodynamics." The following is an abstract of the lecture:—

Thermodynamics was a very difficult subject. The reasoning involved was such as could only be expressed in mathatical language; but this alone would not prevent the leading facts and features of the subject being expressed in popular language. The physical theories of astronomy, light and sound involved even more mathematical complexities than themodynamics, but these subjects have been rendered popular, and this to the great improvement of the theories.

What rendered the subject of Thermodynamics so obscure, was that it dealt with a thing of entity (heat), which, although its effects could be recognized and measured, was yet of such a nature that its mode of operation could not be perceived by any of our senses. Had clocks been a work of nature, and had the mechanism been so small that it was absolutely imperceptible, Galileo, instead of having to invent a machine to perform a definite function, would have had, from the observed motion of the hands, to have discovered the mechanical principles and actions involved. Such an effort would have been strictly parallel to that required for the discovery of the mechanical principles of which the phenomena of heat were the result.

In the imagined case of the clock, the discovery might have been made in two ways. By the scientific method, from the observed motion of the hands the fact that the clock depended on a uniform intermittent motion, would have led to the discovery of the principle of the uniformity of the period of vibrating bodies, and on this principle the whole theory of *dynamics might have been founded. Such a theory of me*chanics would have been as obscure, but not more obscure than the theory of the thermodynamics based on its two laws. But there was another method, and it was by this that the theory of dynamics was brought to light—to invent an artificial clock, the action of which could be seen. It was from the actual pendulum that the principles of the constancy of the periods of oscillating and revolving bodies were discovered, whence followed the dynamical theories of astronomy, of light and of sound.

As regarded the action of heat, no visible mechanical contrivance was discovered which would afford an example of the mechanical principle and motions involved so that the only apparent method was to discover by experiment the laws of the action of heat, and to accept them as axiomatic laws without forming any mental image of their dynamical origin. This was what the present theory of thermodynamics purported to be.

In this form the theory was purely mathematical and not fit for the subject of a lecture. But as no one who had studied the subject doubted for one moment the mechanical origin of these laws, Professor Reynolds would be following the spirit if not the letter of his subject if he introduced a conception of the mechanical actions from which these laws sprang. This he should do although he doubted if he should have so ventured, had it not been that while considering this lecture he hit upon certain mechanical contrivances, which he would call *kinetic-engines*, which *afforded visible examples of the* mechanical action of heat, in the same sense as the pendulum was a visible example of the same principles as those involved in the phenomena of light and sound. Such machines, thanks to the ready help of Mr. Foster his assistant in constructing the apparatus, he should show, and he could not but hope that these kinetic engines might remove the source of the obscurity of thermodynamics on which he had dwelt.

The general action of heat to cause matter to expand was sufficiently obvious and popularly known; also that the expanding matter could do work was sufficiently obvious. But the part which the heat played in doing this work was very obscure.

It was known that heat played two, or it might be said three, distinct mechanical parts in doing this work.

These parts were:—

1. *To supply the energy necessary to the performance of work.*

2. To give to the matter the elasticity which enabled it to expand—to convert the inert matter into an acting machine.

3. To convey itself, *i.e.*, heat, in and out of the matter.

This third function was generally taken for granted in the theory of thermodynamics, although it had an important place in all applications of this theory.

The idea of making a kinetic-engine which should be an example of action such as heat, had no sooner occurred to him than various very simple means presented themselves Heat was transformed by the expansion of the matter caused by heat.

At first he tried to invent some mechanical arrangement which would expand when promiscuous agitation was imparted to its parts, but contraction seemed easier—this was as good. All that was wanted was a mechanism which would change its shape, doing work when its parts were thrown into a state of agitation.

In order to raise a bucket from a well either a rope was pulled or the windlass wound—such a machine did not act by promiscuous agitation, but if the rope was a heavy one (a chain was better) and it was made fast at the top of the well so that it just suspended the bucket, then if it was shaken from the top waves or wriggles would run down the rope until the whole chain had assumed a continually changing sinuous form. *And since the rope could not stretch, it could not reach* so far down the well with its sinuosities as when straight, so that the bucket would be somewhat raised and work done by promiscuous agitation The chain would have changed its mechanical character, and from being a rigid tie in a vertical direction would possess kinetic elasticity, *i.e.*, elasticity in virtue of the motion of its parts, causing it to contract its *vertical length against the weight of the bucket. Now it was* easy to see in this case that to perform this operation, the work spent in shaking the rope performed two parts of imparting energy of motion to the chain and raising the bucket. A certain amount of energy of agitation in the chain would be necessary to cause it to raise a bucket of a certain weight through a certain distance, and the relation which the energy of agitation bore to the work done in raising the bucket, followed a law, which if expressed would coincide exactly with the second law of thermodynamics. The energy of agitation imparted to the chain was virtually as much spent as the actual work in raising the bucket, that is to say, neither of these energies could be used over again. If it was wanted to do further work, the raised bucket was taken off, and then to get the chain down again it must be allowed to cool, *i. e.*, the agitation must be allowed to die out. then attaching another bucket, it would be necessary to supply the same energy over again.

He had other methods besides the simple chain, which served better to illustrate the lecture, but the principle was the same.

In one there was a complete engine with a working pump. By mere agitation the bucket of the pump rose, lifting 5 lbs. of water 1 foot high, before it would make another stroke the agitated medium must be cooled, *i.e.*, the energy which caused the elasticity must be taken out, then the bucket descended, and, being agitated again, made another stroke.

He felt that there was a childish simplicity about these kinetic-engines, which might at first raise the feeling of "Abana and Pharpar" in the minds of some of his hearers. But this would be only till they realized that it was not now attempted to make the best machine to raise the bucket, but a machine that would raise the bucket by shaking. These kinetic-engines were no mere illustrations or analogy of the action of heat, but were instances of the action of the same principles The sensible energy in the shaking rope only differed from the energy of heat in the scale from the energy of heat in a metal bar The temperature of the bar, ascertained from absolute zero, measured the mean square of the velocity of its parts multiplied by the weight per foot of the chain, really represented the energy of visible agitation in the chain.

The waves of the sea constituted a source of energy in the form of sensible agitation; but this energy could not be used to work continuous one of these kinetic-machines, for exactly the same reason as the heat in the bodies at the mean temperature of the earth's surface could not be used to work heat-engines.

A chain attached to a ship's mast in a rough sea would become elastic with agitation, but this elasticity could not be used to raise cargo out of the hold, because it would be a constant quantity as long as the roughness of the sea lasted.

Besides the waves of the sea, there was no other source of sensible agitation, so there had been no demand for kinetic-engines. Had it been otherwise, they would not have been left for him to discover—or had they been, he might have been tempted to patent the inventions But there had been a demand for what might be called sensible kinetic-elasticity to perform for sensible motion the part which heat-elasticity performed in the thermometer.

And it had not been left for him to invent kinetic-mechanism for this purpose, although it might be that its semblance to the thermometer had not been recognized. The principle was long ago applied by Watt. The common form of governors of a steam engine acted by a kinetic-elasticity, which elasticity, depending on the speed at which the governors were driven, caused them to contract as the speed increased. The governor measured by contraction the velocity of the engine, while the thermometer measured by expansion the velocity in the particles of matter which surrounded it; so that it could now have been seen that having to perform two operations, the one on a visible scale, the other on a molecular scale, the same class of mechanism had been unconsciously adopted in performing both operations

The purpose for which these kinetic-engines was put forward was not that they might be expected to simplify the theory of thermodynamics, but that they might show what was being done. The theory of thermodynamics could be deduced by the laws of motion from any one of these kinetic-engines, just as Rankine deduced it from the hypotheses of *molecular vortices*.

Nothing has yet been said of the third part which heat played in performing work, namely, conveying heat in and out of matter. It was an innovation to introduce such considerations into the subject or thermodynamics, but it properly had a place in the theory of heat engines. It was on this part that the speed at which an engine would perform work *depended*.

The kinetic-machines showed this. If one end of a chain was shaken the wriggle ran along with a definite speed, so that a definite interval must elapse before sufficient agitation was established to raise the bucket, further, an interval must elapse before the agitation could be withdrawn, so that the bucket might be lowered for another stroke. The kinetic-*machine, with the pump, could only work at a given rate.* He could increase this rate by shaking harder, but then he expended more energy in proportion to the work done. This exactly corresponds with what went on in the steam-engine, only owing to the use of separate vessels, the boiler, cylinder and condensers, the connection was much confused. But it was clear that for every H.P. (2,000,000 ft.-lbs. per hour) *15,000,000 ft.-lbs. had to be passed from the furnace into* the boiler, as out of the 15,000,000 no more than 2,000,000 could be used for work, the remaining 13,000,000 were available for forcing the heat into the boiler and out of the steam in the condenser, and they were usefully employed for this purpose.

The boilers were made as small as sufficed to produce steam, and this size was determined by the difference of the internal temperatures of the gases in the furnaces, and the water in the boiler; and whatever diminished this difference would necessarily increase the size of the heating surface required, *i.e.*, the weight of the engine. The power which this difference of temperature represented could not be used in the steam-engine, so it was usefully employed in diminishing the size of the engine.

Most of this power, which in the steam engine was at least eight times the power used, was spent in getting the heat from the gases into the metal plates, for gas acted the part of conveyance far less readily than boiling water or condensing steam. If air had to be heated inside the boiler and cooled in the condenser with the same difference of temperature, there would be required thirty or forty times the heating surface—a conclusion which sufficiently explained why attempts to substitute hot air for steam had failed. In one respect the hot air engines had an advantage over the steam-engine. During the operation in the cylinder the heat was wanted to be kept in the acting substance; this was easy with air, for it was such a bad conductor of heat that unless it was in a violent state of internal agitation it would lose heat but slowly, although at a temperature of 1,000 degrees and the cylinder cold.

Steam, on the other hand, condensed so readily that the temperature of the cylinder must be kept above that of the steam. It was this fact which limited the temperature at which steam could be used. Thus, while hot air failed on account of true economy, the practical limit of the economy of steam was fixed by that which a cylinder would bear. These facts were mentioned because at the present time there appeared to be the dawn of substituting combustion-engines in place of steam engines.

Combustion-engines in the shape of guns, were the oldest form of heat-engine. In these, the time required for heating the expansive agent was zero, while they had the advantage of incondensible gas in the cylinder, so that if the cylinder was kept cool it cooled the gas but slightly, although this was some 3,000 degrees in temperature.

The disadvantage of these engines was that the hot gas was not sufficiently cooled by expansion, but a considerable amount of heat carried away might be used again could it be extracted and put into the fresh charge, to do this, however, would introduce the difficulty of heating-surface in an aggravated form. However, supposing the cannon to have been tamed and coal and oxygen from the air to be used instead of gunpowder Thermodynamics showed that such engines should still have a wide margin of economy over steam-engines, besides the advantage of working with a cold cylinder and at an unlimited speed. The present achievement of the gas-engine, stated to be some 2,000,000 ft.-lbs. per ton of coke, looked very promising, and it was thus not unimportant to notice that whatever the art difficulties might be, thermodynamics showed no barrier to further economy in this direction, such as that which appeared not far ahead of what was nearly accomplished with steam-engines.

But however this might be, he protested against the view which seemed somewhat largely held that the steam-engine was only a semi-barbarous machine, which wasted 10 times as much heat as it used—very well for those who knew no science, but only waiting until those better educated had time to turn their attention to practical matters, and then to give place to something better. Thermodynamics showed the perfections not the faults of the steam-engine, in which all the heat was used, and could only enhance the admiration in which the work of those must be held who gave, not only the steam-engine, but the embodiment of the science of heat.

RINGED ADDERS CREEPING OUT FROM THE EGGS, IN THE BERLIN AQUARIUM.—*(Sc. Am.)*

Inventions and Miscellaneous Notes.

COMBINED TRIANGULAR AND SUSPENSION BRIDGE TRUSS.

A paper by Mr. E. Thatcher describing a Combined Triangular and Suspension Bridge Truss, and comparing its cost with that of the Warren, Pratt, Whipple, and Howe Trusses was read at a recent meeting of the Am. Soc. of Civil Engineers. The author presented drawings and descriptions of a truss formed by a combination of the triangular and suspension systems, the primary system being composed of top and bottom chords and a web of struts and ties arranged in the form of triangles free to change figure under the effects of temperature. The centre ties extend each over not less than two panels and over not more than the number in half spans less one. A careful analysis was presented of the strains in these bridges; and tables was also given showing the uniform live loads which may be substituted for the wheel loads of the leading types of 10 wheel and consolidation engines in spans ranging from 10 to 500 feet. The writer discussed the defects of various forms of bridge truss compared with what were considered the advantages of the particular truss described in the paper. He also presented estimates of the cost of bridges built upon this principle as compared with the cost of the Warren, Pratt, Whipple and Howe trusses, deducing a lower result for all spans built by this method. He presented comparative estimates as to the economy of bridges built entirely of iron as compared with those built with the combination of wood and iron, with the result that the ultimate cost of the combination bridge was considerably lower than the other.

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FUSIBLE SAFETY BOILER PLUGS.

These handy contrivances are in general use, their office being to give notice of lowness of water that may be dangerous. They are usually made of "composition"—brass—quite hard, and have a drilled hole from end to end, the entire length being sufficient to pass through the shell of the boiler and project far enough beyond the inside surface to be above the sediment or scale. The lower end is formed into a bolt head, and the shank is threaded and is screwed into a tapped hole over the fire-box, in the crown sheet. The *Locomotive* sustains the rule of the United States Steamboat Inspection service as to the fusible filling, which shall be of pure Banca tin.

To this filling there may be objections, and possibly objections may be found to *any* fusible composition. It is possible that the experience of engineers, as accumulated, proves that "life" of easily fusible metals is destroyed under certain circumstances. At all events, it can be readily substantiated by facts that easily fusible plugs have refused to act under the the most exacting circumstances after having been in use two years—sometimes less

There is a remedy in removing and refilling the safety plug once in six months or once a year. But perhaps a better method would be to discard the use of brass—composition—and substitute wrought-iron, of a similar character to that of the boiler plate Tin is the core to be fused. It is surrounded by brass, a compound of which tin is an important component. With the action of heat there may be a chemical action that destroys or impairs the fusibility of the tin; experience seems to point this way.

The recommendation of the *Locomotive* that the core for receiving the fusible filling should be tapered from the inside of the boiler to the outside of the plug, the larger diameter being inside the boiler, is a reasonable one, and will commend itself to engineers.

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THE piercing of the Arlberg Tunnel was unexpectedly completed on Tuesday afternoon last week. In length the new tunnel ranks third among the great tunnels of the world, its length being 10,270 metres, while the Mont Cenis Tunnel is 12,323, and the St. Gothard 14,900 metres. But while the excavation of the first lasted no less than fourteen years and a half, and that of the second about eight, the Arlberg Tunnel will have taken, when vaulted and ready to receive the first locomotive, not more than four years, thanks to the experience acquired during the construction of the first two Alpine tunnels, and to some innovations which constitute another important step in the art of engineering required for the construction of large tunnels. The engineer of the St. Gothard Tunnel introduced dynamite for blowing up the rocks, already pierced through by the boring machine, which useful tool was naturally not disregarded in the construction of the new tunnel. It was also only natural that the Ferroux percussion boring machine, first introduced at the Mont Cenis works, should be again employed, under the supervision of the inventor himself, who in the mean time had considerably improved his powerful boring instrument; but this time the Brandt turning borer, first employed at the works of St. Gothard, was allowed to compete with the Ferroux percussion borer, the former being used in boring on the tunnel's western side, and the latter on the eastern. To this end, several streams from the heights of the snow-covered Arlberg were gathered on the eastern side into reservoirs from which two turbines and three water columns were directed to the machines, which compressed the air to five atmospheres, with which the Ferroux borer was worked; while on the western side pumped water was pressed through pipes to the tension of over a hundred atmospheres, to work Brandt turning borer, which cuts cylindrical blocks of rock from the mountains. The eastern entrance to the Arlberg Tunnel—namely, St. Anton—is 1300 metres above the level of the sea, while the western entrance is only 1215 metres, by which difference a good ventilation of the future railway tunnel seems secured. The vaulting and all other necessary works will be finished at the latest on August 1, 1884.

JOINTS OF SANATORY PIPES, ETC.—Instead of the socket end usually attached to pipes, Mr. A. B Wren, makes his cylindrical, or rectangular, throughout their entire length. To form the joint, the end of one pipe enters the other for about an inch. For about an inch from its extremity one end of the pipe is reduced to about half its thickness by removal of substance from its exterior. Similarly, for about the length of an inch from the other extremity of a pipe, it is reduced to about half its thickness by removal of substance from the interior. The interior and exterior angles thus formed by the removal of substance are slightly rounded, to facilitate the opening of the joint when necessary. One end of a pipe being introduced into the end of another, the joint is sustained, held firmly in position, and rendered water-tight by a bandage of canvas, or other suitable material, well saturated with tar, paraffin-wax, or other suitable material, stretched tightly round it. The joint, when used for sanatory or other pipes for conveying water, is further strengthened by being coated wide plastic cement, or other suitable material, and a collar pipe drawn tightly over the cemented joint. A hole may be made at the top of this collar, for the admission of plastic material if thought desirable. When used as a joint for electric wire conductors, the collar is divided longitudinally into halves. One half is placed under the joint to prevent tipping, the other half being placed over it for protection, and no cement is required. When examination of the electric wire may be required, the upper half is removed, a sharp knife passed along the joint separates the bandage, and the joint is opened. After the examination the joint is closed, a fresh saturated bandage applied, and the half collar replaced.

BESSEMERIZING COPPER MATTES.—Pierre Manhés claims to have overcome all the difficulties in Bessemerizing copper matte, and to have charge of an establishment which is, at the present time, successfully making copper on a commercial scale. He melts the ore in a suitable cupola furnace, casting the matte produced into a Manhés converter, when, under the action of a high pressure blast, it is rapidly transformed into 98 0/0 to 99 0/0 black copper The Manhés works consist of three cupolas of twenty-five to thirty tons' capacity per day; two small cupolas for remelting the matte in case of need; three Manhés converters, treating a ton and a half of matte at each operation, and each making twenty-two to twenty-four operations per day; and the necessary blowing-engines. Manhés claims that cost of labor is reduced to a minimum, because operations last only a few minutes, and large quantities of metal are handled. The cost of fuel is low; because no fuel is needed to bring the matte forward to black copper, except that used for the blowing-engine. The saving in cost over the Welsh or Swansea process, according to local conditions, is from 50 0/0 to 75 0/0.

ECONOMICAL PUMPING-ENGINES.—Mr. C. T. Porter reports the duty of the Gaskill engines at Saratoga as 106,000,000 pounds, raised one foot high, per 100 pounds of hand-picked coal. The Corliss engines at Pettaconsett, Providence, R.I., gave a duty of 113,271,000; and the Pawtucket engines have an average, for the year 1882, of 113,500,000. The slip of valves is reduced to one-half of one per cent.

Economy of steam-boilers.—William Kent reports, to the American society of mechanical engineers, the results of a series of tests of fuels in various ways, and under various forms of boilers. He gives the following as relative values of fuels determined by burning under the Babcock & Wilcox boilers:—

Welsh bitum	109.6.
Scotch bitum	109 5.
Cambria, Penn., semi-bitum	91.2.
Pittsburgh, Penn., bitum	99.5.
Ohio bitum	84.9.
Vancouver's Island	85.7.

Preventing the Freezing of Water in Water Closets. According to this invention, the inventor, Mr. J. W. Blakey, applies a receptacle or box at any suitable or convenient position between the water main and the point where such water is discharged, and fills the receptacle or box with rock or other salt. The water pipe is coupled or attached to each end of this receptacle or box, so that any water that comes from the main to the discharging point has to pass through the box. The pipe connections are moreover so arranged that a portion only of the salt is exposed to the rush of the water, and so that only a suitable portion of the salt is taken up each time. The water passing through the box takes up the required quantity of salt which has the effect of preventing it freezing. A salt-supply receptacle is arranged in connection with the box and a valve for recharging the latter therefrom as required.

Hardening soft limestones with fluosilicates.—The application of alkaline silicates to the exterior of buildings, in order to prevent the deterioration of the stone, has not been attended with satisfactory results. H. L. Kessler proposes to use a solution of fluosilicates of bases whose oxides and carbonates are insoluble in a free state. When soft limestone is saturated with a concentrated solution of a fluosilicate of magnesium, aluminum, zinc, or lead, a very considerable degree of induration is soon reached, and the resulting products, except the liberated carbonic anhydride, are less soluble than the stone itself. No varnish is formed, and therefore no danger arises from expansion of frost beneath it. The process has resisted the severe tests of winter. Colors may be introduced satisfactorily.

Simple and Compound Engines on Short Routes.—Mr. Boulvin has determined a series of formulas expressing the relations between size of vessel, weights carried, and distances traversed, and the weights of the simple and the compound engine, and finds, that, for short routes, the best form of engine is the single cylinder rather than the compound. He finds that for lines from twenty to sixty miles in length, as those from Dover to Calais and from Ostend to Dover, a gain of a knot an hour may be obtained by the use of the simple engine instead of the compound, in consequence of the saving in weight of machinery. On long routes the economy is on the side of the compound engine, in consequence of the saving in weight of fuel. The later practice of English constructors has been in accordance with this result, and with the principles involved in the work of Mr. Boulvin. He constructs curves showing the equations graphically, and illustrates their use by examples.

Heavy engines and American railroad-tracks.—Mr. O. Chanute states that heavy "consolidation" engines do not injure the track more than the lighter engines formerly did. Trains have been lengthened from 22 cars in 1874 to 38 in 1883; and the weights hauled, from 106 to 228 tons. By strengthening draw-heads, links, and pins, accidents from breaking apart of trains have been diminished, and the cost of haulage has been reduced from one cent to a half-cent per ton per mile.

M. P. **Tihon** has lately shown at the Industrial Science Society of Lyons a new semi-incandescent lamp, giving the brilliancy of an arc light. This is attained by having two carbon rods, slightly inclined to one another, brought down on to a small prism of chalk, and separated from one another by a small rod of the same material. The current passes through the chalk rod making it incandescent. By this means the light is rendered steadier than an arc light, and it is said to have the same brilliancy.

Mahogany Stain.—A very good and cheap method of preparing mahogany stain is to boil one pound of logwood in four quarts of water, and add a double handful of walnut peelings. Boil again, take out the chips, and add one pint of vinegar. This does best for beech wood. Another method is to grind burnt sienna in ale or vinegar, make it thin, spread on with a brush, and, while wet, it may be grained and shaded with the same, using burnt umber. For black walnut use the same, using burnt umber. For yellow stain, grind and mix with ale or vinegar, aloes or gamboge; or, make a stain by boiling curcuma in water.

Nature-Printing.—A novel style of printing from natural objects has just been perfected by Mr. Thos Stonywood. In this process the impressions are taken directly from the objects themselves, thereby possessing a vigour and a freshness, to which mere copying, however artistically done, could never attain. Articles as diverse as a spider's web and a mutton chop are reproduced with almost photographic exactitude, round objects and flat being copied with equal facility. Thus leaves are copied with exquisite effects. As impressions of both large and small specimens can be transferred and on any substance, many channels are opened for the employment of this ingenious method of printing.

Credit to an American Naturalist.—In an official report by M. Bouchen-Brandely, secretary of the college of France, the author states that he has learned by two years of study that the sexes of the Portuguese oyster are confined to separate individuals; that after this discovery he conceived that it might be possible to artificially fertilize the eggs of this mollusk; and that, after two years more of experimenting, this attempt has been successful. Americans will be interested to learn that in 1879 an American naval officer, Lieut. Francis Winslow, who was stationed at Gibraltar for a few weeks, determined the unisexuality of the Portuguese oyster, and reared it from artificially fertilized eggs. His results were printed in the *American naturalist* in 1879 or 1880; but, as I have no opportunity for reference at present, I cannot give the exact date.

Cocoa and Chocolate.—Many drinkers of these pleasant beverages are unaware as to the method by which the cocoa seeds are obtained. Cocoa, or cacao, is extracted from the seed of small trees of the genus theodrama, which, when cultivated, grows from 12 ft. to 18 ft. high, but to a higher elevation in their wild state. The flowers are small, and cluster on the branches and trunks, the matured fruit appearing as though artificially attached. Out of each cluster only one pod is allowed to mature, and this when full grown is from 7 in. to 10 in. long by 3 in. to 4½ in. wide. The five cells contain each a row of from five to ten seeds embedded in a pink, acid pulp, the cocoa bean. The tree is indigenous to Mexico, but it can be cultivated within the 25th parallels of latitude, and thrives at any elevation under 2,000 ft., but it requires a rich soil, a warm humid atmosphere, and protection from cold winds. The trees are propagated from seeds in a nursery until they attain a height of from 14 in. to 18 in., when they are transplanted and carefully sheltered by planting other trees about them. They commence to bear about the fifth year, but do not attain maturity until the eighth, and continue yielding fruit for nearly half a century. There is no special time for harvesting the crop, as the trees continue bearing all the time, flowers and fruit in all stages being curiously borne on the same tree. But in Venezuela the principal gatherings are in June and December. Chocolate is generally made from the finer varieties of cocoa seeds, and was a favourite beverage in Central America long before Columbus discovered the New World. As at present prepared, chocolate is made in cakes, while cocoa is usually sold in powder, flakes, or nibs. The constituents of the average cocoa seed are as follows: — Fat, cocoa butter, 32; nitrogenous compound, 20; starch, 20; cellulose, 2; theobromine, 2; saline substances, 4; water, 10; cocoa red, essential oil, 10.

The following is an illustration of what private enterprise may effect for the benefit of science. When the Swedish ship *Monark* was leaving Sweden last year for Australia the second officer on board applied to the Zoological Museum at Upsala for the loan of a trawl and some vessels for preserving natural history objects. The results have been the collection of some 120 species of fish, 50 of insects, some birds, and about 100 varieties of the lower sea fauna of the Pacific, which have now arrived at Upsala.

A strange sassafras-leaf.

The observations upon the sassafras-leaves — a report of which appeared in SCIENCE, no. 36 — have been continued through the year, with results which do not differ materially from those already given. Three other forms, however, have been found, which are given in the accompanying outline-engravings. Fig. 1 shows a peculiar modification of the three-lobed form, and differs from it in having the main central lobe reduced to a slightly raised emarginate end to the leaf. At first sight it seemed as if the leaf had lost its middle lobe by some foraging animal; but the absence of any roughness in the outline, and other characteristics of the edges, preclude this view. The form shown in fig. 2 helps to confirm the above view. In this we have a three-lobed form, with the lateral lobes unequal, and the central and upper portions of the leaf inverted heart-shaped (obcordate). The mid-rib has stopped short, and divided into two equal parts, which run to the tips of the two diverging lobes. If this failure of the mid-rib to extend had taken place earlier, a leaf might have been produced similar to the one shown in fig. 1.

FIG. 2.

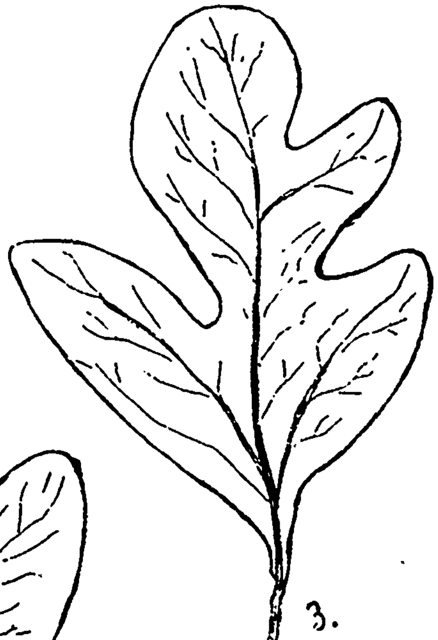

FIG. 3.

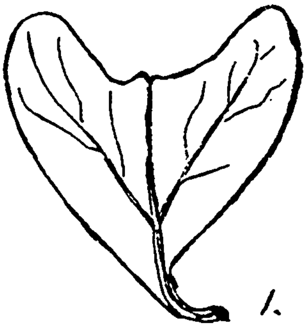

FIG. 1.

The most interesting of the three new forms is shown in fig. 3. Here we have a happy combination of the three-lobed and the 'mitten' form. The manner in which this has been accomplished is simple, and is fully shown by the outline given. The middle lobe has become lobed upon one side, — a 'thumb' has formed; and, were the lower portion of the leaf removed, it would leave a 'mitten' of good shape. The whole framework of the leaf has become somewhat distorted: the mid-rib does not take a direct course; and the lower lobes are neither equal, nor at the same distance from the base of the leaf.

It is due the reader to state that these three forms were all found upon the same shrub, — not a large one, — and that only a single specimen of each was discovered. These were all upon the same branch, though scattered among fifty or so of leaves of the three forms before described, and which, from their uniform presence, may be considered normal. How shall these deviations be viewed? Is the foliage of the sassafras passing through a period in which different forms of leaves are being tried to see which is best adapted to the surroundings? It may be that there is a tendency from the simple towards the more complex; and fig. 3 shows the form which even the philosophic botanist know but little; but, when one finds these deviations from the common form, he cannot help wondering after what end the plant bearing them is striving.

BYRON D. HALSTED.