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BRIDGE ACCIDENTS.

BY P. A. PETERSON, M. INST. C.E.

The accidents that have occurred on this continent to iron railway bridges, built within the last fifteen years, have not been the result either of faulty design or of weakness of the material used, and while so much is being constantly written about design, nature of strains, safe loads, factors of safety &c., little or nothing has been urged as to the duty of protecting the bridge, after it has been well built, from the accidents caused by derailed trains, which experience has shown to be its greatest, if not its only, source of danger.

A large percentage of railway bridges are so placed that all trains going towards them have to go down a grade and round a curve to reach them, and have another curve to go round and grade to ascend in getting away from them, and with heavy freight trains and light engines, drivers run very rapidly down the grade and round the curve over the bridge, in order to get up the grade and round the curve on the other side, and consequently bridges are often crossed with heavy freight trains at speeds exceeding fifty miles per hour. Of course engineers will report against this practice, and superintendents will issue orders against it, and drivers will endeavour to carry them out, till they get stuck in the grade two or three times, and are censured for not *making time*, when they return to their old practice and their old pace over the bridge, of which the superintendent takes no notice— he has issued his order and thinks he has done his duty in the matter—and when one of the many things, that may throw a freight train off the track at this speed, happens and pitches a locomotive or car into the end post of a bridge, knocking it out, and so throwing the bridge and train into the river, the bridge has to take the burden of the blame, and is found fault with for not fulfilling a duty for which it was never intended, and which it never should be called upon to perform.

Within the last five or six years bridge-floors have been very much improved, and generally, upon first-class lines, the floors are now so constructed, that an engine can pass as safely over a bridge off the track as upon it, providing it does not run into one side of the bridge and knock out an end post or some other important member. Upon a few lines, rails running from a point in the centre of the track, about 100 feet from the end of the bridge, diverge gradually, till near the face of the abutment they come close to the track, where cast iron inclines are placed to lift the wheels on the rails. This has been found very effectual when the speed has not been too great, in putting derailed trains upon the track.

With good floors, proper guard rails and safety points, "deck" bridges are comparatively safe, but something more is required for "through" bridges. The first thing that suggests itself is that they should be widened. The writer made an attempt to have this carried out some six years ago, and endeavoured to get two feet added to the width of all the bridges upon an important line of railway, he only succeeded in getting the addition of one foot sanctioned by the government, it being urged by the contractors as well as the builders of the bridges that even this was one foot more than the standard adopted on the American roads. The idea of additional width is, however, gaining ground, the Great Western Railway being the first to give a clear width of twenty feet between the inside of the trusses of its "through" bridges.

In addition to this increased width there should be some manner of more fully protecting the end posts, and the most ready method of accomplishing this seems to be by means of heavy masonry walls, laid in Portland cement and well dowelled together, carried up eleven feet apart, to the height of an ordinary passenger car. While it can not be said that these modifications and additions will prevent all accidents to bridges, yet it must be admitted that they will go a great way towards it, and in such an important matter all that can be done should be done.

ANTWERP WATER WORKS AND USE OF SPONGY IRON FOR FILTERING.

At the eighth Meeting of the Session of the Institution of Civil Engineers held on Tuesday, the 16th of January, Mr. James Brunlees, F.R.S.E., President, in the chair, the Paper read was on "The Antwerp Water Works," by Mr. William Anderson, M. Inst. C.E.

The Author commenced by stating that in 1879 the concession for the supply of water to the city of Antwerp fell into the hands of his firm. Antwerp had a population of 200,000 inhabitants; it ranked as the third largest port in Europe, and was being rapidly extended and embellished. Previous to the construction of the works the water supply was derived from shallow wells and open canals. As the sewage arrangements were very imperfect, the well water, though clear, bright, and sparkling, was for the most part dangerously contaminated. The scheme adopted by the Author's firm, the only one practicable from a financial point of view, was originally suggested by Mr. J. Quick, M. Inst. C.E.. and consisted in taking the waters of the river Nethe, an affluent of the Escaut, at a point 11 miles from Antwerp, where it was crossed by the Malines Road. The waters of the Nethe were, however, quite unfit to compete with the existing supply, after only ordinary filtration through sand, because they were greatly coloured by peaty matter, and very finely suspended mud, which could not be separated either by subsidence or filtration. Moreover, there would have been great risk in introducing into an important town, water from a river which flowed through a highly cultivated and populous country; and the attempt to supply Antwerp from the Nethe would probably never have been made had not Professor Bischof's process of filtration through spongy iron come under the notice of the Author. The properties of finely divided metallic iron as a material for filters had, for some time, attracted the attention of chemists. Professor Bischof, Dr. Frankland, and Mr. Hatton had demonstrated that it possessed the power of destroying organic impurities, removing colour, separating finely suspended matter, softening, and above all, destroying the germs of putrefaction, of bacteria, and probably those of epidemic diseases. To confirm the evidence afforded by laboratory experiments, and by spongy iron domestic filters, which had been in use for some time, it was determined to carry out experiments on a large scale at Waelhem, the proposed site of the intake of the works, under the auspices of Mr. Ogston, Assoc. Inst. C.E. The arrangement recommended by Professor Bischof took the form of a pair of filters, having an aggregate area of 680 square feet. The first filter was to be placed on a higher level than the second, and to be filled with a bed of spongy iron and gravel, mixed in the proportion of one to three, covered by a layer of ordinary filter sand, the office of which was to separate the grosser suspended matter. In this filter the water would become charged with iron, to eliminate which it was to be exposed to the air, and passed through a second or ordinary sand filter in which the red oxide would be deposited. The experiments were carried on for three months, and proved so satisfactory that all doubts about the efficacy of the process were removed, and the designs were made for the permanent works.

The terms of the concession required a daily supply of 33 gallons per head for 175,000 inhabitants, or nearly 6 million gallons per day; but, in the first instance, the pumping machinery and main were to be laid down for only 40 per cent. of that quantity. The works consisted of a 42-inch intake pipe, two settling ponds of an aggregate capacity of 2,640,000 gallons, a pair of Airy's screw pumps, worked each by an independent engine, for raising the settled water 19 feet into the spongy iron filter beds; three spongy iron filters having an aggregate area of more than 31,000 square feet, three sand filters of the same area, two cast iron filtered water tanks, containing together 340,000 gallons, and two pairs of beam pumping engines of 170 H.P. each, together with their boilers and fittings. The Nethe being a tidal river, carrying up the drainage of Malines on the flood and bringing down that of the villages on its upper waters on the ebb, the authorities prescribed certain limits within which alone the waters should be taken; these restricted the time available for filling the settling ponds to about three quarters of an hour in each tide. The settling ponds, of a capacity to hold twelve hours supply, were excavated immediately in rear of the river bank and lined with dry stone pitching. The nature of the ground was exceedingly treacherous, a bed of water-logged silt extending under the whole area, at a depth of 6 to 7 feet below the surface; it was thought prudent, therefore, to construct the filter beds entirely of earthwork resting on the surface, and to trust to puddle linings to secure the necessary water tightness, and to adopt pile foundations for the engine house and chimney.

The environs of Antwerp being very flat did not permit of a high service reservoir being constructed, the filtered water-tanks were, therefore, placed close to the engine house, and the service was maintained by uninterrupted running of the engines, which, for this purpose, were arranged in pairs, each pair coupled at right angles, so that they could run at any speed between 1½ and 22 revolutions per minute. To provide against the effect of frost, the novel expedient was adopted of heating the water, as it flowed to the screw pumps, by means of injected steam, the Author stating that the experience of last winter seemed to indicate that the arrangement would prove efficient.

The result of eighteen months working had been very satisfactory, the water having remained pure, bright and clear throughout the time. The spongy iron had not shown any signs of deterioration or wasting; and Dr. Frankland, who had visited the works, had reported very favourably of the process employed, not only with respect to the chemical condition of the water, but also with reference to the complete destruction of bacteria and their germs.

The water from the pumping station was carried in a 20 inch main for 10 miles along the Malines Road; its course was described at length, together with the appliances for getting rid of air and of avoiding dangerous shocks. The distribution of subsidiary mains and service pipes in the city was explained, together with the manner in which the various services were laid on. By the system adopted a constant circulation was kept up as far as possible in the distribution pipes throughout the city. It permitted a ranges of pipes to be shut off without stopping the supply of the neighbouring streets, and even often enabled the service to be kept up when portions of one of the mains had to be shut off. A comparison was instituted as to the relative cost of German and English pipes. The manner of testing, as fast as the pipes were laid, was described, and the Paper concluded with the statement that the works were erected in fifteen months, at a cost of £280,000.

◆

ON GOVERNING ENGINES BY REGULATING THE EXPANSION.

BY WILSON HARTWELL OF LEEDS.

(*Concluded from page* 50.)

Perfect governing.—Perfect governing with automatic expansion gear is illustrated by Fig 7, Page 49. The full line on the lowest third of the diagram indicates the load, that is, the mean pressure on the piston which would exactly balance the load: this may be called the independent variable. The dotted power-line running beside it shows the actual mean pressure on the piston, or the power. It is obvious that the spaces enclosed between the zero line and the load line, and between the zero line and the power line, will on the average be equal to each other, as illustrated by the horizontally and vertically shaded spaces. *When the load is in excess, the speed and the* position of the governor will fall. When the power is in excess, the speed and the position of the governor will rise. The diagram is merely illustrative, and not quantitative. Thus the load is supposed to rise suddenly from 3 to 4, and simultaneously the speed of the engine, the position of the governor, and the mean pressure on the piston begin to vary, until the power rises to balance the load. The speed then remains uniform, but rather slower. This is shown by all the lines changing to position 4, and remaining there. The horizontally shaded space represents the power given out by the fly-wheel. Further on the load is supposed to fall to 2, and the speed to rise to 2. The vertically shaded space then represents the power absorbed by the fly-wheel.

Retardation from storage.—This is illustrated by Fig. 8, Page 49. The load is supposed to vary from 2 to 4. The speed line falls from 2 to 4, and the governor line does the same; but owing to the storage the mean pressure or power line does not simultaneously rise to line 4. The speed therefore continues to fall, say to line 5, and the governor, instead of remaining at position 4, falls to position 5, thus putting on too much steam. The speed will then begin to rise again until too much steam is shut off; and in consequence several oscillations of speed take place without any further change in the load.

Retardation from friction.—Fig. 9, Page 50, shows the outline of a pendulum governor with balls 5 in. diameter, about the size usual in an 8-HP. engine. Fig. 10 shows the speed due to the balance of the centripetal and centrifugal forces, and to the effect of friction. Here A R_1 and A R_2 are the minimum and maximum radii of the governor balls. The centripetal curve C_1 C_3 C C_2 is drawn so that any vertical ordinate R C equals the centripetal force at radius A R (say in lbs. to any convenient scale), due to the weight of the balls. The vertical ordinate drawn from R^2 to 60 represents the centrifugal force at radius A R^2 and at a speed of 60 revolutions per minute. Since the centrifugal force due to 60 revolutions per minute varies as the radius, any vertical ordinate to the line drawn from A to 60 will equal the centrifugal force at that radius due to that speed of 60 revolutions per minute. In like manner the other divergent lines indicate the centrifugal forces shown by the respective speeds figured on the ordinate at R_2. Let the point C be the intersection of the centripetal curve by any radial line, say that for 60 revolutions. Then R C is both the centripetal force at radius A R and the centrifugal force at the speed (*i. e.*, revolutions per minute) figured on that radial line. The speed is that which would support the ball at radius A R. The speed that would be indicated on the scale by a line drawn from A through any point C may be called "the speed due to point C."

The friction curves F_1 F_3 F F_2 and G_1 G_3 G G^2 are drawn by measuring C F equal to the friction to be overcome to move the balls outwards at any radius A R, and C G equal to that to be overcome to move the balls inwards.

The speed due to the point F is that to which the governor must rise before the balls can move outwards from radius A R, because R F is the centripetal force to be overcome. Similarly G indicates the speed to which it must fall before the balls can move inwards from that radius; because R G is the centripetal force pulling the balls inwards. For intermediate speeds at that radius, the radial distance of the balls will remain unaltered.

If the governor balls range from R to R_3 under variations of load, the variations of speed will be those indicated by the curves F F_3 and G G_3 instead of C C_3; and however slight the variations of load at radius A R, the speed cannot vary less than indicated by the points F and G.

If the radius be taken in feet, the area of the quadrilateral C^3 F_3 F C (measured by the horizontal width and mean vertical height to the respective scales) gives the work done by the governor in overcoming friction while opening from radius A R^3 to A R; and similarly the area C G G_3 C_3 gives the work done in closing from A R to A R_3. Similarly the area C_1 F_1 F^2 C_2 gives in foot-pounds (measured as above) the work done by the governor in moving outwards through its entire range; and C_1 G_1 G_2 C_2 the same on its return inwards. These areas will probably not be equal, unless the connections to the throttle-valve are balanced. Nor will the vertical lines C F, C F_3, etc., be usually equal. The area R_1 C_1 C_2 R_2, enclosed between the centripetal curve C_1 C_2 and the base line R_1 R^2, shows the work done to open the balls in lifting the governor weights, or compressing the spring in a spring governor. This may be described as the *governor power*. The "sensitiveness" of the governor is here taken to mean the ratio per cent. which the difference between the speeds indicated by the points C_1 C^2 bears to their sum. Thus, if S^1 and S_2 be those speeds, V =

$$100\left(\frac{S_2 - S_1}{S_2 + S_1}\right).$$

The "retarded sensitiveness" here means the sensitiveness under friction, or a similar percentage taken for the speeds given by the positions of the points G_1 and F_2.

The difference between the speeds due to the points F and G, measured as a percentage of the mean speed, may be called the "detention" at radius A R.

Under the conditions of ordinary practice, whatever be the form of centrifugal governor for which such a diagram as Fig. 10 is drawn, it will much resemble this figure in form. The speeds due to the points G, C, F will vary as the square roots of the ordinates R G, R C, R F. If the friction be comparatively small, the "detention" at radius A R will be nearly $100 \times \frac{\frac{1}{2} FG}{CR}$, which will be about the same as $100 \times \frac{\frac{1}{2}\text{area of } G_1F_1F_2G_2}{\text{area of } R_1C_1C_2R_2}$; or in general, the detention with all forms of centrifugal governors, will be equal or nearly equal to 100 times the mean friction to be overcome in traversing from R_1 to R_2 divided by the governor power (both measured in foot-pounds).

Governor Power.—Whatever the difference of construction between any two good centrifugal governors, still, if they are of equal power, the "detention" wil be the same; and if they are equally sensitive, the "retarded sensitiveness" will be the same; thus the governors will be about equally efficient. Otherwise the one with most governor power will govern best. In the above example the sensitiveness is about 5 per cent. from the mean. If the mean friction of the throttle-valve be 3 per cent. of the governor power, the detention will be 3 per cent., and the retarded sensitiveness will be 5 + 1½ = 6½ per cent.

In order to be ample, the governor power should be say 20 times the friction to be overcome; it may be 40 times with advantage. The description of any governor should state its free variation and its power. For example, the governor shown in Fig. 9, Page 52, with 5-in. balls at 8½ in. maximum radius, allows 6 per cent. variation from the mean speed, and its power is 5·6 ft.-lbs. It may be shown from Fig. 10, Page 52, and Fig. 28, Page 68, that as the friction curve is raised the governor begins to be unstable, commencing at the least radius. This would cause continuous "hunting," the balls flying out and returning slowly. The more sensitive the governor, the more possible is such an occurrence.

Retardation from friction.—The effect of this is to oblige the engine to change its speed sufficiently to overcome the friction every time the load is in the least changed, as shown in Fig. 11, Page 49. The load increasing from 2 to 3, the speed falls to 3 before the governor commences to move, and falls, say to 4 before the governor has fallen to 3. The increase of load again being taken off, the speed makes a large excursion in the opposite direction.

Retardation from storage and friction combined.—The total variations of speed, arising from the combined retardation from storage and from friction, are much greater than either separately. They are illustrated in Fig. 12, Page 49, where the load is supposed to increase from 3 to 4, and to remain constant. The governor, owing to the friction, does not begin to fall until the speed has fallen to 4; and when it does fall, the power line is not sufficiently changed till a little later. In consequence the speed continues to fall still more, and too much steam is admitted. The mean pressure thus continues to rise, and produces an opposite variation before the governor begins to go in the opposite direction. Thus one small variation of the load may produce a series of disturbances in the speed, although there be no further variation in the load. These effects may be noticed in an exaggerated form in a compound engine, where the governor works stiffly. By comparing Fig. 7 with Fig. 12, the immense advantage of governing the cut-off gear will be apparent. It is however but just to state that the same effect could be produced with the throttle-valve, if friction were a very small fraction of the governor power, and if storage could be got rid of.

SPECIAL AUTOMATIC EXPANSION GEAR.

The writer will now describe two arrangements of automatic expansion gear which he has devised, and which have been extensively and successfully used for some years.

The governor shown in Figs. 13 and 14, Page 68, and also in Figs. 18 to 21, Page 69 is fixed to the crank shaft, and was schemed especially for portable engines. Its design resulted from the following considerations: (1) that very great governor-power (several hundred ft.-lbs.) could be obtained by placing the governor in the fly-wheel; (2) that with so much power it would be easy to move the eccentric, and by some form of wedge gear to hold it when moved. It was afterwards found that sufficient power could be obtained in a much smaller diameter than that of the fly-wheel; and separate governor-drums were then adopted as more convenient.

Form applied to a separate cut-off valve.—Figs. 13 and 14, Page 68, represents this governor as applied to the cut-off eccentric of a fixed engine. It consists of a drum A. and weights BB, swivelling on the weight-pins C C. The weights are connected by the coupling-rod D., which is acted upon by the spring E. The eccentric F has play upon the shaft, as shown in Fig. 14 and also in Fig. 15, Page 68, but is solid with the eccentric-carrier G, swivelling on the eccentric-pin H. The governor is coupled to the eccentric-carrier by means of a curved solid link I called a quadrant (although really less than a quarter of a circle), which is fixed to the quadrant arm K, and works through a slot in the quadrant-pin J on the eccentric carrier G. The quadrant is placed oblique to the circular

AUTOMATIC EXPANSION.

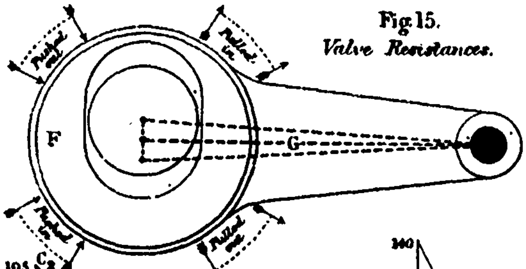


Fig 15. *Valve Resistances.*

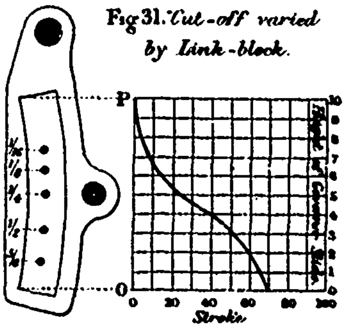


Fig 31. *Cut-off varied by Link-block.*

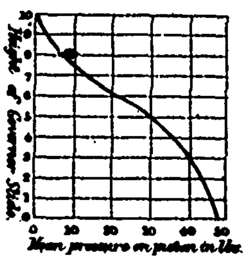


Fig. 32.

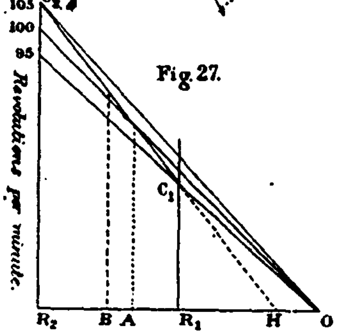


Fig 27.

(Proceedings Inst. M.E. 1882.)

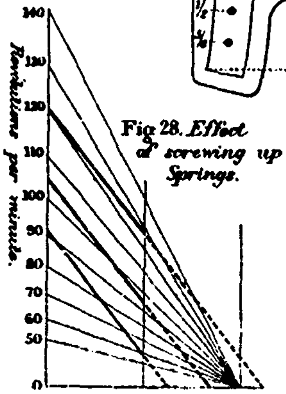


Fig 28. *Effect of screwing up Springs.*

Fig 29. *Variation 2% from mean.*

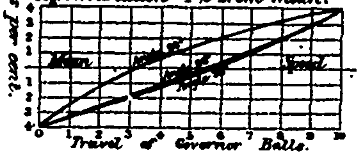


Fig 30. *Variation 4% from mean.*

Governor for separate cut-off valve.

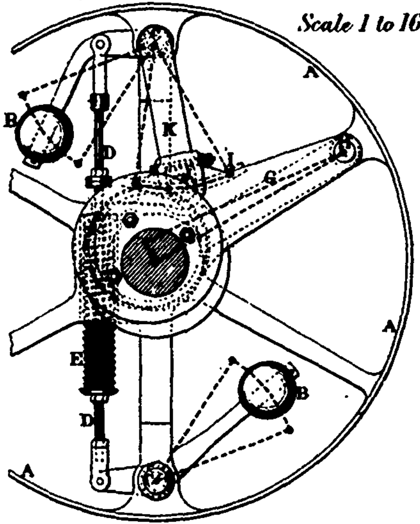


Fig 13. *Elevation.*

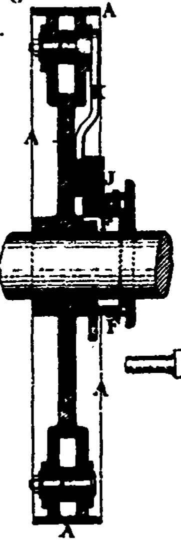


Fig 14. *Section.*

Scale 1 to 16.

(Proceedings Inst. M.E. 1882.)

Automatic Expansion Regulator

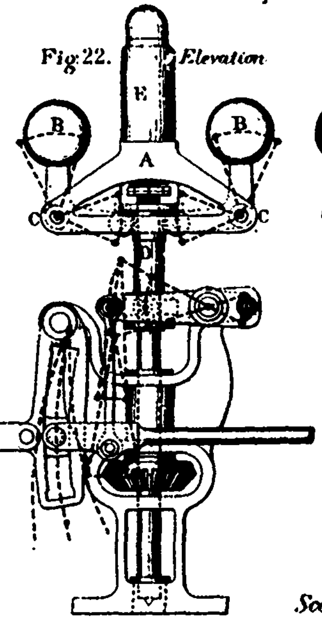


Fig 22. *Elevation.*

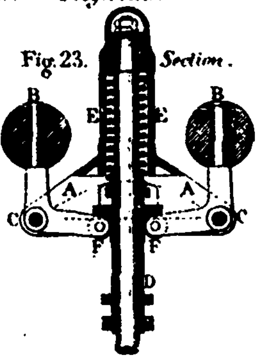


Fig 23. *Section.*

Fig 24. *Plan.*

Scale 1 to 8

AUTOMATIC EXPANSION.

Governor applied to single slide-valve.

Simpler form of Single-slide Governor.

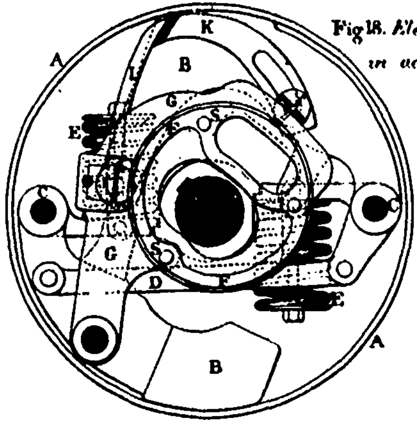


Fig 18. *Elevation, in action.*

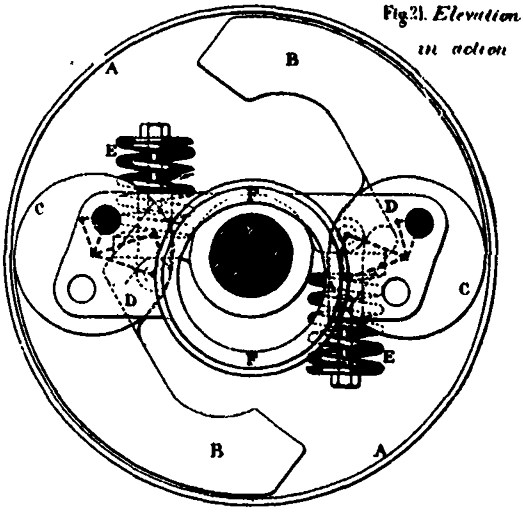


Fig 21. *Elevation, in action*

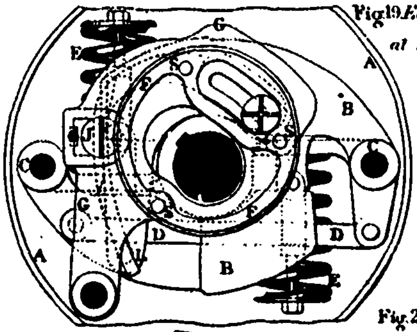


Fig 19. *Elevation, at rest.*

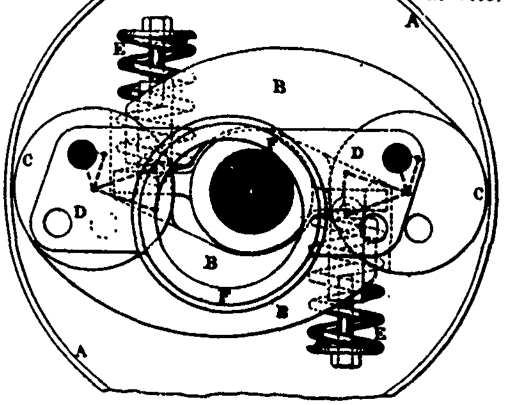


Fig 21*a*. *Elevation, at rest.*

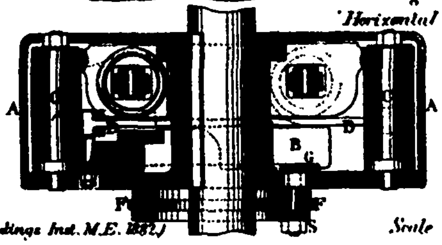
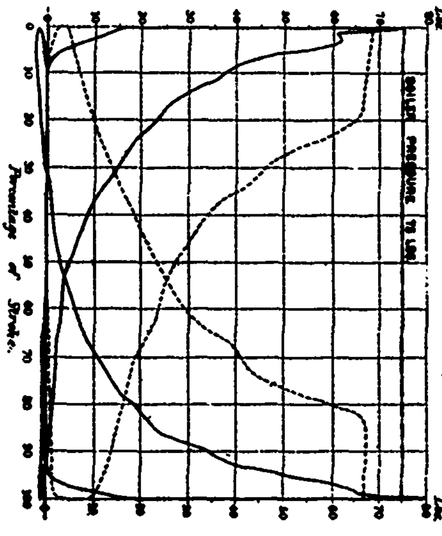


Fig. 20. *Horizontal Section.*

(Proceedings Inst. M.E. 1882.)

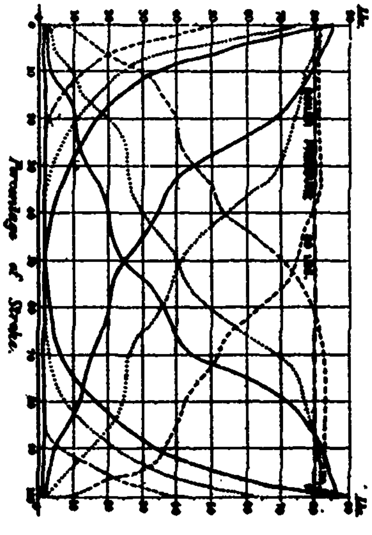
Scale 1 to 6.

Pressure above atmosphere, lbs. per sq. in.



(Proceedings Inst. M.E. 1882.)

Fig 34. *With Expansion Valve.*



Indicator Diagrams.

Fig. 33. *With Governor working single slide-valve.*

Pressure above atmosphere. lbs. per sq. in.

path it describes round the centre C, thus acting as a wedge, so that by its intervention the governor can move the eccentric, but *the eccentric, acting nearly at right angles to the wedge, cannot move the governor. It will be noticed that the eccentric* and the weights are guided in circular paths by pins, and not in straight line by slides; thus reducing friction to a minimum, and so ensuring greater delicacy of action.

The resistance of the valve may be considered as a force acting on the centre of the eccentric, as shown in Fig. 15, Page 68, and tending alternately to push it towards and pull it from the centre of the shaft during each semi-revolution. Thus the power required to shift the eccentric is obtained from the crank-shaft, and not from the governor. The incline of the link, and the other moving surfaces, are so proportioned that the friction produced by the resistance of the valve equals, as nearly as possible, the pressure tending to alter the throw of the eccentric. Thus the governor has little or nothing to do in order to hold the eccentric in place; and freely adjusts it at such times as the governor and the eccentric are acting in the same direction.

The cut-off valve used may have single ports; but to reduce *the travel of the eccentric, multiple ports* have been generally used, as shown in Fig. 16, and especially in Fig 17, Page 52.

Governor applied to ordinary slide-valves.—With small engines, say with less than 10-in. cylinders, it has been preferred for the sake of simplicity to use but one slide-valve. The governor was at first placed in the fly-wheel. It is now generally placed in a separate drum, attached to an eccentric which is coupled direct to the valve-rod. Fig. 18, Page 69, shows the interior of the governor as used for an 8-HP, or 10-HP. portable engine, with the weights open and the eccentric in mid gear; Fig. 19 shows the weights closed and the eccentric in full gear; Fig. 20 is a sectional plan. The drum is confined to 18 in. diameter, in order to clear the boiler. The parts have been arranged to use all the available space. The construction is essentially the same as in Fig. 13, but the quadrant can be set oblique in either direction, in order to reverse the engine. As before, A is the drum in three pieces, namely the disc-plate which is keyed to the shaft and turned on both sides to carry all the working parts, and the casing in halves; B B are the weights, C C their pins, D the coupling rod, E E the two springs, F the eccentric, G the eccentric-carrier, H its pin, I the quadrant, J the quadrant,pin, K the quadrant-arm. The eccentric F being outside the drum A, while the eccentric-carrier G is inside, the two are here fixed together by three stud-bolts S, which work through slots in the disc-plate of the drum, as shown in Fig. 20, these slots being struck from the centre-pin H of the carrier G. In Figs. 18 and 19 the disc-plate of the drum is supposed to be transparent. The outer *extremity of the quadrant I is pivoted in a prolongation of the* weight B which carries it, as seen at L in Fig. 19. The path of the centre of the eccentric from full gear forward to full gear backward is a circular arc struck from the centre-pin H. When the weights are closed, Fig. 19, the engine being at rest, the quadrant I puts the eccentric in mid gear (*i.e.*, opposite the crank-pin of the engine). In this position the quadrant-pivot L is nearly concentric with the carrier-pin H. The other end of the quadrant is held by a screw N. Suppose the quadrant set obliquely, to run the engine forward. Then, to reverse the engine, set the piston near the *end of its stroke*, insert a strong screw-driver through the open part of the eccentric across, and tighten the screw again.

This form of governor was first used at the Cardiff engine-trials ten years ago, and was immediately adopted by Messrs. E. R. & F. Turner, for their 8-HP. portable engines; from that time uninterruptedly until now the throttle-valve has been abolished in their 8-HP. engines. So far as the writer is aware, from that date it is the only automatic gear which has been thus used for portable engines, to the entire exclusion of the throttle-valve; or which is ever so used at the present day. With this governor it is difficult to detect any variation of speed under the most rapid and frequent changes of load. After a few governors had been made on the Cardiff pattern, it was found that larger wearing surfaces and more accurate work were desirable. The form of the drum was altered to that shown, in order to facilitate the application of machine work. The bearing surfaces were enlarged, and the adjustment fitted to the quadrant-pin; retaining however almost the identical centre lines. Some of these earlier governors were replaced; as were also the piston-valves, shown at Cardiff, by ordinary slide-valves. So far as the writer is aware, with the above exceptions the governor has been uniformly satisfactory; and he anticipates that automatic expansion governors fixed on the crank-shaft will in future be more used for small engines than any other kind of governor.

Another form of this governor is shown in Figs. 21 and 21a, Page 69. A is the drum, BB the weights, CC very large centre pins cast on the weights, D, the coupling rod, EE the springs, F the eccentric fixed on the coupling rod D. Although the friction of the pins C cannot hold the whole thrust of the eccentric, yet with quick-running engines the governor works well with the ordinary slide valve. Being simple and inexpensive it is being applied to such engines, including the cheapest forms, without increasing their cost. It can be reversed by attaching the coupling rod D to the opposite sides of the axes of the weights. Thus by means of governors placed on the crank-shaft and acting on the eccentric, throttle-valves may be abolished, and the advantages of being governed by regulation of the cut-off may be obtained in all sizes of ordinary engines.

Automatic expansion Regulator.—A governor and expansion gear not fixed on the crank-shaft, and therefore called for distinction by the above name, is shown in Figs. 22 to 24, Page 68. Here A is the body casting, B B the weights swivelling on the pins C C, D the slide, E the spring, F F two rollers which press on the slide. This was designed as a simple compact automatic expansion *gear suitable for small engines. It is capable* of any required degree of sensitiveness, and so powerful that it readily controls the expansion gear. The form of slide-valve used may be the same asgin Fig. 16 and 17, Page 52. That shown in Fig. 17 has been chiefly used for large engines. The cut-off is varied by means of the link gear shown in Fig. 22, which has been arranged so that, with a mean load, the eccentric-rod and valve-rod are in line, and there is little or no slip on the block. The whole is hung on the governor stand. The maximum incline of the link should not exceed 1 in 6.

Governor power obtained with springs.—This is much greater than can be obtained by the action of gravity in the same space. Fig. 9, Page 52, shows an outline of a pendulum governor for an 8-HP. engine, and Fig. 25, Page 52, shows that of the 8-H P. automatic expansion regulator to the same scale. The power of the former is 5·6 ft.-lbs, and that of the latter 37·2 ft.-lbs. The dotted circle, Fig. 25, shows the diameter of ball which, being raised the same height as the *spring, will give* an equal power. Fig. 26 shows a regulator for a 50-HP. engine with double springs; its governor power is 270 ft.-lbs. Comparing Figs. 9 and 25, both for the 8-HP. engine, the spring governor is six times more powerful. The most advantageous travel for the balls may be shown to be half the maximum radius. The large governor, Fig. 26, is of unusual power. The expansion governor used at the Cardiff trials had about 90-ft.-lbs governor power. The usual power for an 8-HP. engine is about 50 ft.-lbs.

Sensitiveness.—In this design the sensitiveness, or the variation from the mean speed required to traverse the governor, can be varied as desired. About 4 per cent. from the mean speed has been found best for small engines, and 3 per cent. *for large ones. The size of the fly-wheel must be such that* the variation of speed from the main in each semi-revolution is less than half the sensitiveness of the governor. Suppose *for the sake of simplicity* that the arms B C, C F of the bell-crank levers in Fig. 23, Plate 78, are equal and at right angles; then in all positions the vertical compression of the spring equals the radial movement of the balls.

Let us suppose that the *mean speed* is 100 revolutions per minute, and the sensitiveness 5 per cent. Let Fig. 27, Page 68, be a diagram drawn in the same manner as Fig. 10, Page 52. The centripetal line with a right-angled bell-crank will evidently be a straight line. Draw this centripetal line C_2 C_1, and produce it until it meets the base at H. Then H R_1 is the initial compression of the spring required, H R_2 is the total compression, R_1 C_1 and R_2 C_2 are the minimum and maximum loads or pressures due to these compressions. Obviously the spring may be such as to give any desired maximum and minimum speed of revolution which will balance it in those positions; *or the governor may be made isochronous, if the initial* compression bears the same ration to the total compression that the minimum radius of the ball bears to the maximum.

Screwing up the springs.—This necessarily increases the mean speed of the governor, since it increases the load to be overcome; but it also increases the sensitiveness. This will be obvious by inspection from Fig. 28, Page 68, which is constructed like Fig. 27, but with several centripetal lines parallel to each other. These show the centripetal forces exerted by the same spring with more or less initial compression. If the minimum speed is 57, the maximum is 90 as in the lowest line; but if the speed at the least radius be 125, that at the greatest radius is only 120. For the increase of centripetal force due to the spring is a constant quantity; whilst to maintain the sensitiveness unaltered the difference between the centripetal forces at the extreme positions of the balls should increase with the square of the speed. If screwed up too much, the governor "hunts," because the speed required to open the balls is greater than that at which they begin to close. The governor balls, when they begin to move, are in unstable equilibrium, and travel rapidly from one extreme to the other. The speed of the engines alternates from the maximum to the minimum, the governor balls pausing at the least radius while the speed rises, and *vice versa.* These results from screwing up the springs are evidently true, whatever the form of the centripetal curve may be; and are therefore the same in all known forms of spring governors. To increase or diminish the speed of any spring governor, stiffer or weaker springs must be used, since screwing and unscrewing any particular spring would make it either too sensitive or too sluggish, excepting for very small adjustments.

Angle of the bell-cranks.—In Fig. 27, Page 68, the radial distance of the point where the centripetal curve is intersected by the line indicating the mean centrifugal force is the radial distance of the governor balls at mean speed. It appears from inspection that the mean radius of the balls with a rectangular bell-crank must be greater than the radius due to the mean speed. To correct this the angle of the bell-crank, B C F, Fig. 23, Page 68, has been increased. This causes the centripetal lines (in such a diagram as Fig. 10, Page 52,) to become curved. The exact effect of increasing the angle has been calculated for a progressive series of angles and for various mean speeds. This effect is indicated in Figs. 29 and 30, Page 68, by "variation curves." Thus the vertical from point 5 to the upper curve, Fig. 29, gives the variation of speed, above or below the mean, at 0·5 of the travel, the crank-angle being 90°, and the sensitiveness 2 per cent.; and similarly for the other curves. The angle of crank chosen for the automatic Expansion Regulator is 96°, but for the governor with 5 per cent. limits of speed the angle may be increased.

Thus in Fig. 23, Page 68, when the spring E is at right angles to its lever C F, the ball levers C B make an angle greater than 90° (such as 96°) with the direction of the centrifugal force, in order to make the mean position of the governor weight nearly correspond with the mean speed. These considerations apply equally to the governor on the crank-shaft, Figs. 13, 14, and 18 to 21, Pages 68 to 69; and the position of its spring-lever must be determined on the same principles, so as to make the two forms nearly equally sensitive at corresponding radial position of the balls. Rollers F F, Fig. 23, Page 68, carry the pressure of the spring to the end of the levers, and are used in preference to links, because by this means the direction of the pressure is always exactly parallel to the axis, thus maintaining the correct relation of the cosines of the angles which C B and C F make with the vertical and horizontal respectively. The varying inclinations of connecting links were found to produce inadmissible irregularities in the various curves.

The relation between the position of the link-block in its link and the point of cut-off, with the automatic regulator, Fig. 22, Page 68, is shown in Fig. 31, Page 68. The link itself is shown on the left. The length of the horizontal base line represents the stroke of the piston; and the horizontal distances of the curved line from O P give the mean points of cut-off for the corresponding heights of the link-block in the link. By means of this curve the points of cut-off may be marked on the link itself, as shown.

The relation between the height of the governor slide D, Fig. 31, Page 68, and the mean pressure on the piston with 60 lbs. initial pressure (as in Fig. 2) is shown by Fig. 32. The horizontal distances to the curved line represent the main pressure on the piston in lbs., corresponding to the heights of the governor slide, which are marked in tenths. These mean pressures vary a little according to the proportion of the valves and gear, and of course vary with the initial pressure of steam on the piston. Assume Fig. 32 to be correct for any automatic regulator whose sensitiveness is 4 per cent., with its variation curve like Fig 30. Then, when the mean position of the governor is at 5 in Fig. 32, the engine would be nearly at the mean speed, and at the mean pressure of the piston, or 30 lbs. If one-third of the work were thrown off, reducing the mean pressure to 20, the position of the governor slide would be at 6 in Fig. 32, and the speed of the engine would be increased, as shown by Fig. 30, only about ⅜ per cent. In like manner, if half the load were taken off, reducing the main pressure to 15 lbs, the position of the governor would be about 6·6 on Fig. 32. showing an increase of speed of only about 1¼ per cent. on Fig. 30. Thus it will be noticed that great variations of load are required to produce 1 per cent variation in speed.

Applications of the governors.—The expansion governor, as already noticed, has been adopted by Messrs. E. R. & F. Turner on all their 8-HP. engines since the Cardiff show of 1872: the first few made were however replaced by the later form which has been described. It has also been much used, acting upon the expansion valve, for various fixed engines made by Messrs. Turner themselves, and also by Messrs. Allen Ransome & Co. and others. The expansion regulator has been extensively used by Messrs. Marshall Sons & Co. on engines of all sizes, fixed and portable, and on all their large stationary engines. It has been applied to large compound condensing engines, and has been comparatively much used for electric-light engines.

Indicator Diagrams.—Those for the expansion governor with single slide valve are identical with those produced by link motion, as will be seen by those shown in Fig. 33, Page 69. Fig. 34 shows others taken with a separate expansion-valve; and these are identical in general arrangement with those obtained from the automatic regulator.

ECONOMY IN STRUTS AND TIES.

BY J. A. L. WADDELL, C. E., Ma.E.

Prof. of Civil Engineering in the University of Tokio, Japan.

Much has been written concerning economy both in bridges as a whole and in their members, but in the writer's opinion the method of investigation adopted has not been a correct one. There are so many variables to be considered in dealing with the subject that it is impossible to employ any exact analysis, as there is no use in writing out a long string of equations to determine the most economical style of bridge. By the latter we do not mean a structure where the stresses are reduced to a minimum, nor the one which weighs the least, but the one which for a given strength and stiffness will cost the least money.

So then in dealing with the bridge members mentioned in the title of this paper, it will not be sufficient to ascertain the most economical inclination of struts and ties, but it will be necessary to consider the effect of these inclinations upon the other members and upon the whole structure.

For a number of years it has been known that where the working stresses for compression and tension are equal the best arrangement would be to incline both strut and tie equally to the vertical, supposing also the sections of both members to be the same.

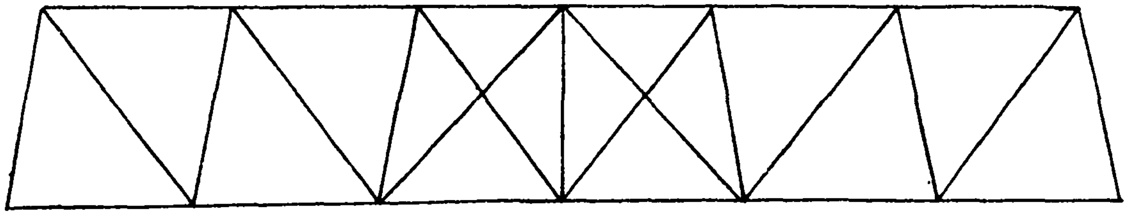
Again it may be shewn by a very pretty demonstration involving the use of the calculus, that where k is the ratio of the working stresses (k being greater than unity) and where a and b are the angles of inclination of the strut and tie, respectively, to the vertical, the amount of material in these members will be a minimum, sections only being considered, when

$$\frac{\tan b}{\tan a} = k.$$

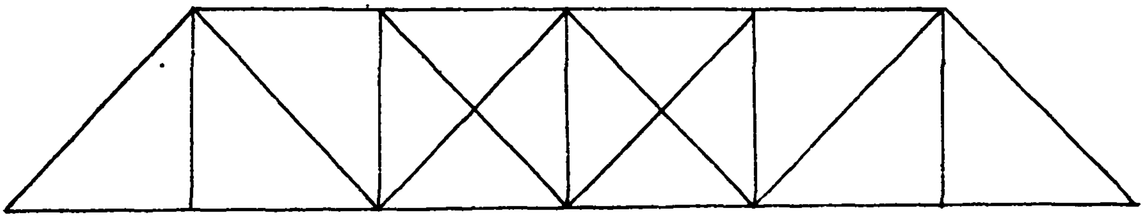
But this result is of no practical value, for k itself is a variable, and moreover the weight per running foot of the strut is increased by the latticing and rivets. Nor does the variation end here for the cost per lb. of strut iron is greater than that of tie iron.

How then should the problem be investigated? Simply in a practical manner, by assuming several cases

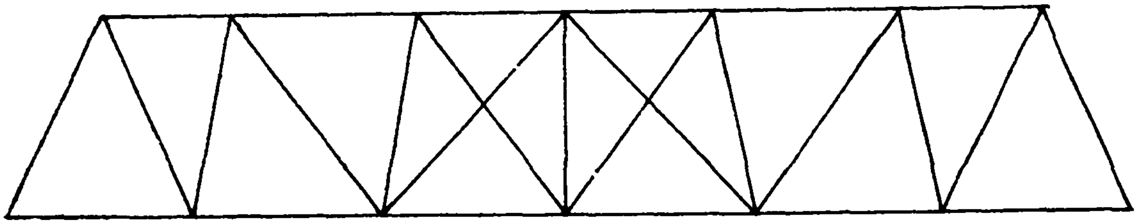
TRUSS 1.



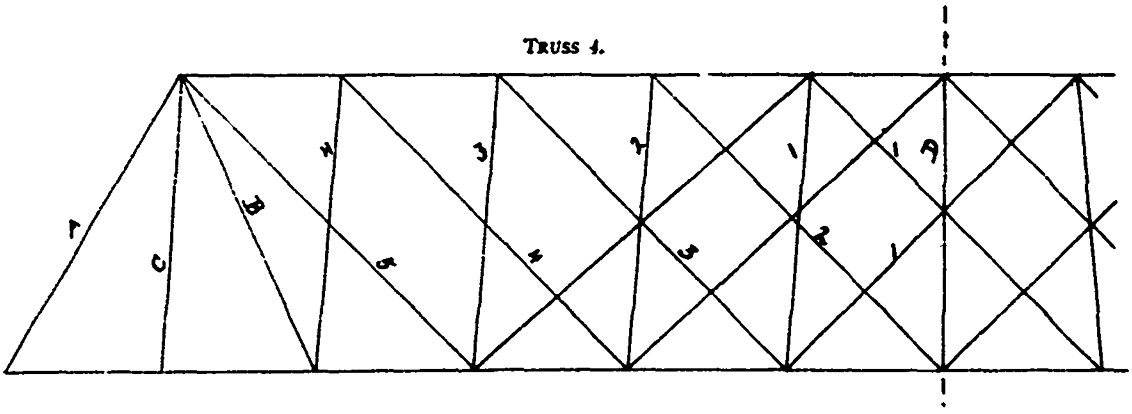
TRUSS 2.



TRUSS 3.



TRUSS 4.



TRUSS 5.

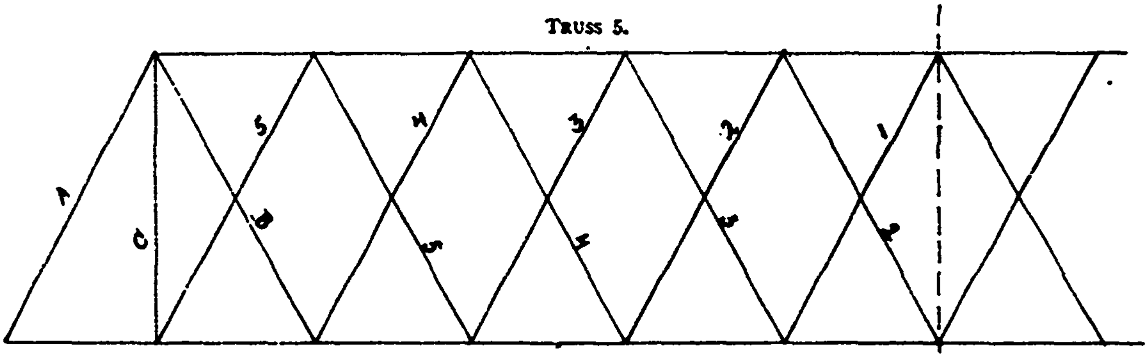


TABLE I.

No.	TIES.							STRUTS.										Total Cost in $
	Length	Sec.	Stress.	Sect'n in sq. ins.	Equiv. Length	Wgt. in Lbs.	Cost in $	Length	Section.	Stress.	Chans.	Work'g Stress in Tons	Section in sq. ins.	Wght. in Lbs.	Wgt. of Details in Lbs.	Total Wght. in Lbs.	Cost in $	
1	22.36	1.118	22.36	4.47	25.36	378	17.77	22.36	1.118	22.36	8–17.8	2.094	10.68	796	489	1285	70.68	88.45
2	22.83	1.141	22.83	4.57	25.83	393	18.47	21.93	1.096	21.93	8–17.18	2.127	10.31	754	481	1235	67.93	86.40
3	23.32	1.166	23.32	4.66	26.32	409	19.22	21.54	1.077	21.54	8–16.62	2.160	9.97	716	474	1190	65.45	84.67
4	23.85	1.193	23.85	4.77	26.85	427	20.07	21.19	1.059	21.19	8–16.12	2.193	9.67	683	468	1151	63.31	83.38
5	24.41	1.221	24.41	4.88	27.41	446	20.96	20.88	1.044	20.88	8–15.62	2.227	9.37	652	463	1115	61.33	82.29
6	25.00	1.250	25.00	5.00	28.00	467	21.95	20.62	1.031	20.62	8–15.19	2.262	9.11	626	458	1084	59.62	81.57
7	25.61	1.281	25.61	5.12	28.61	488	22.94	20.40	1.020	20.40	8–14.8	2.297	8.88	604	454	1058	58.19	81.13
8	26.25	1.312	26.25	5.25	29.25	512	24.06	20.22	1.011	20.22	8–14.67	2.297	8.80	593	451	1044	57.42	81.48
9	26.91	1.345	26.91	5.38	29.91	536	25.19	20.10	1.005	20.10	8–14.37	2.332	8.62	578	449	1027	56.49	81.68
10	27.59	1.379	27.59	5.52	30.59	563	26.46	20.03	1.001	20.03	8–14.32	2.332	8.59	574	448	1022	56.21	82.67
11	28.28	1.414	28.28	5.66	31.28	590	27.73	20.00	1.000	20.00	8–14.30	2.332	8.58	572	447	1019	56.05	83.78

TABLE II.

No.	TIES.							STRUTS.										Total Cost in $
	Length	Sec.	Stress.	Sect'n in sq. ins.	Equiv. Length	Wgt in Lbs.	Cost in $	Length	Sect'n	Stress.	Chans.	Work'g Stress in Tons	Section in sq. ins.	Wght. in Lbs.	Wgt. of Details in Lbs.	Total Wght. in Lbs.	Cost in $	
1	36.06	1.202	24.04	4.81	39.06	626	29.42	32.31	1.077	21.54	12–20	2.100	12.00	1292	819	2111	116.10	145.52
2	36.62	1.221	24.42	4.88	39.62	644	30.27	31.96	1.065	21.30	10–19.65	1.806	11.79	1256	782	2038	112.09	142.36
3	37.21	1.240	24.80	4.96	40.21	665	31.26	31.62	1.054	21.08	10–19.3	1.820	11.58	1221	775	1996	109.78	141.04
4	37.81	1.260	25.20	5.04	40.81	686	32.24	31.32	1.044	20.88	10–18.82	1.849	11.24	1179	769	1948	107.14	139.38
5	38.42	1.281	25.62	5.12	41.42	707	33.23	31.05	1.035	20.70	10–18.5	1.864	11.10	1149	764	1913	105.22	138.45
6	39.05	1.302	26.04	5.21	42.05	730	34.31	30.81	1.027	20.54	10–18.23	1.878	10.94	1123	759	1882	103.51	137.82
7	39.70	1.323	26.46	5.29	42.70	753	35.39	30.59	1.020	20.40	10–17.97	1.893	10.78	1099	755	1854	101.97	137.36
8	40.36	1.345	26.90	5.38	43.36	778	36.57	30.41	1.014	20.28	10–17.72	1.906	10.63	1077	751	1828	100.60	137.17
9	41.04	1.368	27.36	5.47	44.04	803	37.74	30.27	1.009	20.18	10–17.52	1.920	10.51	1061	748	1809	99.50	137.24
10	41.72	1.391	27.82	5.56	44.72	829	38.96	30.15	1.005	20.10	10–17.4	1.925	10.44	1049	746	1795	98.73	137.69
11	42.43	1.414	28.28	5.66	45.43	857	40.28	30.07	1.002	20.04	10–17.3	1.931	10.38	1040	744	1784	98.12	138.40
12	43.14	1.438	28.76	5.75	46.14	884	41.55	30.02	1.001	20.02	10–17.24	1.935	10.36	1035	743	1778	97.79	139.34
13	43.86	1.462	29.24	5.85	46.86	914	42.96	30.00	1.000	20.00	10–17.21	1.937	10.33	1033	743	1776	97.68	140.64

such as occur in ordinary practice and ascertaining for any given panel length, depth of truss and shear, what *position in the panel, of the apex of strut and tie, will* make the actual cost of these two members a minimum.

In regard to the difference in cost of the two kinds of iron, there will be a little variation, depending upon where the prices come from. Those quoted to the writer about a year ago were 5·5 cents per lb. for heavy iron bridges and 4·7 cents per lb. for heavy combination bridges in the shop. If these prices be employed for strut and tie iron respectively, the results so obtained will probably be as nearly correct as is necessary for practical purposes. Let the ties be proportioned *for a working stress of five tons (10,000* lbs.) per square inch; let the struts employed consist of channel bars connected by lattice bars which are riveted together at their intersection, and let them be hinged on the pins at both ends and be proportioned by C. Shaler Smith's formula

$$p = \left(4 - \frac{H}{20}\right) \frac{37,800}{1 + \frac{H^2}{1,900}}$$

where p is the working stress per sq. inch and H *the ratio of length to diameter.* In respect to detail, the struts and ties will be designed in accordance with the writer's practice as indicated in his paper on "A System of Designing Highway Bridges," and "Details in Ordinary Iron Bridges." Let us suppose for convenience in calculation that we can obtain tie bars of the exact section required, and we will use the channel sections given in Carnegie's Pocket Companion. Let the first case considered be that of the single intersection, and let us take a span of 120 feet in six panels, the depth from centre to centre of chords being *20 ft., live load 3400 lbs. per lineal foot on both trusses,* and let us confine our attentions to one of the middle panels where the maximum shear will be 20 tons. Starting with equal inclinations of strut and tie to the vertical, when their apex will be in the vertical centre line of the panel let us move the apex a foot at a time towards the nearer end of the bridge until we reach the side of the panel: the most economical arrangement will lie between these limits and can be determined by inspecting Table 1 page 73.

It may be noticed near the bottom of the column of working stresses for struts, that the numbers increase irregularly: this is due to the fact that they were taken from table XVIII. in "A System of Designing Highway Bridges," which gives stresses for the different values of H varying by half a unit. As this is a practical investigation, there is no need of figuring out these working stresses to the third decimal place, so we do as in practice, viz., employ the table.

By inspecting the column of total cost we see that No. 7, which corresponds to the case where the apex is situated about two-tenths of the panel length from the side of the panel farthest removed from the centre of the bridge, gives the most economical result as far as each pair of diagonals is concerned.

But how will the use of these most economic inclinations for diagonals affect the rest of the structure? To discover let us inspect the skeleton diagrams shown in trusses 1, 2 and 3, page 72, in which trusses 1 and 3 employ these economic inclinations, and truss 2 the vertical posts.

The exact way to find the cheapest of the three would, of course, be to design them completely and find the total weight and cost of each, but we can ascertain *what we wish to know without the expenditure of* so much time as this method would entail.

Let us consider the two end diagonals and the end panel of the upper chord in Truss 1 and the batter brace, hip-vertical and end panel of the upper chord in Truss 2. By an approximate calculation it is found that there is a saving of about twelve dollars worth of iron at each end of the bridge in favour of Truss 2, from this subtract the saving of $5.30 in the centre panels as taken from the table and we will have $19.70 to be added to the difference in cost between the in*termediate struts and ties of Truss 1 and the end dia*gonal ties of Truss 2. This difference is about $178.00 which makes $207.70 in favour of Truss 2. From this we must deduct about $21.20 due to the fact that the top chord of Truss 1 for 40 feet on each side of the centre line has an average stress that is a little less than the corresponding stress in Truss 2, leaving $186.50 in favour of Truss 2.

In a similar manner comparing Trusses 2 and 3 we find a difference of $113.00 in favour of Truss 2.

Nor can there be any other truss formed from Truss *1 by changing the slope of the batter-brace so as to be* cheaper than Truss 2. There are two ways in which a slight saving might be accomplished by varying from Truss 2, first by inclining the intermediate posts at the most economical angle, and second in addition to this by making the hip-vertical parallel to the posts and increasing the inclination of the batter-brace. In the first arrangement there would be a little reduction of material in the intermediate struts and their ties and in the top chord, but it would be obtained at the expense of the appearance of the bridge, for not only *would there be a variety of inclinations, but the end* panels of the top chord being so much longer than the other panels would give to the truss an unsightly aspect. Again, if there were seven panels, it would be still worse, for in addition to all this variation there would be another different panel length in the chord. The second method suggested would be open to two objections, first the flat appearance it would give to the ends of the bridge, and second the inclined tie at the hip would make the stress in the second panel of the bottom chord less than that in the first panel. *This last objection is not an important one, and* could be surmounted by making the end panel of the bottom chord longer than the others, and the tie at the hip vertical; nevertheless none of these arrangements are desirable on the score of appearance in a bridge of this height.

The greater the number of panels, the less important becomes the objection of having several different inclinations, because the proportional irregularity would be less; but as engineers are beginning to believe in the economy of long panels, and as the limit for economy *of the single intersection is in the neighbourhood of* 160 feet, corresponding to eight or nine panels, we may conclude that, all things considered, the Pratt truss is the best for single intersection bridges.

Next let us take the case of a 192 foot span, double intersection, twelve panels, live load 2600-lbs. per lineal foot, dead load 1600-lbs. per lineal foot, depth of truss 30 feet; and let us consider the strut at the second panel point from the end, and its tie, on which the maximum shear will be 20 tons.

Let us take the apex of the strut and tie at 12 feet from the side of the panel most remote from the centre of the bridge, and move it a foot at a time towards that side: the most economical position will lie between these limits and can be ascertained by inspecting Table II page 73.

In figuring the above table it was assumed for convenience of comparison that ten inch channels weighing between 16l-bs. and 17.5-lbs. per lineal foot are obtainable, although none such are given in Carnegie's Pocket Companion.

Any apparent irregularity of variation in the columns of the tables is caused by the approximate values of the working stresses, which are however correct enough for the purpose of this paper.

The second table gives a less inclination to the vertical of the most economic strut than does the first table, the latter being about one in six, while in the first it is about one in five.

Truss 4 drawn to scale, as were also all the other trusses, represents the arrangements of the members *with the most economical inclinations of struts and* ties. Its effect is not at all displeasing to the eye, and there is a saving in using it in preference to the ordinary Linville truss, but this saving is such a small percentage of the total cost of the bridge that it is doubtful whether it would be worth while to incline the posts.

Let us take another case, viz, a 280 ft. span, double intersection, fourteen panels, 44'-ft. centre to centre of chords, live load 2400-lbs. per lineal foot, dead load 2480 lbs. per lineal foot, and let the diagonals be halved and intermediate struts be used at the middle of the posts so that the latter can be figured half length. Let us consider the post at the third panel *point* and the main diagonal cutting its upper extremity, the shear being about 40 tons; and let us start with the apex of the strut and tie, as in the last case, twelve feet from the side of the panel.

From these data Table III page 76 is made.

By inspection we see that a batter of about one in five for the struts would give the most economical result. The skeleton diagram of the truss would be very similar to Truss 4, and the remarks made in connection with the latter will apply also to this case.

Posts are sometimes designed with one end fixed, and their sections are in consequence somewhat reduced.

To see how this will affect the economic inclination, let us take the same data as in case 2, and figure the stints for one hinged end and one fixed end. Table IV, page 76, is the result.

In proportioning the compressive members we have for the purpose of facilitating comparison made use of 9-inch channels where 10-inch ones would have been more economical, and we have used sections not given in Carnegie's Pocket Companion. The result of the Table is to show that the most economic batter for the struts is not affected by figuring for one fixed end instead of both ends hinged.

Had we figured in cases 2, 3 and 4 for an equal inclination of strut and tie, we would have found for the cost of these members $148.00, $292.40 and $141 respectively, which would have been the figures for a Warren girder: the corresponding amount for the Linville truss are $140.64, $290.38, and $135.53; while those for the trusses employing the most economic inclination of struts and ties are $137.17, $278.94 and $131.83. For the first case the figures were $88.45 for the Warren girder, $83.78 for the Pratt truss, and $81.13 for the truss with the economic inclinations. As far, then, as any pair of web members is concerned the Warren girder is the most expensive of the three styles of truss, and by comparing the diagrams of Trusses 4 and 5 we will see that the Warren girder as a whole is more expensive than the Linville truss, supposing for the present that the posts in Truss 4 are vertical, because comparing the two trusses member for member, A and B in Truss 4 weigh the same as A and B in Truss 5, the two half diagonal ties and the post marked 1 in Truss 4 weigh less than the strut marked 1 and its counter-bracing in Truss 5 and the sum of the weights of the members marked 2, 3 and 4 in Truss 4 is less than the sum of the weights of the corresponding members in Truss 5. Although the diagonal tie marked 5 in Truss 4 is both longer and of larger section than the corresponding tie in Truss 5, and the two counter ties in Truss 4 require more iron than the corresponding counterbracing in Truss 5, on *the other hand the member marked C in Truss 4 weighs* only one third of the corresponding member in Truss 5, and there is only one half of the light strut marked D in Truss 4 to go against the whole of the heavy strut marked 5 in Truss 5. Anyone at all acquainted with bridge work will see that Truss 4 is the more economical.

To recapitulate: our investigations show that, for the ordinary bridges met with in an engineer's practice, the most economical inclination for the strut is a batter of one in five or one in six, but that the saving obtained by its use is such a small percentage of the total cost of the bridge that it is scarcely worth while to depart from the usual Pratt or Linville trusses; and that the latter are decidedly cheaper than the Warren girder.

◆

ON HYDRAULIC LIFTS FOR PASSENGERS AND GOODS.

BY EDWARD BAYZAND ELLINGTON.

(*Concluded from Page 40*)

Reference was made to the best general of hydraulic-power chain-hoists. It was only fair to mention, as the author did, that Sir Wm. Armstrong and Co. were the first to bring out a lift in that particular form; and in his own opinion nearly all the hydraulic short-stroke cylinders used to the present time had been constructed on that idea. It was therefore to Sir Wm Armstrong that the sole credit of producing that class of apparatus belonged. It was stated, that in these short-stroke lifts there was a certain danger, if the cage were too nearly balanced, because there was a chance of the cage sticking and the chain running off the pulley at top, and leaving the cage free to fall subsequently. That danger however could be entirely avoided by winding off as you wound on—using a large drum below, and winding off from the bottom of the cage as you were winding on from the top. The cage could thus be balanced within a few pounds of its weight, and would be always safe. This plan was designed by himself, and had always worked perfectly. With regard to the winding drums, in such cases his experience had been that they should be made large, and that wire ropes should never pass over a pulley of less diameter than from 14 to 18 inches, and should be taken as direct as possible from the top pulley to the drum, without passing over leading pulleys; otherwise by the constant bending of the rope in different directions it became brittle, and at last broke suddenly.

It was remarked, that with direct-acting ram lifts there was a limit to the height at which they could be used. Practically however there was no limit, as far as the ordinary buildings in London and elsewhere were concerned. The height of an hotel or other building where a hoist was used certainly would not exceed 90 or 100 feet; and an ordinary ram and

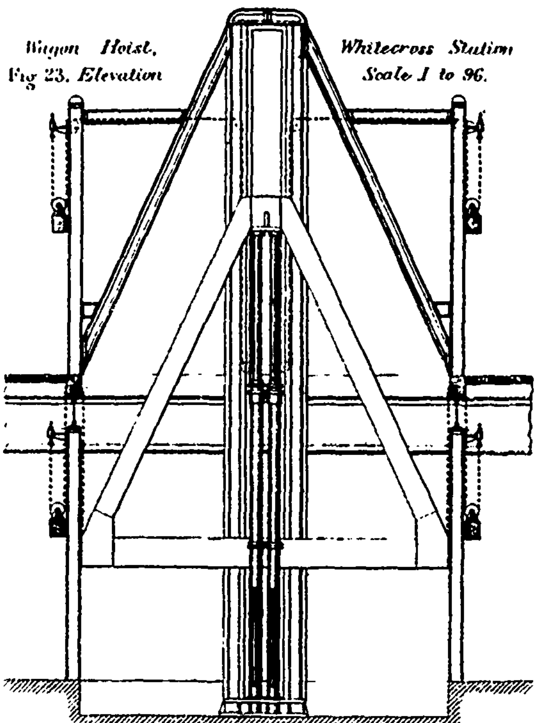
TABLE III.

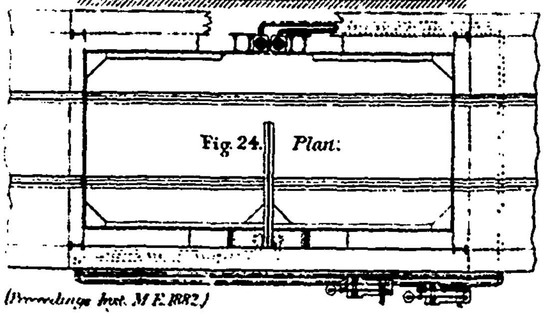
No.	TIES.							STRUTS.										Total Cost in $
	Length	Sec.	Stress.	Sect'n in sq. ins.	Equiv. Length	Wgt in Lbs.	Cost in $	Length	Section.	Stress.	Chans.	Work'g Stress in Tons	Section in sq. ins.	Wght in Lbs.	Wgt of Details in Lbs.	Total Wght. in Lbs.	Cost in $	
1	52.15	1.185	47.40	9.48	55.15	1743	81.92	45.61	1.037	41.48	12–23.92	2.890	14.35	2182	1410	3592	197.56	279.48
2	52.70	1.198	47.92	9.58	55.70	1779	83.61	45.35	1.031	41.24	12–23.73	2.897	14.24	2152	1404	3556	195.58	279.19
3	53.25	1.210	48.40	9.68	56.25	1815	85.31	45.12	1.026	41.04	12–23.53	2.907	14.12	2123	1398	3521	193.66	278.97
4	53.82	1.223	48.92	9.78	56.82	1852	87.04	44.91	1.021	40.84	12–23.33	2.917	14.00	2096	1393	3489	191.90	278.94
5	54.41	1.237	49.48	9.90	57.41	1895	89.06	44.72	1.016	40.64	12–23.17	2.923	13.90	2072	1388	3460	190.30	279.36
6	55.00	1.250	50.00	10.00	58.00	1933	90.85	44.55	1.012	40.48	12–23.03	2.930	13.82	2052	1384	3436	188.98	279.83
7	55.61	1.264	50.56	10.11	58.61	1975	92.83	44.40	1.009	40.36	12–22.91	2.937	13.75	2034	1380	3414	187.77	280.60
8	56.22	1.278	51.12	10.22	59.22	2017	94.80	44.28	1.006	40.24	12–22.80	2.942	13.68	2019	1377	3396	186.78	281.58
9	56.85	1.292	51.68	10.34	59.85	2063	96.96	44.18	1.004	40.16	12- 22.72	2.946	13.63	2008	1375	3383	186.07	283.03
10	57.49	1.307	52.28	·0.46	60.49	2109	99.12	44.10	1.002	40.08	12–22.65	2.949	13.59	1998	1373	3371	185.41	284.53
11	58.14	1.321	52.84	10.57	61.14	2154	101.24	44.05	1.001	40.04	12–22.61	2.951	13.57	1992	1371	3363	184.97	286.21
12	58.80	1.336	53.44	10.69	61.80	2202	103.49	44.01	1.000	40.00	12–22.57	2.953	13.55	1987	1370	3357	184.64	288.13
13	59.46	1.351	54.04	10.81	62.46	2251	105.80	44.00	1.000	40.00	12–22.57	2.953	13.55	1986	1370	3356	184.58	290.38

TABLE IV.

No.	TIES.							STRUTS.										Total Cost in $
	Length	Sec.	Stress.	Sect'n in sq. ins.	Equiv. Length	Wgt in Lbs.	Cost in $	Length	Section.	Stress.	Chans.	Work'g Stress in Tons	Section in sq. ins.	Wght in Lbs.	Wgt of Details in Lbs.	Total Wght. in Lbs.	Cost in $	
1	36.06	1.202	24.04	4.81	39.06	626	29.42	32.31	1.077	21.54	9–18.56	1.933	11.14	1199	773	1972	108.46	137.88
2	36.62	1.221	24.42	4.88	39.62	644	30.27	31.96	1.065	21.30	9–18.15	1.956	10.89	1160	766	1926	105.93	136.20
3	37.21	1.240	24.80	4.96	40.21	665	31.26	31.62	1.054	21.08	9–17.76	1.979	10.65	1123	759	1882	103.51	134.77
4	37.81	1.260	25.20	5.04	40.81	686	32.24	31.32	1.044	20.88	9–17.4	2.000	10.44	1090	753	1843	101.37	133.61
5	38.42	1.281	25.62	5.12	41.42	707	33.23	31.05	1.035	20.70	9–17.09	2.018	10.26	1061	748	1809	99.50	132.73
6	39.05	1.302	26.04	5.21	42.05	730	34.31	30.81	1.027	20.54	9–16.83	2.034	10.10	1037	743	1780	97.90	132.21
7	39.70	1.323	26.46	5.29	42.70	753	35.39	30.59	1.020	20.40	9–16.59	2.050	9.95	1015	739	1754	96.47	131.86
8	40.36	1.345	26.90	5.38	43.36	778	36.57	30.41	1.014	20.28	9–16.39	2.062	9.84	997	735	1732	95.26	131.83
9	41.04	1.368	27.36	5.47	44.04	803	37.74	30.27	1.009	20.18	9–16.25	2.073	9.75	984	732	1716	94.38	132.12
10	41.72	1.391	27.82	5.56	44.72	829	38.96	30.15	1.005	20.10	9–16.10	2.081	9.66	971	730	1701	93.56	132.52
11	42.43	1.414	28.28	5.66	45.43	857	40.28	30.07	1.002	20.04	9–16.00	2.087	9.60	962	728	1690	92.95	133.23
12	43.14	1.438	28.76	5.75	46.14	884	41.55	30.02	1.001	20.02	9–15.96	2.090	9.58	958	727	1685	92.68	134.23
13	43.86	1.462	29.24	5.85	46.86	914	42.96	30.00	1.000	20.00	9–15.93	2.092	9.56	956	772	1683	92.57	135.53

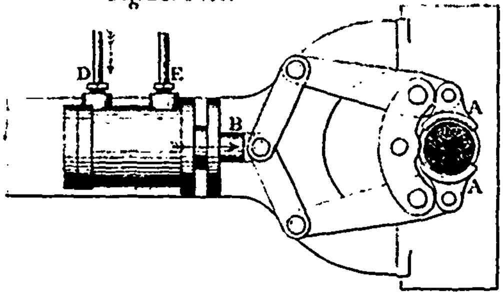
HYDRAULIC LIFTS.





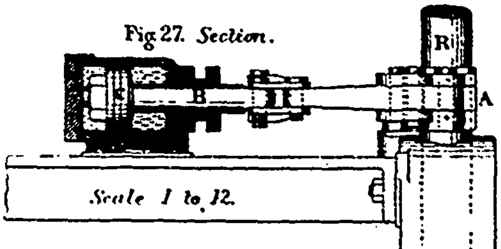
(Proceedings Inst. M E 1882.)

Fig 26. Plan



Safety Brake for Direct-acting Lifts.

Fig 27. Section.



(Proceedings Inst. M. E. 1882.)

cage could be raised 100 feet with the greatest ease. If a lift were needed for a greater height,—as at Queen Anne's Mansions, Westminster, where he believed one was at work, made by Messrs. Easton and Anderson,—it was easy to provide a second lift, starting from the level where the other ended. In that way there was practically no limit to the height that could be worked. As to danger from the use of counterweights and chains, he maintained that when an apparatus of this kind was properly designed there was no such danger as stated. The varying strain upon the ram, described by the author, was a matter of theory rather than of actual practice. No case had ever occurred in this country, to his knowledge, where, in a well constructed hydraulic lift with continuous ram, an accident had taken place through the ram breaking away from the cage. He had seen the lift at the Grand Hotel, Paris, just after the accident, and was not much surprised that it had taken place, as the construction, *especially at that part*, was very faulty—a remark which applied to a great many of the French lifts. A fault in many hydraulic lifts was that of attaching the counterbalance chain to the centre of the cage. That should never be done; it was a very dangerous practice. In his designs there were two chains, attached to the sides of the cage by jaws riveted to the *side suspending irons*; and the chains and counterbalance weights passed down grooves in the wall at each side; there was thus no gear whatever overhead, and no accident could *arise from* that cause. In *addition to* this the top of the cage was made, as was usual, of ¼ in. boiler-plate, so that, if there was a fall of any heavy weight from any of the floors, the passengers were still safe inside the cage. He did not agree that there was necessarily any danger in using lifts of that kind, and he was borne out in this statement by the large number of such lifts that had been in use for many years without any accident occurring. With his own experience of over fifteen years, he could point to a large number of hydraulic ram lifts worked by counterbalances, which were in constant use, on which there had scarcely been any repairs, and with which certainly no accident had ever occurred.

The author's own design, he could not think a very good one, because it comprised the addition of a very complicated apparatus, very liable to get out of order, and very likely to fail at a critical moment. According to his own experience, simplicity of design should be the first consideration in all such cases; and that certainly would not be obtained by the addition to the original machinery of such complicated apparatus as was proposed by the author. It was stated, that hydraulic passenger lifts *could* be run at a speed of 200 ft. per minute. Of course high-pressure lifts might be run at almost any speed; but he thought it would be objectionable to run a lift at such a speed as 200 ft. per minute, as it only frightened the public and prevented many from using the lifts.

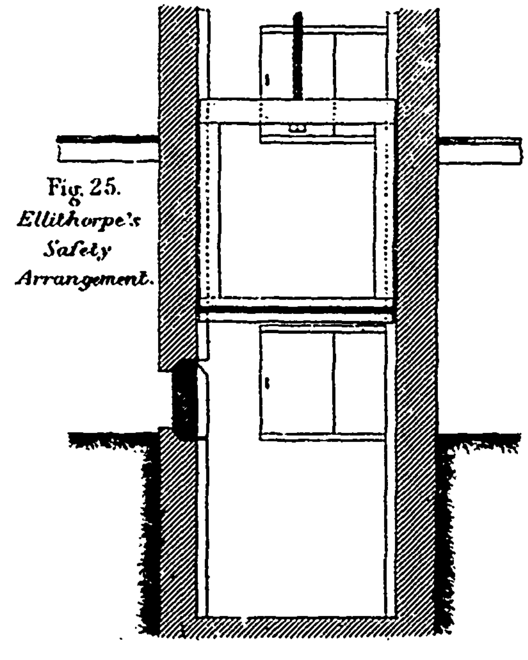


Fig. 25.
Ellithorpe's
Safety
Arrangement.

He did not think it was really safe to work at more than 100 or 150 ft. per minute. It was also stated, that there ought to be doors to the cage; but in his opinion they were rather an element of danger than of safety, since in nine cases out of ten they were never closed. As to its being desirable for an attendant to work the lift, he thought it was absolutely necessary for the safety of the public that a skilled attendant should always be provided.

It was stated, that the accumulator gave a useful effect of 75 per cent: but it had been shown by the experiments of Sir Wm. Armstrong & Co. that the useful effect was really as high as 90 or 93 per cent. The friction of the ram in hydraulic lifts was mentioned, as if it were rather a serious matter; but in experiments he had made some two years ago, he had found that a 9-in. ram, with 110 ft. head of water upon it, did not require more than 2 lbs. per sq. in. pressure to overcome the friction of the leather collars, chains, wheels, counterbalances, and all the moving parts. Taking into consideration the fact that the cage in this case fitted very closely to the guides, which of course increased the friction, he thought this showed a very small amount of friction for an apparatus capable of lifting 19 to 20 cwt. It was stated that gas engines were suitable for driving pumps for hydraulic lifts; but he thought a gas engine was an expensive machine to use for such a purpose, especially when it was possible to have a direct head of water from a tank. With regard to low-and high-pressure lifts, he thought that low pressures were to be preferred, because of their smaller leakage and the fact that they could be used after the pumping engine had been stopped for some hours; while the wear and tear was very much smaller, and the risk from bursting pipes was also reduced. Where two or three lifts only were worked in one place, low-pressure were certainly much more economical than high-pressure lifts.

As to the hydraulic lifts at the Seacombe pier, it appeared to him that the credit of this plan was really due to Mr Edwin Clark, from whose design almost exactly the same thing had been put up at Anderton on the River Weaver. The method had also been used in many other instances, especially in the north of England. As to the question why hydraulic lifts were not more generally used for raising passengers and goods, the principal reason was that people in too many instances had not the courage to make the necessary outlay; they looked more to their pockets than to the important element of saving human life.

Before sitting down he should like to refer to a statement made by Mr. Walker in reference to worm gearing. He himself quite agreed with Mr. Ellington that there was an immense loss of power from the friction of worm gearing: and he considered it was the worst form of gear that could possibly be used for lifting. With regard to belt gear, he also agreed with Mr. Ellington, as against Mr. Walker. He had seen serious accidents arising entirely from the breaking of the belt. In those cases there had perhaps been no safety gear, or at any rate only of a very poor description. With regard to pitch chains, although they could be used in many cases very conveniently, he thought they were the most dangerous form of chain that could possibly be used for a passenger lift. As far as he was concerned he would never, if he could help it, allow a passenger to travel in any lift raised by a pitch chain. Coming back finally to the hydraulic lift, whether it was of the high-pressure or low-pressure kind, he thought a continuous direct-acting ram was the only perfectly safe lift in use at the present time, suitable equally for passengers and goods.

Mr. Alfred Davis said that perfect safety, particularly in the case of passengers, was no doubt a most desirable element in lifts; but all mechanical contrivances were more or less unsafe, and, as a matter of fact, when required they were generally out of order. There was however one form of safety apparatus, invented by Mr. Ellithorpe, which was free from that objection, and which was now being very extensively used in America. The lift chamber, Fig. 25, Page 77, was continued below the surface of the ground as an air-tight well, the depth of which was, as a rule, about one-eight or one-twelfth the height of the lift; it was slightly contracted towards the bottom, and the cage had a washer of india-rubber or leather round the bottom edge. Then, in case of a fall of the cage from any cause, the resistance of the cushion of air in the well completely broke the fall. He had himself in several cases seen glasses of water and eggs placed in the cage, and, after the rope had been cut or the cage liberated, not a particle of water had been spilt, and the eggs had remained quite intact. He had been told that many passengers had also been allowed to fall, in some cases 80 or 100 feet, and had suffered no injury. It had also been proposed by Mr. Ellithorpe, and carried out in some cases, he believed, to make the shaft of the lift and the doors perfectly air-tight, and thus make the shaft answer the same purpose as the air-tight well; so that in case of an accident the cage, instead of falling to the bottom, only dropped a few feet. In that case a flap-valve A was provided at the bottom of the shaft, opening inwards, so as to admit air freely when the cage was rising. while there was sufficient leakage round the bottom edge of the cage to allow of its descent at the ordinary rate. He believed the principle of the air-tight well—not that of making the entire shaft air-tight—had by this time been applied to a large number of lifts in America, and up to the present time had given great satisfaction.

Mr. R H. Tweddell thought the paper was a very interesting one, especially as Mr. Ellington had made a specialty, and successfully so, of distributing hydraulic power to small consumers; and in connection with lifts he had, at all events, made certain suggestions which were deserving of attention. The only fault he could find with the paper was that it advocated one particular system too much at the expense of others. For instance, great doubt had been thrown on the efficacy of chains. Now in many cases, quite as important as that of lifts, lives were entrusted to ropes or chains, as in the case of mines, ship's cables, &c: and where accidents occurred they could generally be traced to using tackle having too small a margin of strength, with a view of economising in first cost. Cheapness should not enter into the consideration of any machine, such as a lift, where human life was at stake; but if sufficient care was taken in the choice of the chains, a sufficient margin of safety allowed, and the apparatus duly attended to after it was put up (which was one of the most important matters), he thought there was still room for the use of chain lifts in many cases.

With regard to Mr. Ellington's lift, the fact that it required no head-room for drums or cylinders would sometimes be an advantage; and the whole design was undoubtedly an improvement on the French system referred to, especially in the principle of using hydraulic power throughout the whole system.

He could not agree with the remark, that it was an advantage in the case of a burst cylinder or pipe that the hemp packing of a direct-acting ram served as a brake. If so, it was a brake of a very expensive description, because it must be on all the time of working; and he should much prefer some other means of retarding the descent in such an emergency, rather than having to tighten up the packing so much as to perform the function of an automatic brake every time the lift descended. With reference to the use of wire ropes, he had no doubt they were tolerably safe, if there could be sufficiently large drums for them to work over; but he had had some experience with wire ropes in connection with lifting weights of about 30 cwt., and the useful effect obtained was very small.

The ratio of length to diameter of ram, was in one case as much as 223 to 1; and it would be interesting if Mr. Ellington would state what his experience was with respect to such very long and thin columns and the strains upon them. Supposing the cage was to jam by any accident, and there was an excess of pressure, what would happen? With reference to the remark, about the difference in the stress on such a column, according to the point where it was taken, there could be little doubt about that. It was an interesting fact, and very apt to escape the notice of those who were not continually engaged in such work. No doubt however the ram should be made as small in diameter as was consistent with safety, because where there were lifts, as in numerous cases at the present time, going up 500 or 600 or even 800 times a day, any question of economy consumption of water became of great importance; this of course did not apply to Mr. Ellington's lift, and some others also.

The paper, in describing the other forms of lifts, omitted any allusion to the Cyclic Elevator, of which there were some at work in the City, and which worked continuously, passing round a drum at top and bottom. Perhaps Mr. Ellington could give some explanation of how that was arranged. Speaking of curious lifts, he might refer to the opera-glass lift, patented by Bramah in 1812, and described by him in terms not so modest as those used by the author of the paper in reference to his invention. Mr. Bramah, after describing now he proposed to lift and lower weights by a compound lift, on the principle of the opera-glass or common sliding telescope, explained it thus:—" For instance, suppose I cause five hundred tubes of five feet in length to slide one within another, perfectly air and water tight" (then followed certain details of construction, and he continued) "then it must appear that, when all these tubes are slided out to their ultimate bounds, the *aggregate* altitude will be 5 × 500 = 2500 feet, and which can be performed if required in a few seconds of time." Mr. Bramah evidently had a high opinion of this invention, for he concluded by saying that "this patent does not only differ in its nature, and *in its boundless extent of claims to novelty, but also in its* claims to merit and superior utility, compared with any other patent ever before sanctioned by the legislative authority of any nation."

Mr W. E. Rich thought the first thing to be observed in the construction of lifts, *where life was at stake*, was to make them safe; and that condition was best ensured by making them as simple in their details as possible, with few working parts and large margins of strength. For efficiency's sake they required as few piston rod and piston packings as possible; but Mr. Ellington had introduced five times as many packings in his new lift as were required in the ordinary direct-acting lift. He had four in his accumulating apparatus, Figs. 16 17, Page 37, namely, two stuffing-boxes and two pistons, besides the packing of the lift ram. Now he was certain that those packings would in actual practice be a source of great inconvenience. The packing-up and renewal of leathers, if leathers were used, or the introduction of new packings, if hemp packings were used, would be a source of much more frequent work of those who had to keep the lifts in order, and at the same time the efficiency of the lift would be immensely reduced. If with an ordinary balanced-ram lift 60 per cent. of efficiency could be obtained, he thought not more than 50 per cent. would be obtained with the form shown in Figs. 16 17. Mr. Heurtvisé had gone in the same direction, Fig. 15 Page 37, but only half as far, his lift having two extra packings instead of four. He himself failed to see in what the greater safety of that type of lift consisted. In case of the bursting of a cylinder in such a lift when near the top of its stroke, serious results could scarcely be avoided, as the ram *would descend with nearly the full velocity* due to the height, while under similar circumstances the ordinary ram lift, with counterweights, would descend at a reduced velocity, just as occurred in the well-known Attwood machine.

He thoroughly endorsed the remark, that "workmen and others are *in the habit of travelling in goods lifts*, and a prohibition against this practice is productive of inconvenience. Considerations of expense however will often stand in the way of the adoption of the safest kind of lift for goods alone." He thought that employers at the present day needed to be very wary if they trusted *their servants in goods lifts* which they would not consider safe enough for passengers. He had not met with any such case since the Employers' Liability Act came into force; but he should think that, in case of accident, it would go badly with employers who had considered a lift safe enough for their servants to travel in, but at the same time not safe enough for passenger use. That was yet another reason for hesitating to employ any lift with elaborate gearing, where human life was at stake.

Again, he thoroughly endorsed what was said, as to safety apparatus. The note at the bottom of that page was, he thought, especially suggestive, namely that out of eleven elevators, whose fall was reported, only two were unprovided with safety catches. He did not himself remember any case in which a lift accident had been prevented by a safety catch. What were called safety appliances for hydraulic and other lifts were innumerable, and nearly all, when in perfect order, would probably be effective if the chain or rope were suddenly chopped through close above the cage; but that was a condition of things that rarely existed. An accident might of course take place in that way; but in a geared lift, at any rate, something generally broke at some distant part of the mechanism, and left a residual strain on the rope or chain, which was quite sufficient in an ordinary way to prevent the catches from coming into play. In most cases of accidents to geared lifts, it was also found that on the day in question the safety apparatus was out of order. The fact was it was nobody's business to attend to it, and probably it had been out of order for years. Similarly the brake apparatus referred to in connection with hand-power lifts, were not reliable; indeed he believed some accidents were actually caused rather than prevented by the suddenness with which some brakes and safety gears came into action.

The efficiency of an hydraulic lift reached its maximum when working at the lowest possible speed. In order to work at a speed fast enough to be practically serviceable, some efficiency must be sacrificed, the loss being expended in overcoming fluid friction in the pipes and valves; the faster any lift was worked the lower its efficiency became. Thus it resulted that the speed of a *lift was practically limited by the size of the* pipes.

Mr. Jeremiah Head said allusion had been made by Mr Colyer to direct-acting steam lifts These were largely used for mineral and goods purposes in the North of England, especially at *foundries, where the use of a long inverted cylinder* as a lift for the cupolas was very common indeed, and worked remarkably well. Steam cylinders would probably do anything that hydraulic cylinders would, in the way of lifting, provided they were made proportionate; but the objection, as he took it, *to using steam cylinders for such purposes lay in the elastic* nature of steam as compared with the inelastic nature of water. For instance, if the lift stuck by reason of extra resistance at a particular point, then the steam rose in pressure under the lift, and when the resistance was overcome the cage ran away, *or, as the workmen called it, "snatched."* At one set of *blast* furnaces in the Cleveland district there was a direct steam lift —a ram coming up out of a well, which raised the materials for the furnaces perhaps 60 or 70 ft. There had been a very bad accident with that lift some years since, not owing to any *snatching in going up*, but rather in coming down. *The lift* had got to the top, and the handles had been so placed as to allow it to go down, but for some reason or other it stuck. Of course the steam all escaped from beneath the ram; and then the latter got free, and came down with a run, causing terrible damage. Such a thing could not happen with water, as long as it had to be forced back against head.

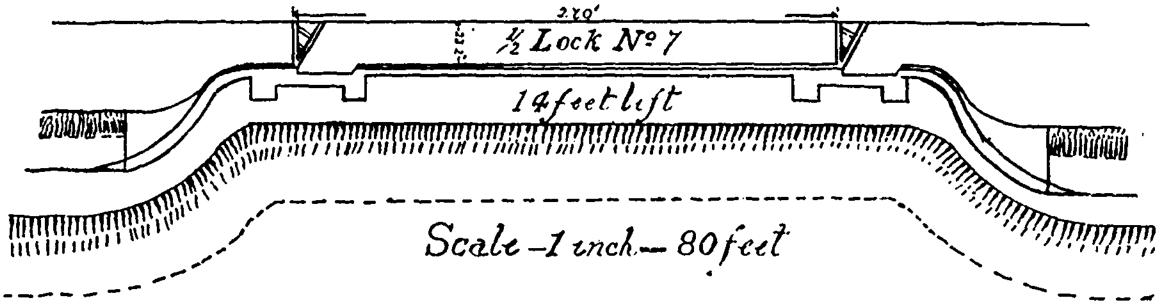
With regard to economy in lifting heavy weights to great weights, they could not do better than turn their attention to the method adopted in collieries. There all sorts of ways had been tried in past times, and they had come round to one particular method, which was now prevalent everywhere, namely an engine winding and unwinding a rope upon a drum, this rope passing over sheaves and down the pit. There was possibly one improvement on this, which might be mentioned, and that was a lift designed by Mr. R. Howson for Messrs. Samuelson's furnaces at Middlesbrough. Here there was a second staging, 10 or 12 ft. above the charging staging at the top level of the blast furnaces, and on this a regular engine-house was built. That engine-house contained a double drum, having a cog-wheel around the periphery; into that wheel geared a pinion, which was worked by an inverted engine direct. By that arrangement the sheaves to alter the direction of the rope were saved, and it was as direct a lift as could possibly be conceived. It was in fact a return to the old-fashioned arrangement for drawing water from a well by means of a horizontal rope-barrel, with ascending and descending buckets balancing each other. The only thing to be taken up to the full height of the engine-house was the steam, which of course lifted itself. The engine-house at the bottom, where room was very valuable, was got rid of; and being a direct lift, constructed with only one pinion and wheel, it seemed to him about as safe an arrangement as could possibly be conceived. Attached to the cages were double steel-wire ropes, each one sufficient to carry the whole weight if the other should break.

Mr. Ellington, in reply, said he had to congratulate himself on the general consensus of opinion, that there was only one really safe style of lift to be adopted for passenger use in buildings, namely the direct-acting ram. That was going a long way *towards the special solution of the problem* which he had endeavoured to lay before the Institution.

Mr. Walker had expressed his belief in the direct-acting principle, but then proceeded to say that he also had confidence in a safety apparatus, because he had known cases in which it had *been successfully brought into operation*. He himself did not doubt that for a moment; but the question was whether such apparatus could be always depended on, and he thought no one would really maintain that they could be. Mr. Rich had pointed out the true cause of many failures in safety apparatus, which was *that it could not come into operation* except when the chain broke in a particular way. That of course was the way always selected when the apparatus was shown off. As an illustration of how accidents happened, he might mention that he had known several instances in which the cage of a lift such as *that shown in Fig 7, No. 2, had* stuck; and if there was no counterweight to the ram, and the valve was open to the exhaust, the weight of the ram itself was sufficient to exhaust the water, the ram descended, and the ram chain gathered into a heap on the ground below the winding dram. *If by any means the cage happened to be released* by somebody jumping into it, or by overcoming the resistance

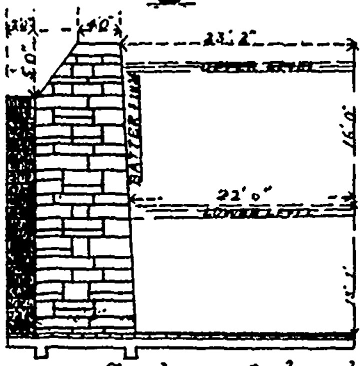
WELLAND CANAL.

A



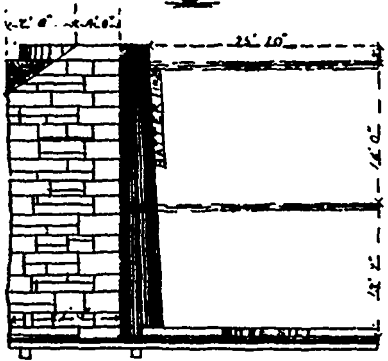
Scale -1 inch — 80 feet

B



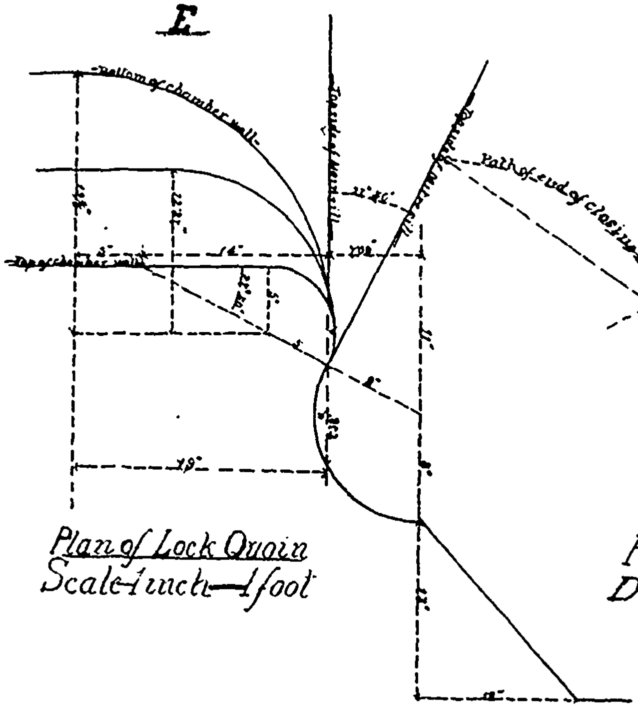
½ Section of chamber
Scale-1 inch—16 feet

C



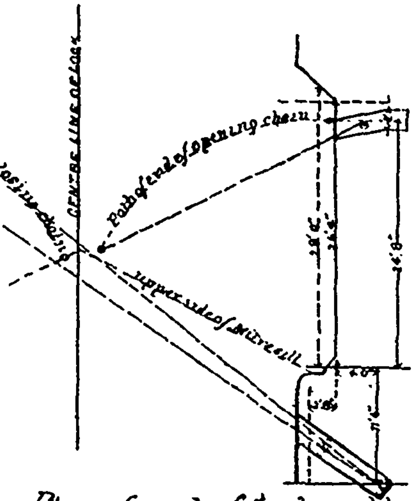
½ Section of recess
Scale-1 inch—16 feet

E



Plan of Lock Quoin
Scale-1 inch—1 foot

F



Plan of part of lock wall
& Diagram of chain movements
Scale 1 inch 16 feet

in some way, the safety apparatus could not act, because the lift chain had to be unwound off the drum by the descending cage; consequently the cage fell, until it was suddenly brought up when the chain became taut. The apparatus which Mr. Davis had mentioned was applicable in all cases; but even that, it was evident, might sometimes fail.

In reference to the gas engine, Mr. Walker advocated its use for pumping with hydraulic machinery, as recommended in the paper. It being best and safest to use hydraulic machinery in lifts, it did not matter whether the power was obtained by steam or gas engines, or whether it was ready stored in street mains or in a tank, so long as the most economical means available at any particular place for obtaining the pressure were adopted.

With regard to Mr. Colyer's remark on the lifts at Seacombe, he would point out that they were not constructed at all upon the system adopted by Mr. Clark for the Anderton canal lift. The only connection between the two designs was that in both the two lifts were connected by a valve, so that as one went down loaded the other went up empty.

Mr. Colyer had further stated that it was not the fact that there was a limit to the height of lift with a direct-acting ram. The statement was only correct on the supposition of there being a balance weight and chains on the lift; there was then no limit to height. Supposing however there was nothing but a direct-acting ram (which was the point he wanted to arrive at), and excluding the effect of the hydraulic balance, there was a limit, with a given pressure, to the height to which the lift could be raised, as was clearly shown in the paper. Mr. Colyer also stated that almost any speed could be obtained with any high-pressure hydraulic lift; but his own experience was that, in the particular case of a chain-balanced lift, such as shown in Fig. 11, Page 36, it was impraticable to obtain high speeds of working, excepting of course with exceedingly high pressures. He did not know of any instance of a lift of that kind, with pressures of water under, say, 200 lbs. per sq. in., which worked at speeds of anything like 150 ft. per min. with a load.

In reference to Mr. Tweddell's remarks, he himself was also of opinion that in a great many instances a chain lift was the right thing to use; but only in cases where a direct-acting ram lift was impracticable. He also agreed that, if a chain lift was properly constructed, if all the parts of the chains and attachments were exactly as they should be, and if the superintendence was good, there was reasonable security in the use of such a lift. His point was that superintendence as a general rule was not good, and that in the majority of cases such lifts were not made in accordance with the best rules; and therefore, speaking as to general practice, he did not think that the system was one to be recommended.

With regard to particulars of efficiency there was a very good reason for taking the observations at the slowest practicable speed at which the lifts could be worked. If any increased speed had been taken, of course a lower efficiency would have resulted; but the unknown effect of the friction of water in the pipes, valves, and passages, would have made the results of no value for purposes of comparison. The observations were all taken from lifts which had been actually working, some for many years, and some only a few months. He had however given in a Table the maximum speed attained, when the lift might be said to have been doing no useful work, and the whole of the power was absorbed in friction, excepting that amount which was needed for lifting the dead load subsequently used to bring the cage down. The net loads lifted as given in the Table did not include the weight required to bring the cage down empty at the working speed of descent; and the column of efficiencies gave the ultimate efficiency when the cage was just balanced. In many cases of passenger lifts this latter would be the most desirable working condition; but the precise margin of power allowed must of course depend on the special circumstances under which each lift was to work.

It might also be pointed out that, as a general rule, loads had to be lowered as well as raised; and as stated in the paper, the particular arrangement of hydraulic balance, as shown in Fig. 17, Page 37, permitted this fact to be turned to useful account for increasing the lifting power in the ascent of the loaded cage. When working the lift in this way, the efficiency on Mr. Rich's assumption would be apparently as much as 100 per cent. The true loss by friction at constant speed being practically constant, a method of calculation which would produce these anomalous results could not be accepted as being of any scientific or practical value. There could not of course be any real difference between Mr. Rich and himself on this matter. The Table of efficiencies in the paper had evidently no reference to the practical efficiency realised under ordinary conditions of working; but it gave the maximum efficiency under the most favourable conditions when the cage was just balanced. Mr. Rich had given a column of what might be termed the practically useful effects under one particular condition of working; but the efficiency thus obtained was limited to that particular condition, and was not the maximum. It was worth notice that Mr. Rich's column of efficiencies gave a much greater proportional increase of efficiency for the author's hydraulic-balance lifts than was given by the Table in the paper.

As to the length of the ram subject to compressive strain, the greatest proportion of length to diameter that he had himself used was something under 180 to 1. In the case of the greater proportion referred to by Mr. Tweddell the ram was for half its length in tension. He was aware that there was a want of experimental data as to the behaviour of long columns under strains such as those upon the ram in a direct-acting hydraulic lift. He believed the proportion of about 120 to 1 was the greatest at which any reliable experiments had been made; but the above proportion of about 180 to 1 he had used in lifts for many years, and they had given exceedingly good results. In another case there was a 3½-inch ram with a stroke of 50 ft. 6 in., being the lift constructed as shown in Fig. 16, Page 37. That ram had been loaded, without any guides at all to support it, with about twice the working load, and under those conditions the bending of the ram was of no moment. He had also run that lift up at full speed, without any load on, against the stops at the top. There was a slight spring, and it then came to a stand without any damage to the ram or to the machinery. As a rule, the rams for these hydraulic-balance lifts were made of solid steel. Of course it was possible to get solid bars very much longer than hollow tubes, so that joints could be avoided, at any rate in the centre; and steel might now be got so tough that such a ram might be tied in a knot without fracture. Moreover, directly the deflection of the ram, from any cause, became at all serious, the friction on the guides would be so great that the lift would necessarily stop.

Mr. Tweddell has asked for particulars of the revolving or Cyclic lift. He had ventured in such a lift, but certainly for general use in dwellings it was not the right thing. He thought it a decidedly dangerous arrangement. There were no doors either to the lift or to the well. It was extremely slow in its action, and it was made with the plate chains which Mr. Walker advocated, but which Mr. Colyer condemned. No doubt a plate chain in some circumstances was a very good thing, but on the whole he would rather have a short-link chain for continuous use.

Mr. Rich had expressed his preference for a chain-balanced direct lift. No doubt if that gentleman had to do with the construction of such a lift as was shown in Fig. 11, Page 36, it would be made to all intents and purposes secure; and he himself should have no hesitation in going up in it at any time. But the security would be due to the good construction of the lift, the principle being defective. An accident such as that at the Grand Hotel in Paris was quite possible, not so much from the breakage of the chain, as from the breakage or disconnection of the ram from the cage. Mr. Colyer had suggested that the point noted in the paper, as to the strains upon the ram being in tension at one portion and in compression at another, was of very little moment; that it was a purely theoretical matter. If however that theoretical matter had been borne in mind by the constructor of the Grand Hotel lift, he believed the accident would not have happened. Probably it had been thought that the ram was only pushing the cage up, and that therefore its connection with the cage was a secondary matter; but if it had been considered that the upper part of the ram was practically hanging from the cage, it would rather have opened the designer's eyes to what was the true character of a direct-acting chain-balanced lift, as regarded security. Practically it was this, that the ram and its cylinder became a safety apparatus to the lift, while the motion was due to the counterbalance.

He could quite understand Mr. Colyer's advocacy of a low-pressure lift, for he also preferred counterbalance weights and chains, which were unsuitable for use with high pressure. Taking for example a lift 90 ft. in height, the working pressure being 700 lbs. per sq. in., obtained from a system of public hydraulic power, it be necessary to abandon the direct-acting ram unless the hydraulic balance were introduced, for otherwise the cost of the power would be prohibitive. The smallest area that could possibly be given to the ram would still be sufficient, when subjected to so high a working pressure, to lift not only the load, but the weights of the ram and cage as well; and it would be useless to balance the lift at all with a chain and weight. But the principle of his own hydraulic balance was that the lift could be constructed with a ram of any required *size to give security*, and by the addition of a second ram of any convenient stroke, alongside that lift-ram, the latter would be perfectly balanced, its displacement would also be balanced, and the same balancing effect would be obtained as that due to a heavy chain and counterweight in a low-pressure lift; thus realising the advantage of high pressure, without sacrifice of economy and with additional security. The *addition of this second ram certainly compared favourably* in point of complication with chain counterweights and head gear. Moreover with a *high pressure of water* the lift could be worked without a balance at all, since the balance in such a case as that shown in Fig. 18, Page 40, was really only an economiser of power. Therefore in case of any serious derangement, or need of packing a gland or inserting a new leather, which Mr. Rich *feared* would often happen, then, if working at high pressure, the valve shown in Fig. 20, Page 40, might simply be closed, and *the lift might* continue to be worked without the balance until all was made right again. But in using hydraulic rams it was not absolutely necessary even to use a balance constructed as shown in Fig. 17 and 19. Taking Fig. 15, Page 37, as an illustration, the lower cylinder B would be *made of* smaller capacity than the upper cylinder D. There would thus a differential arrangement, and the cylinder *A could be reduced, and the whole of* the counterweights and chains E could be taken away; precisely the same effect would then be produced as with the balance arrangement shown in Fig. 17, Page 37. There was yet a further simplification, in which the lower cylinder B, Fig. 15, could be dispensed with altogether.

THE WELLAND CANAL.

BY CECIL BRUNSWICK SMITH.

(Summer Report for 1882 in Course of Civil Engineering, McGill University.)

This report gives a short historical sketch of the different canals known under the general head of "Welland Canal" and, also a more detailed description of the locks of the new Canal.

The most obvious method of *providing free vessel* communication between Lakes Ontario and Erie, and so overcoming that great obstacle to navigation, the Niagara Falls, was by a canal, the realization of which has conferred a lasting benefit on Canada. Mr. W. H. Merritt, M.P., *first* resolutely set himself to obtain this canal, and with a few neighbours made a rough level survey of the country through which they proposed it should pass. They then petitioned parliament for a proper survey, and $2,000 was granted for the purpose. As a result of this survey "The Welland Canal Company," with a capital of $40,000, was incorporated in 1823, and vessels first passed through the canal in 1829.

In 1837, the Government seeing how advantageous this Canal would be *to the country*, bought up the shares of the company and, in 1842, began the enlargement and improvement of the Canal.

NOTE.—Remains of one of the small wooden locks of 1829 may still be seen at Thorold.

The canal not only provided the much needed vessel *communication between the* two lakes, but also gave very great accomodation, in the form of water power, to factories and mills, and along its course from Lake to Lake there are now many in operation.

The need of a larger and deeper canal soon began to be felt, as no vessels drawing more than 10 ft. of water, or more than 150 ft. long, could pass through the canal. Many years before this the Welland Railway had been built for the express purpose of lightening vessels at the ends of the canal, but this was found by the ship owners to be very expensive.

The main requirement was larger lock accomodation and, as a great amount of small traffic could still go through the canal then in operation, it was decided to build an entirely new set of locks, and a corresponding length of canal.

It was also considered adviseable to build the locks of such a size as to allow of a tug remaining in the lock alongside the vessel. The locks were therefore made of ample width (46'. 4") an obvious advantage, as owing to the increasing scarcity of horses, *tug-power* is much less costly than horse-power.

In the year 1870, surveys for the location of a new canal were made, and in 1873 began the work of construction.

It soon became evident that the Canadian Government had determined to build a very superior structure both in workmanship and equipment.

The work was completed in 1881 and even a superficial observer can at once see that it is a *complete* structure in every respect.

No one need have any hesitation in saying that it is one of the best canals in the world.

$16,000,000 seems a large sum to pay for some *13* miles of canal, but the benefit will be great, and future generations will see the wisdom of the undertaking.

This new canal branches from the old one at Allanburg, 19 miles from Lake Erie, and, after *taking an* easterly détour through the country, joins the old canal again at Lake Ontario.

The old canal was deepened from the junction at Allanburg to Lake Erie, and thus, vessels drawing under 12 feet of water can pass from one lake to the other.

On the locks, bridges and guard gates of this new canal about 300 men are constantly employed, 8 men at each lock, and thus there is a heavy running expense which is however more than counterbalanced by the tonnage tolls charged for passing through the canal.

The main prism of the canal has a bottom width of 100 ft., is 12 ft. deep, and has side slopes of 1 to 2, thus making the surface about 150 feet across.

The rock excavation, however, is 14 ft. deep, so that if at any future time the canal needs deepening, it can be effected without much difficulty.

The contract price of earth excavation ranged from 20 to 30 cts. per cubic yard, that of rock from $1.00 upwards. This excavation was evidently *the chief* item of expenditure, the next in order being the locks, and then the regulating weirs.

The tenders for the locks ranged from $160,000 each, downwards, according to the distance of the quarries from the work, but most of them were much less. The highest tenders were given when stone was to be brought from the Peléo Islands, but subsequently *good* stone was found in the vicinity of the canal, so that the cost of transportion was materially reduced.

In the 13 miles from Lake Ontario to *Allanburg*, the difference of level is about 313 feet and as there are 25 locks in this distance, the average lift of each lock is about 13 feet The lifts range from 16 feet to 12 feet. From Allanburg to Lake Erie there is one level, but guard gates are placed at each end of this length.

A subject closely connected with that of the canal proper is that of Weirs. On the old canal very few weirs were required but, with such a large body of water as in the new canal regulating weirs become an important factor. These weirs have stone sides *throughout their whole length to prevent the wearing* of the soil, and stone bottoms part of the way; they are connected with one another and the canal basin. The flow of water in them is generally rapid and is regulated by sluices. The sluices are simple in design being merely squares of sheet iron which are raised and lowered by screws.

The cost of building these weirs was considerable owing to their extent, some being at least 100 yards wide.

It is now proposed to describe the locks of the new canal, and as *they are all similar, attention will be confined* to lock No. 7, which will be discussed under the following heads:—

(1) General description of the lock.
(2) Timberwork of the lock.
(3) Masonry.
(4) The lock gates.
(5) The machinery for opening and shutting the lock gates.
(6) The machinery for opening and shutting the sluices.

(1) GENERAL DESCRIPTION.—*Lock* No. 7 is 270 feet long from main sill to main sill, 46 ft. 4 ins. wide on the upper reach, and 45 ft. wide on the lower. The walls (Figs. B and C, page 80) are 29 ft. 1 in. in height, and have a front batter of 1 in 24 except in the gate recesses where they are vertical. The coping is 1 ft. above the water surface. These walls are backed up by 3 feet of rammed puddle to make them water-tight. The contract price for this puddle ranged from 75 cts. to $1.00 per cubic yard and there are about 2750 cubic yards in each lock.

There are 12 *feet* of water over the mitre *sills on the* lower reach and thus any vessel which can pass through the St. Lawrence canals may enter the upper lakes by this route.

(2) TIMBERWORK.—The principal feature under this head is the floor of the lock.

On the bottom are laid two 12-ins. x 12 ins. mud sills, one on each side of the lock, extending throughout its whole length and parallel to its sides. Across the lock at intervals of 12-ins., are stretched 12-ins. x-12-ins. stringers, all of Oak. Upon these is laid a course of 3 ins. *pine planks, which again is covered by a top* course of 2-ins. pine planks breaking joint with those beneath.

The gates are all of white oak. The mitre and main sills (Fig. 1, page 84) are made of 19ins. x 19-ins. timbers braced together by 3·4 ins. x ·83 in., wrought iron straps which are fastened by 1½ in. bolts.

SUMMARY OF TIMBER.

Pine timber in mitre sill platforms Oak " " " "	13602′. 6″
Anchor timbers	180′
Splice blocks	1308′
Mud sills	1415′ 6″
Total	16,506 cubic feet.

(3). MASONRY.—All the masonry of the lock, with the exception of the wing walls is cut ashlar limestone of a very firm texture, hard and close-grained, but which stains somewhat after a time, proving the presence of iron. The stones are large, each averaging from 10 to 25 cubic feet.

The greater part of the stone came from quarries in the neighborhood, (Queenston, St. Davids, etc.), but the stone for hollow quoins was brought from the *Pelée Islands in Lake Erie, and was cut and dressed* ready for use at the quarries.

Most of the stone was cut by British stone-cutters whose wages averaged from $2.50 to $3.00 per diem.

The wing walls are of ashlar but not face-cut. The stones are merely squared and trimmed at the edges, and are also smaller. All the masonry is laid in Thorold cement mortar. The contract price of this cement was about $1.50 per bbl. (delivered).

At the back of the chamber walls are 24 counterforts, 12 on each side, their dimensions being 6′ x 3′ x 29′ 1″. *The puddle is rammed in between them.*

SUMMARY OF MASONRY.

Chamber walls	117,929·5025		Deductions.
Counterforts	10,404·	Chain holes	1166 8552
Recess walls	81,198·	Recesses	11172·0812
Upper wings	7,780·648	Round. of copings	257·4144
Lower wings	7,349·122	Checks	8·96
Breast walls	3,286.7945	Nosing	9.4146
	227,948·0670	Cubic feet	12,614·7254
	12,614·7254		
	215,333·3416	*do*	*7975·308 C. yds.*

The contract price of this masonry necessarily varied, but $8 to $12 per cubic yard will include the price of almost all, although when the stone was easily obtained prices fell as low as $5 per cubic yard.

Great difficulty was experienced in building the hollow quoins so as to prevent their settling unevenly.

In one or two instances the gates had to be taken out and retrimmed so as to make them water-tight, but in general no unevenness has occurred.

4. *Lock gates.*

These gates are four in number, 2 at each end of the lock. They are about 2½ ft. thick and are made of white Oak timbers bolted together so as to form a solid mass except in the upper part where they are left hollow for a few feet and loaded with flat bars of iron according to the strain which may come on them.

At the centre of the lock where the two gates meet they are bevelled to about 60° so as to form a water-tight joint, the other edge is made circular so as to fit in the hollow quoins, (Fig. E, page 80), and form a water-*tight joint. The same provision is made at the bottom* by bringing the gates against a mitre-sill 19ins. deep.

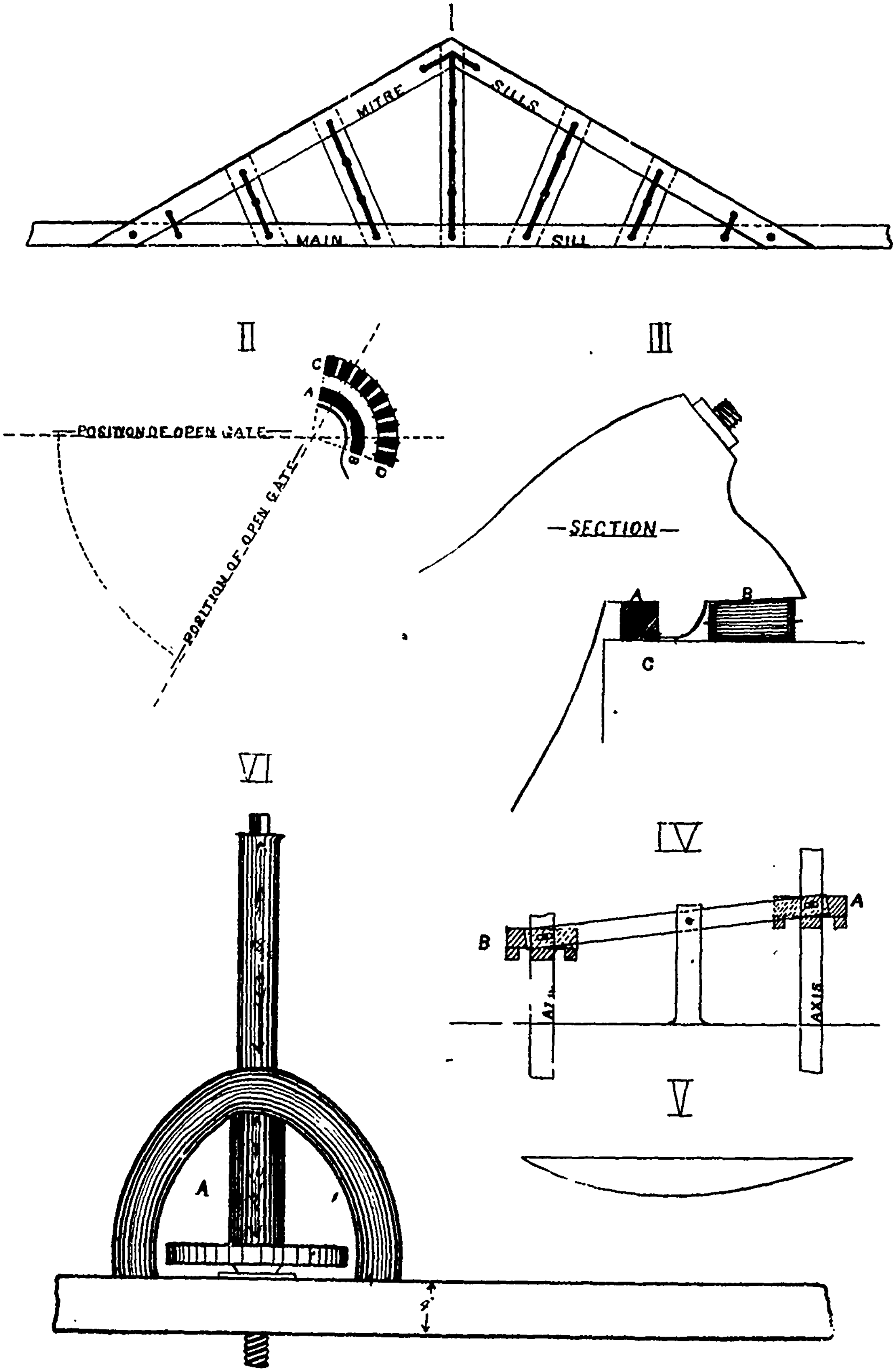
On each face of each gate and running from the top corner at the hinge across the gate to the diagonally opposite corner, is a heavy wrought iron brace 6-ins. x 2-ins. which effectually prevents the gate from sagging.

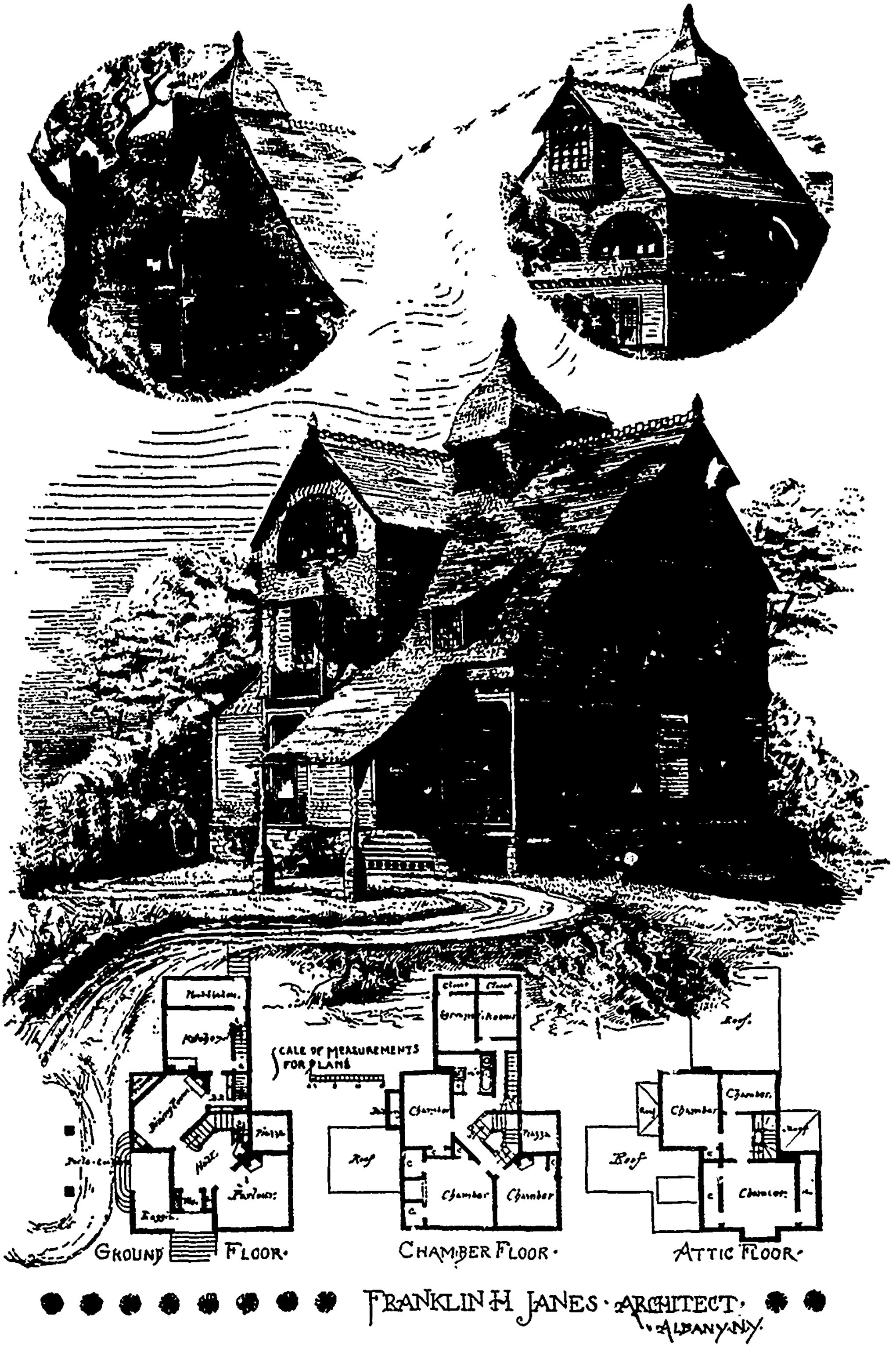
The whole weight of each gate (minus the weight of water displaced by the gate) is suspended from the coping which is therefore made very strong at the point of suspension.

An iron plate bolted to the coping and stayed by 5 bars *also securely bolted, has a circular-shaped rim* (eccentric with the hollow quoin and about 100° in extent) projecting above it and about 4 ins. square.

A wrought iron hook-like piece bolted firmly to the gate engages with this rim and is kept from binding and held in position, by a series of small iron rollers, placed outside the rim and in a circle eccentric with it; on these rollers the aforesaid piece runs as the gate opens and shuts. (Fig. 2, page 84.)

WELLAND CANAL.




SCALE OF MEASUREMENTS FOR PLANS
Kitchen
Dining Room
Hall
Piazza
Parlour
Closet
Closet
Chamber
Chamber
Chamber
Chamber
Roof
Piazza
Roof
Chamber
Chamber
Chamber
Roof
Roof
GROUND FLOOR·
CHAMBER FLOOR·
ATTIC FLOOR·
FRANKLIN H JANES · ARCHITECT · ALBANY, N.Y.

5. *Machinery for opening and shutting sluices :*

The machinery for opening and shutting *one* pair of gates is divided into 4 sets similar to one another, two on each side of the lock. (Fig. F, page 80.)

A description of one of these 4 sets will suffice for the whole.

A circular vertical chain well about 2 ft. in diameter is made about 6 feet from the wall front. An outlet from this into the lock is obtained by means of a square passage through which the chain passes, and which also offers a mode of entrance for repairs.

The chain is attached to the outer edge of the gate 2 or 3 feet from the bottom ; it passes first into the passage and over a guide pulley 10 ins. in diameter, then round a concave drum 20 ins. in diameter, which revolves on a horizontal axis 10 ins. long, and finally up the chain-well and round another barrel drum to which it is fastened.

This drum is turned by a simple combination of two bevel wheels with a third smaller one, the latter being used only when purchase is needed in case of a storm.

A lever turned by a man, walking in a circular path, sets the whole arrangement in motion and effects the closing or opening of the gate. The machinery for opening the gate is 25 feet from the hinge *up* the lock, and that for closing is 10 feet *down* the lock.

6. *Machinery for opening and shutting gates .*

A cunning device has turned to account the flow of water.

In fact it does away with one hard part of a lock man's toil on this canal, viz., the opening and shutting of the sluices. If it has only done so partly, the fault lies entirely with the lockmen themselves, as will afterwards be shown. The prime-mover by means of a bent lever and a rod, from his position on the platform of the gate raises a small sluice about 6 ins. x 12 ins., which allows the current to act upon a small turbine beneath low-water level. This rotates a small rod which transfers the power to near the top of the gate, and sets in motion a train of wheels, and finally a very slow motion is given to a hollow tube, the inner side of which is in the form of a nut, through which passes a heavy screw. This screw raises and lowers the sluice through which the water pours down. The sluice is raised at first very rapidly, then slower, and at last stops when the water finds its level.

But as there is always a slight current in the canal (made by the Weirs) a simple reversal would cause the sluice to slowly shut down again, and here carelessness has detracted from its usefulness. The reversal is effected as follows :

The current may, at any time, be shut off by simply sliding a clutch up one of the axes (next to the final one) and allowing the spur wheel on this axis to ride loosely (clutch *A*, Fig. IV. page 84), but at the same time that one clutch is raised, another (*B*) is lowered and thus forces another spur wheel on another axis to turn as the axis does ; but this axis turn in an opposite direction to the first one and thus the motion is reversed and the screw lowered, but unless one clutch is entirely lowered the other will catch on the spur wheel and get broken. For this reason the reversing clutch had to be turned upside down and the sluice lowered by a crank.

The value of the train of wheels is about 2-13 x 2-13 x 2-5 equals 8-845 or about 1-106. The pitch of the screw is ½ inch, so that about 212 revolutions of the turbine rod are needed to raise the sluice 1 inch ; the sluices are raised in about 2 minutes. These sluices are about 5 ft. x 1½ ft. and are shaped as in Fig. V to withstand the pressure.

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MORTAR. (*Building News.*)

Certain recent decisions have brought this subject prominently before the trade, and, indeed, from every point of view it is one of very great importance. Whether the mortar is good or bad, and whether it is suited to the purpose *to which* it is applied, are matters which concern not only the builder but the tenant. *The durability of the mortar is also of considerable moment*, and it is noteworthy that the modern made lime has never attained the hardness of that *manufactured* by the ancients. This may be accounted for by the length of time which they allowed the *mortar to stand* before using. The lapse of time also may have something to do with the hardness. The best *mortar* is not to be obtained from burning chalk—a very common practice—as it contains too great a quantity of foreign matter ; while to obtain really good tenacious brickwork stiff made mortar should be used with wet materials. The "rich limes" are more preferable for ordinary building purposes, as *they* increase in volume *when slaked*, and they also carry more sand. The disadvantage which attends *the* use of *the rich lime is that it is inapplicable for* external walling, or, in fact, for any works likely to be exposed to running or tidal water. In the matter of buildings which are exposed to the action of water, hydraulic lime is the only kind proper for making mortar. This description has an immense advantage over the rich lime ; it has the power of setting under water. There is an artificial hydraulic lime made by the addition of clay containing soluble silicate of alumina to the pure carbonate of lime. It may be made also by adding pounded or underburnt brick or tiledust, to the mortar of rich limes. These artificial hydraulic limes are well fitted to resist the soluble action of water. In mixing them *the* greatest care should be exercised, and no detail should be left to the eye or *judgment of the labourer conducting the process of slaking*. The sand used must be free from loam and clay, and be distributed equally through the mass.

The mixing of ordinary mortar is also occasionally varied by the addition of foreign substances such as smiths' ashes and pounded tiles. Where the mortar is to be used for pointing old brick work and for analogous purposes, the addition has obvious advantages. A mortar of the kind should be avoided for interior work, the ordinary and unmixed mortar being preferable.

The most important stage in the process of making mortar is "slaking." This is a most delicate operation and cannot have too much care bestowed on it. The primary point to be kept in view *is not to add more water to the materials than* will bring them to the consistency of tenacious clay. The rich lime especially requires care in the slaking. *A much greater* quantity of water may be used than with the hydraulic, some builders reducing it to a fluid state and running it off into a tank, where the excess of water evaporates.

There is considerable danger to the building where the mortar hardens too rapidly, many of the fractures seen in modern buildings being due to this cause. The chances of mortar hardening rapidly become less as it lies remote from the surface of the wall. It may also be noted that petrifaction greatly depends on a sufficient supply of carbonic acid. The chemistry of mortar is, however, obscure. The primary cause of its hardening is due *to the formation of carbonate of lime, though in* some very old samples a silicate of lime also appears to have formed. As we know nothing of the proportions and *preparation* of ancient mortars, and our far off posterity will be equally ignorant of to day's practice, it is evident that no analysis will ever give other than approximate results.

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THE MODLING-BRUHL ELECTRIC RAILWAY.—The track is 1-metre (3.28 ft.) wide, the maximum incline is 15 in 100, and the minimum curve radius is 30-metres (98.4 ft). The maximum speed will be 20 kilos (12.4 miles) per hour. The stations, at important points, will be provided with telegraphic and telephonic apparatus. The trains will consist of 3 cars, each with 18 seats, per engine.

PRESERVATION OF RAILWAY TIES.

Some interesting data are published showing the relative value of different methods of injecting railroad ties. On the route from Hanover and Cologne to Minden, for example, the pine ties injected with chloride of zinc required a renewal of twenty-one per cent, after a lapse of twenty-one years; beech ties injected with creosote required a renewal of forty-six per cent after twenty-two years' wear; oak ties injected with chloride of zinc required renewal to the extent of about twenty-one per cent after seventeen years; while the same kind of ties not injected necessitated fully forty-nine per cent of renewals. The conditions in all these cases were very favorable for reliable tests, and the road bed was good, permitting of easy desiccation. the unrenewed ties showed, on cutting, that they were in condition of perfect health. On another road, where the oak ties were not injected, as large a proportion as 74·48 per cent had to be renewed after twelve years, the same description of ties injected with chloride of zinc required only 3·29 per cent renewals after seven years, while similar ties injected with creosote involved, after six years, but 0·09 per cent.

Metallurgy, Electricty, &c.

Cutting Glass by Electricity.—M. Fahdt of Dresden cuts glass in the following manner:—

He surrounds the glass vessel with a copper wire connected by two screws to the poles of an electric battery. The wire becomes red hot on the passage of the current, and the glass is evenly cut, under the action of the heat developed.

Automatic Locomotive Distance Indicator.—M. Giacomo Leto Vito, a Sicilian, has just invented a very simple machine which gives the driver the following information:—

1st. It indicates the position of the train within about 30 ft.

2nd. It calls his attention by a whistle at all points at which great watchfulness is required.

These results are obtained by a system of toothed wheels and by a cord which unwinds like the paper band of the Morse machine. When this cord, divided unto equal sections proportional to the distance traversed, is at a dangerous point, the alarm-whistle is sounded by a special contrivance.

Oxidisability of Cast-Iron, Steel, and soft iron.—In a recent number of *Comptes Rendus*, M. Gruner gives an account of his researches on the relative oxidisability of cast iron, steel, and soft iron. Various plates, suspended in a frame by their four corners, were immersed simultaneously in water, acidulated with ½ per cent. of sulphuric acid, or sea-water, or were simply exposedin moist air on a terrace. *Inter-alia*, in moist air chromate steels were oxidised most, and tungsten steels less than mere carbon steels. Cast-iron, even with manganese, is oxidised less than steel and soft iron, and white specular iron less than grey cast-iron. Sea-water, on the other hand, attacks cast-iron more than steel, and with special energy white specular iron. Tempered steel is less attacked than the same steel annealed, soft steel less than manganese steel or chromate steel, etc. Acidulated water, like sea-water, dissolves grey cast iron more rapidly than steel, but not white specular iron; the grey impure cast iron is most strongly attacked.

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ELECTRIC RAILWAYS. (*Nature.*)

Abstract of a lecture at the Royal Institution by Prof. W. E. Ayrton, F.R.S.

In electric transmission of power there is not only waste of power from mechanical friction, but also from electric friction arising from the electric current heating the wire, through which it passes.

Prof. Ayrton explained and demonstrated experimentally that this latter waste could be made extremely small by placing so light a load on the electro-motor, that it ran nearly as fast as the generator or dynamo, which converted the mechanical energy into electric energy; actual experiments leading to the result that for every foot-pound of work done by the steam-engine on the generator, quite seven-tenths of a foot-pound of work can be done by the distant motor.

One reason why electric transmission of power can be effected with so little waste is because electricity has apparently no mass, and consequently no inertia; there is, therefore, no waste of power in making it *go round a corner*, as there is with water or with any kind of material fluid. Another reason why electro-motors are so valuable for travelling machinery is on account of the light weight of the motor. *Experiment shows* that one horse-power can be developed with 56 lbs. of dead weight of electro-motor, and that for large electro-motors of *several horse-power the weight per horse is even much less*; a result immensely more favourable than can be obtained with steam, gas, or compressed-air-engine.

In addition to the loss of power *arising from the heating* of the wires by the passage of the current, there is another kind of loss that may be most serious in the case of a long electric railway, viz., that arising from actual leakage of the electricity due to defective insulation. To send an electric current through a distant motor, two wires, a "going" and "return" wire must be employed, insulated from one another by silk, guttapercha, or some insulating substance; and if the motor be on a moving train, *there must* be some means of keeping up continuous connection between the two ends of the moving electro-motor and the going and return wire. The simplest plan is to use the two rails as the two *wires*, and *make* connection with the motor through the wheels of the train; those on one side being wlel insulated from those of the other,otherwise the current would pass through the axles of the *wheels instead of* through the moter. It is this simple plan that is employed in Siemens' Lichterfelde Electric Railway, now running at Berlin; the insulation arising from the rail being merely laid on wooden *sleepers* having been found sufficient for the short length, 1½ mile. The car is similar to an ordinary tram-car,and holds twenty passengers. It was explained that on this latter railway, *which was 900 yards long*, both the ordinary rails were used at the return wire, and that the going wire was a third insulated rail rubbed by the passing *train*. *In this the going* and *return* wires were *overheadand* insulated, connection being maintained between them and the moving car by two light wires attached to the car which pulled along two little carriages running on the *overhead* insulated wires, and making electric contact with them. [Experiments followed, proving that although two bare wires lying on the ground could be quite efficiently employed as the going and return wire, if the wires were short and the ground dry, the leakage that occurred if the wires were long and the ground moist was so great, as to more than compensate for the absence of the locomotive.] Consequently Prof. Perry and myself have for some time past been working out practical means for overcoming these difficulties, and we have arrived at what we hope is an extremely satisfactory solution. Instead of supplying electricity to one very long, not very well insulated rail, we lay by the side of our railway line a well insulated cable, which conveys the main current. The rail, which is rubbed by the moving train, and which supplies it with electric energy, we subdivide into a number of sections, each fairly well insulated from its neighbour and from the ground; and we arrange that at any moment only that section or sections *which is in the* immediate neighbourhood of the train, is connected with the main cable; the connection being of course made automatically by the moving train. As then *leakage to the earth of the* strong propelling electric current can only take from that section or sections of the rail, which is in the immediate neighbourhood *of the train the loss of power by leakage is very* much less than in the case of a single imperfectly insulated rail such as has been hitherto employed, and which being of great length, with its corresponding large number of points of support, would offer endless points of escape to the motive current.

Dr. Siemens has experimentally demonstrated that an electric railway can be used for a mile or two; Prof. Perry and myself, by keeping in mind the two essentials of success, viz., attention to both the mechanical and electrical details, have, we venture to think, devised means for reducing the leakage on the longest railway to less than what it would be on the shortest.

For the purpose of automatically making connection between the main well-insulated cable and the rubbed rail in the neighbourhood of the moving train we have devised various means, one of which is seen from the following figures.

A B (Fig. I) is a copper or other metallic rod resting on the top of and fastened to a corrugated tempered steel disc D D (of the nature of, but of course immensely stronger than the corrugated top of the vacuum box of an aneroid *barometer*), and which is carried by and fastened to a thick ring E E made of ebonite or other insulating material; The ebonite ring is itself screwed to the circular cast-iron box, which latter is *fastened to* the ordinary railway sleepers. The auxiliary rail A B and the corrugated steel discs D D have sufficient flexibility that two or more of the latter are simultaneously depressed by an insulating collecting brush or roller carried by one or by all of the carriages. Depressing any of the corrugated steel discs brings the stud F, which is electrically connected with the rod A B, into contact with the stud G electrically connected with the well-insulated cable.

As only a short piece of the auxiliary rail A B is at any moment in connection with the main cable, the insulation of the ebonite ring E E will be sufficient even in wet weather, and the cast-iron box is sufficiently high that the flooding of the line or the deposit of snow does not affect the insulation. The insulation, however, of G, which is permanently in connection with the main cable, must be far better. For this purpose we lead the gutta-percha, or india-rubber, covered wire coming from the main cable through the centre of a specially formed telegraph insulator, and cause it to adhere to the inside of the earthenware tube forming the stalk. And as, in addition, the inside of each contact box is dry, a very perfect insulation is maintained for the lead coming from the main cable. Consequently as all leakage is eliminated except in the immediate neighbourhood of the train, this system can be employed for the very longest electric railways. Fig. 2 shows a modification of the contact box when the insulated rail L, instead of extending all along the line, is quite short and is carried by the train, and by its motion presses forwards and downwards a metallic fork on the contact-box, thus making contact between F and G. [Other diagrams were explained, illustrating modifications of the contact-boxes; in one case the well-insulated cable is carried inside the flexible rail, which then takes the form of a tube, shown in Fig. 3; in another case the cable is insulated with paraffin oil instead of with gutta-percha or india-rubber, shown in Fig. 4, &c.]

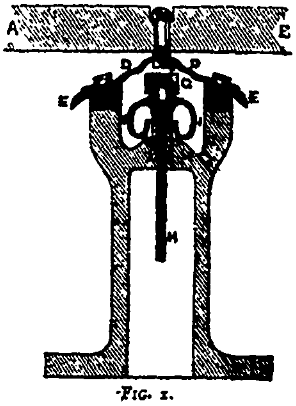

FIG. 1.

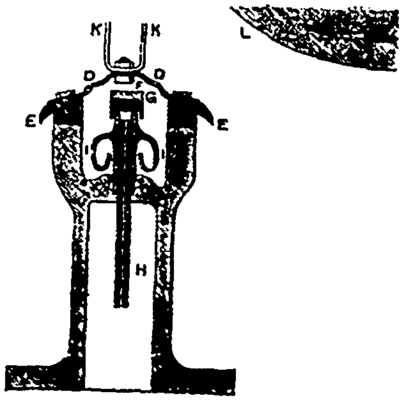

FIG. 2.

The existence of these contact-boxes at every 20 to 50 feet also enables the train to graphically record its position at any moment on a map hanging up at the terminus, or in a signal-box or elsewhere, by a shadow which creeps along the map of the line as the train advances, stops when the train stops, and backs when the train backs. This is effected thus:—As the train passes along, not only is the main contact between F and G automatically made, as already described, but an auxiliary contact is also completed by the depression of the lid of the contact-box, and which has the effect of putting, at each contact-box in succession, an earth fault on an insulated thin auxiliary wire running by the side of the line. And just as the position of an earth fault can be accurately determined by electrical testing at the end of the line, so we arrange that the moving position of the earth fault, that is the position of the train *itself*, is *automatically* recorded by the pointer of a galvanometer moving behind a screen or map, in which is cut out a slit representing by its shape and length the section of the line on which the train is, as shown in Fig. 5. In addition, then, to the small sections of 20 feet or more into which our auxiliary rubbed rail is electrically divided, there would be certain long blocked sections one mile or several miles in length, for each of which on the map a separate galvanometer and pointer would be provided. [Experiments were shown of the system of graphically automatically recording the progress of a train.]

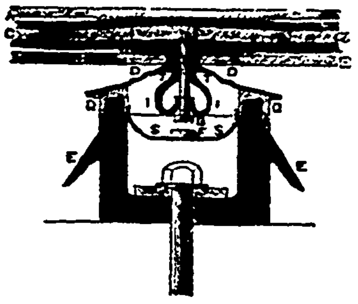

FIG. 3.

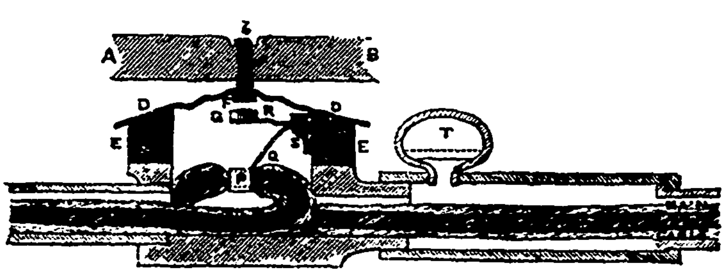

FIG. 4.

In the preceding systems there are several contact-boxes in each section of the insulated rubbed rail, and several sections of the insulated rail in each section of the line blocked, but in the next system the rubbed rail is simply divided electrically into long sections each of as great a length as the particular system employed to insulate the rubbed rail will allow. In this case we arrange that the electric connection between the main cable and the rubbed conductor shall be automatically made by the train as it enters a section, and automatically broken as the train leaves a section. The model before you is divided into four sections, each about 11 feet in length, and you see from the current detectors that as the train runs either way, it puts current into the section just entered, and takes off current from the section just left.

[Experiments were then shown of the ease with which an electric train could be made to back instead of going forwards, by reversing the connections between the revolving armatures and the fixed electro-magnets of the motor, also that the accidental reversal of the field magnets of the main stationary generator, although it had the effect of reversing the main current, produced no change in the direction of motion of an electric engine, the direction of motion being solely under the control of the driver.]

But more than this, not only does the train take off current *from the section* 1 when it is just leaving it, and *entering* section 2, but no following train entering section 1 can receive current or *motive power* until the preceding train has entered section 3. [Experiments were then shown proving that with this system a *following* train could not possibly run into a preceding train even if the preceding train stopped or backed.] Now why does the *following* train when it runs on to a blocked section pull up so quickly? The reason is because it is not only deprived of all motive power, but is powerfully braked, since when electricity is cut off from a section, the insulated and non-insulated rail of that section are automatically connected together, so that when the train runs on to a blocked section the electromotor becomes *a generator short circuited* on itself, producing, therefore, a powerful current which rapidly pulls up the engine. [Experiments were then shown of the speed with which an electromotor, which had been set in rapid rotation and then deprived of its motive current, pulled up when its two terminals were short-circuited.]

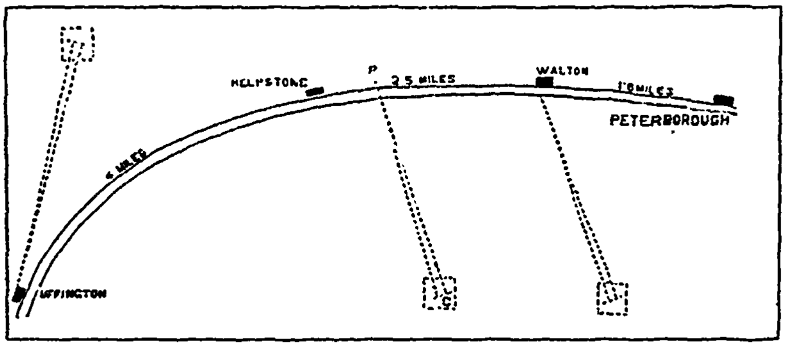

Fig. 5.

Whenever, then, a train, it may be even a runaway engine, enters on a blocked section, not only is all motive power withdrawn from it, but it is automatically powerfully braked, quite independently of the action of the engine driver, guard, or signalman. No fog, nor colour-blindness, nor different codes of signals on different lines, nor mistakes arising from the exhausted nervous condition of overworked signal-men, can with this system produce a collision. The English system of block-is *merely giving* an order to stop a train; but whether this is understood or intelligently carried out is only settled by the happ*ening or non*-happening of a subsequent collision. Our Absolute Automatic Block acts as if the steam were automatically shut off and the brake put on whenever the train is running into danger; nay, it does more than this—it acts as if the fires were put out and all the coal taken away, since it is quite out of the power of the engine-driver to re-start his train until the one in front is at a safe distance ahead.

But all trains will undoubtedly be lighted with electricity; must, then, the train be plunged into darkness when it runs on to a blocked section to which no electric energy is being supplied? No! If some of the electric energy supplied to a train when it is on an unblocked section be stored up in Faure's accumulators, such as are at present used on the Brighton Pulman train, the lamps will continue burning even when the train has ceased to receive electric energy from the rubbed rail.

When, then, we commit the carrying of our power to that fleet messenger to which we have been accustomed to entrust the carrying of our thoughts then shall we have railways that will combine speed, economy and safety; and last, but not least to us, we shall have the entire absence of smoke.

NOTES ON THE RELATIONS OF MANGANESE AND CARBON IN IRON AND STEEL.

BY M. ALEXANDRE POURCEL, TERRENOIRE, LOIRE, FRANCE.

(*A Paper read before the American Institute of Mining Engineers.*)

The perusal of Mr. Willard P. Ward's "Notes on the Behaviour of Manganese to Carbon," presented at the Washington meeting of the Institute in February, 1882, has suggested further reflections on the same general topic, and has led to the preparation of the present paper.

The same observation that Mr. Ward has put on record in his "Notes" was also made by myself at about the same time (in August, 1875), and under almost the same conditions. From a blast-furnace that was *very hot*, as was the furnace mentioned by Mr. Waru, I obtained a pig-iron containing about *fifteen* per cent. of manganese, gray in color, and very tough. It could be pulverized, but could not be cut with the *chisel*. I analyzed this iron and found that it contained, as I had suspected, a large amount of silicon. From this fact I drew the conclusion that the silicon had deprived the manganese of its power of dissolving carbon, since the latter, instead of occurring in the pig in combination, appeared as graphitic carbon. I thus saw reproduced on a large scale, and demonstrated in a visible way, the property that Colonel Caron, a French scientist, had discovered in silicon,—the property of obstructing the process of hardening in steels by keeping the carbon in the graphitic condition.

An attentive study of the conditions under which the phenomenon observed by Mr. Ward takes place led me to go back to operations of synthesis, and to make as I wanted them, pig-irons containing varying quantities of silicon, manganese, and carbon. An iron, thus prepared, was intended to serve me as a *chemical* reagent in the production of steels cast without blow-holes, such as my lamented friend, Mr. A. L. Holley, has introduced and made known to the United States. What I needed in order to make very soft steels, cast without blow-holes, was an iron which, when it was added to the bath of steel, introduced *into the* bath a sufficient amount of silicon and of manganese, with the smallest possible proportion of carbon. Now, in analyzing an iron similar in character to that obtained by Mr. Ward, I found that the amount of combined carbon in the iron was almost nothing, and that the total carbon was between 3 and 3½ per cent., instead of being from 5 to 5½ per cent., as in ordinary spiegels containing 15 to 16 per cent. of manganese.

I then sought for a way of still further diminishing the carbon by increasing the silicon and manganese, and after a few trials I found that when the manganese and silicon are present in the ratio of their chemical equivalents, the carbon reaches a minimum. It is well understood that *the higher* the percentage of manganese and of silicon in the pig is raised, the lower the percentage of carbon will be; an almost complete elimination of carbon might, indeed, be obtained by means of silicon, but the law which determines that the percentage of carbon shall reach its *minimum* is fixed by the ratio Mn : Si. When the manganese increases, the carbon increases also. For example, I have produced a number of tons of iron with from 11 to 13.5 per cent. of silicon, and from 17 to 19 per cent. of manganese, and the percentage of carbon has been the least,—2 per cent.,—with 13.2 per cent. of silicon and 17 per cent. of manganese, that is to say, when the two substances are present in the ratio Mn : Si. (Mn=27.5, Si=21.)

What are the reactions that take place in the blast furnace when a pig-iron, or rather an alloy, of this kind is produced? Are the phenomena simultaneous or successive? My *opinion* is that they are successive, and that the carburet of manganese is the reagent that reduces the silica from which the *silicon is* derived. We can in fact repeat that laboratory experiment which consists in maintaining a quantity of ferromanganese in a molten condition for several hours in a thick crucible, such as is used in the melting of steel. According to the length of time, more or less, that the ferromanganese is kept in the molten state, we find the walls of the crucible to be more or less attacked . the metal incorporates with itself a notable quantity of silicon, and loses some of its manganese and carbon In this experiment there can be no doubt that the carburet of manganese is the reagent by whose action the silicon is derived from the silica in the walls of the crucible.

The laws of thermo-chemistry that have been established by Berthelot's numerous fine experiments equally *confirm* the opinion, to which I some time ago gave utterance, that when silicon and manganese occur together in a pig-iron or in a steel, they are in a state of chemical combination, as a silicide of manganese, if the percentages of the two substances are in the ratio, at least, of Mn Si. It may, indeed, be affirmed that silicon when neutralized by manganese, that is to say, when for each chemical equivalent of silicon there is present a little more than an equivalent of manganese, does not diminish in the least the hardening property of steels. When the amount of manganese increases, the hardening property increases, since manganese possesses the property of dissolving carbon, that is to say, of keeping it in the combined state.

As to the opinion of Mr. Ward that manganese has no injurious effect on the wear of rails, I may say that I hold the same opinion, though for an entirely different reason from that given by Mr. Ward. The deterioration of rails from atmospheric causes, which may be likened to chemical action, is due especially to their physical condition rather than to the chemical composition of the ingot from which the rail was made. A porous ingot, full of blow-holes, will produce a rail, on which, after a few months of service, the surface exposed to wear will be covered with numberless little rays or streaks, which are just so many more points of attack for atmospheric agents. Such a rail if laid in a damp tunnel will very quickly become useless. Possibly it would be used up a little more rapidly if it contained a high percentage of manganese, but in no case would the presence of that element be a principal cause of the effect produced.

If two rails, made from two ingots perfectly sound and free from blow-holes, are compared with each other as regards mechanical wear, my opinion, based on experience, is that the rail whose hardness lies within the limits I am about to point out, will resist wear more effectually than the softer one. The maximum of rigidity, combining resistance to bending with great power of resisting shocks, has been reached in rails of the following composition

Carbon,........................	0 50	to	0.45	per	cent.
Manganese, ...	0.90	"	1.10	"	"
Phosphorus,......................	0.08	"	0.10	"	"
Sulphur,........................	0 05			"	"
Silicon,..........	0.02			"	"

These rails, made from perfectly sound ingots, and laid on one of the busiest portions of a great network of French railways, after *three years* of trial have not given occasion for a *single* rejection, and the wear observed has been insignificant Of other rails made from ingots equally sound, and differing from the preceding only in having a smaller amount—from 0.5 to 0.7 per cent.—of manganese, some, indeed, have always been rejected after the regular test of three years, but that which has been especially remarked is that there has always been a notable wear of the top of the rail.

It is also known to me that the rails which have best stood the rude tests of percussion and bending, demanded by the Russian railways, contain about 0.3 per cent. of carbon, and from 1.1 to 1.2 per cent. of manganese. The manganese, without sensibly diminishing the elongation of the steel, increases its tenacity and rigidity, as well as its power of resisting shocks. It gives to the steel this grand quality of *hardness* without *brittleness*.

In the month of August, 1881, I had at my disposition quite a large number of old steel rails, made at different steel-works in Germany, and taken from the railways of Alsace-Lorraine. These rails had been worn out quite rapidly ; they were all in very bad condition. The oldest of them bore the date of 1874, and the mark "Bochum ;" the most recent came from the steel-works, "G. H Hutte," and were dated 1879 ! These rails in their chemical composition corresponded for the most part with the formula of Dr. Dudley,—those, at least, which did not have any excess of phosphorus or of silicon,—but their resistance to wear has not confirmed Dr. Dudley's opinion.

I have also been able to submit to the test of a blow a rail from the Phœnix steel-works, one from the Osnabruck steel-works, and a third made by Hoesch. The Phœnix rail showed the greatest power of resistance, but the metal is soft, it changes its form considerably, and lacks in rigidity. The Hoesch rail changes in form still more, and, besides, it is brittle. It broke under the shock of a weight of 300 kilogrammes falling through 3½ meters, the anvil weighing 12 tons (tonnes). The Phœnix rail withstood the shock of the same weight falling through 4½ meters. The Osnabruck rail, like that of Hoesch, is brittle, but it changes its form less easily

In conclusion, like Dr. Dudley, I am of opinion that elements like phosphorus, silicon, and sulphur, must be *reduced to an* absolute minimum in a good rail. I should insist especially on the phosphorus and the silicon. and less on *the sulphur*, but I do not put manganese in the category of ingredients that are injurious, either to the rolling or to the use of the rail I should give the preference to a metal containing manganese to the amount of 1 per cent., as I have indicated above, which is excellent for rolling and gives a rail of superior wearing qualities.

Table Showing Partial Composition of Different Rails

Description of Rail.	Mn.	C.	Si.	S.	P.
Phœnix	0.373	0.490	0.093	0.034	0.102
Krupp, ...	0.373	0.323	0.139	0 036	0.146
Bochum, ...	0.240	0.200	0.116	0.026	0.067
Union Dortmund, .	0 240	0.284	0.046	0 039	0 239
G H Hutte, ...	0 480	0.382	0.139	0.039	0.080
Osnabruck.	0.586	0.170	0.466	0.045	0.074
Hoesch	0.453	0.330	0.291	0.038	0.119

THE SAREPTA STONES. —At Sarepta, in Asiatic Russia, there are very curiously formed stones, originating, according to a popular tradition from roots. M. Becker confirms this opinion and states that the *Tragopon ruthenicus*, the *Scorzonera Eusifolia* and the *Euphorbia guardiana*, are plants which reach their full growths in white sand. Their long roots are inhabited and eaten away by insects; a milky juice flows from them, of which the calcareous element accumulates around the root. When the latter has disappeared it is thus replaced by a kind of artificial stone.

PRODUCTS OF THE COMBUSTION OF CARBON.—When carbon burns in an excess of oxygen carbonic acid is formed ; when the proportions of carbon is increased carbonic oxide is produced. This is a well known fact, but it is generally supposed that a higher temperature favours the production of carbonic acid. According to M. Ledeburg, this conclusion is *not altogether* true, and the two gases may be formed at the same time at the following temperatures :—

	Degrees	C.O	C.O$_2$
Below the point of fusion of zinc	350°	78.6	21.4
At the point of fusion of zinc	440°	72 4	27.6
Dull red	520°	71 4	28 6
Cherry red	700°	62.6	37.4
White heat	1100°	1.3	98.7

Temperature then is now the principal agent in the reaction.

"OUR BODIES." (*Knowledge.*)

JOINTS.

By Dr. Andrew Wilson, F.R.S.E

The name "joint" is given to the movable surfaces between two or more bones ; and, as a matter of fact, muscular movements (discussed below) are directed towards the movements of the bones concerned in forming the joint. The scientific name of a joint is an *articulation* . and the reason for the application of this name, at once to the connected series of syllables and words which form "speech," and to bodily mechanics, can be readily appreciated. There are some five structures which enter into the formation of an ordinary "joint." Firstly come the *bones*. Then, secondly, bones are tied together by stout fibrous cords, known as *ligaments*. The beautiful ligaments of the knee, uniting the thigh to the top of the shin-bone, or those of the elbow joint, illustrate the cords in question. Ligaments are related to the sinews (or tendons) of muscles in their composition; both being fibrous cords. Thirdly comes the layer of gristle or *cartilage* which coats the ends of the bones which rub on one another in the movements of the joint. This cartilage is called *articular cartilage*. It is of a beautifully smooth, glistening structure (as may be seen in a butcher's shop, when we inspect the end of a bone which has just been turned out of its socket), and is of a bluish-white colour. This cartilage acts the part of a "buffer," and serves to limit jarring and concussion in joints, besides rendering the movements of the bones smooth. *The fourth structure* found in a joint is a peculiar membrane or layer, which receives the name of *synovial membrane*, and which, practically, lines the cavity of the joint. The office of this membrane is to manufacture a a glairy fluid named *synovia*, which serves as "joint oil," and which, being poured out between the movable surfaces, lubricates the bones in their movements. When, through inflamation of the joint, the *synovial* fluid increases in extent, we suffer from what is popularly called "dropsy" of the joint. The fifth set of structures which may be found associated with joints are known as *bursæ*. These are little cushions or pads, covered usually with synovial membrane, and placed in situations where there is liability to friction. The *bursæ* are to the body, in fact, what the grooved wheel inside the sailor's "block" is to the tackle of a ship; they diminish friction. We discover them in situations where, for example, there is a great play of muscle or sinew over any surface. Between the skin and the knee-cap, for example, where, it is evident, much friction must exist, a *bursa* is interposed. Another exists between the great projection near the head of the thigh-bone and the hip muscles which rub over the projection at every step we take.

Such being the general confirmation of "joints," we may now survey the various forms of articulations met with in our frames. There are three classes of joints to be found in the bodies of man and his neighbour animals. Firstly come what seem to imply a contradiction in terms, namely *immovable joints*. These are well represented in the dove-tailing which is seen between the bones of the skull, a process securing immense firmness of union. The next variety of joints includes those which are named *mixed* articulations. Here we find only a limited range of movement, which may, as in the spine, confer general flexibility, rather than exact movement, upon the parts concerned. In the spine, for example, we have a series of bones, firmly united together (for the protection of the *spinal cord*) by intervening plates of gristle and cartilage. The alternating series of bone and gristle-pads thus seen confers a high degree of flexibility on the spine, without permitting any definite range of motion between the separate bones.

But the most typical joints are these in which free movement in one direction or another is permitted. Under this head—that of *movable joints*—come the ordinary joints of the body elbow, shoulder, ankle, knee, fingers, toes, &c. It is very obvious to any one who swings his arm round and round at the shoulder, that the movement there is of a different nature from that seen in the knee or elbow: whilst the familiar "turn of the wrist" again represents a third kind. Thus it becomes clear that we find in the mechanics of our bodies—firstly, *ball and-socket*. or "universal" joints, capable of free movement in all directions. The deeper the cup, or socket, the more limited is the movement. Witness in proof of the fact, the more limited movement of the hip joint (where the cup is deep) compared with that at the shoulder, where the cup is a mere shallow "saucer" of the shoulder blade. At the elbow, knee, ankle, and in the fingers and toes, *hinge joints* are represented. The motion is backwards and forwards in these joints but such a joint as the knee performs more complex movements than are included under this description. Lastly come the *rotatory joints* in which the movement takes place round a fixed point or *pivot*. When, after keeping the fore-arm fixed with the palm of the hand turned forwards, we suddenly reverse the palm and turn it backwards, one of the bones (*radius*) of the forearm runs (or rotates) round the other bone (*ulna*) of the forearm, and so reverses the position of the hand. The radius thus comes to cross the ulna, as when a speaker, addressing an audience, places both palms downwards on a table in front of him, in the familiar style. Here there is seen the round head of the radius rotating round the ulna, its neighbour-bone; and it may be added that there are certain animals (*e.g.*, elephants and dogs, cats, and carnivora generally) in which the radius is permanently fixed in the crossed position, known scientifically as *pronation*. The position in which the two bones lie side by side (as when the palm is directed forwards) is called *serpination*. When we turn our head on our neck we receive a second illustration of a "pivot-joint." Then the head, together with the first vertebra of the spine, or "atlas," move a little around a little bony peg borne on the second vertebra or *axis*.

It may be added that in the use of the various "joints," highly instructive examples of "animal mechanics" may be occasionally found. Thus the bones really constitute a series of levers of various kinds. When we pull the head backwards on the neck, we are using a lever of the first order. Here the *weight* (the face) is on one side of the *fulcrum* (the neck), and the *power* (the muscles of the back of the neck) is situated on the opposite side of the fulcrum from the weight. Again, if we stand on tip-toe, we use a lever of the second order. Here, the *weight* (*i.e.*, the body or leg) is situated between the *power* (the calf-muscles) and the *fulcrum* (the toes). Or when we raise our hand to our mouth in the act of eating, or of feeding ourselves, when the shoulder is fixed, we use a lever of the third order. For in the latter case, the *weight* (the hand and its contents) is placed at one extremity, the *fulcrum* (the *elbow*) at the other, whilst the *power* (the biceps muscle) acts between the weight and the fulcrum.

MUSCLES.

On one occasion I asked a class of students who were studying physiology in a popular fashion, what they supposed "muscles" were. One student said "muscle" was "sinew"; another told me "it was some kind of fibre"; a third said it was "gristle"; and a fourth that it was "some kind of pulp found in the body." Now the students in question were drawn from the ranks of ordinary middle-class society. They were studying physiology with me, not as a matter of business, but as a labour of love, and were attempting, under my guidance, to obtain a broad and general view of the functions and structure of the human frame. (We should bear in mind that physiology is the science of "functions," and that, as such, it is based on a knowledge of "structure.") I may therefore take my former students as a type of intelligent society around us, and I am not far wrong, I fancy, when I add that if I were to ask the readers of *Knowledge*, head overhead, to return me a plain answer to the question "What is muscle?" I should find only a very small percentage of correct replies. Yet in the appreciation of what muscle *is*, to begin with, lies the key to the understanding of the whole topic. Muscle, in one word is *flesh*. Our muscles are our "flesh," as the muscles of any other animal are its "flesh." What we eat of fish is the muscle of the animal, or rather the collective muscles. Our mutton-chop is the "muscle" of the sheep, as veal is ox muscle in a young condition.

We should never despise homely sources of information. The homelier such means of knowledge are, the better. Here, then, is a readily-accessible source of information concerning the nature of muscle. A slice of cold roast beef lies before me. With the point of my fork I can make out that it consists of things that looks to the unassisted sight like coarse *fibres*, but which are really bundles of fibres. This is observation number one. Muscle is made up of fibres, or bundles of fibres, joined together. Next, I can see that in my slice of beef (which represents a *cross* cut of muscle) there is to be perceived a line of division, through which I can separate so much of the beef from the other half, without tearing any of the fibres. Now this second observation shows me that the flesh of the body is *not* all in one mass. On the other hand, if I were to examine a whole leg of beef I should find that the flesh thereof was grouped into separate portions, each of which is *a muscle*. With the handle of a dissecting scalpel, we can separate out each muscle as a rule from its fellows, and we see that freedom of movement for each muscle is thus secured.

At this stage of our inquiries, we might ask ourselves what, generally, are the uses of muscle. I can enumerate at least five functions which are performed by muscles. Firstly, there are the *common movements* of the body: walking, grasping, etc. These are performed by muscles. Secondly, we obviously *speak* by muscular aid. Thirdly, *we express our emotions*—from sneezing and snarling with our raised lip and uncovered tooth, to shrugging our shoulders—by *means of muscles*. Fourthly, we *circulate our blood* by muscular action, for the heart is simply a hollow muscle. And fifthly, muscle *helps in the digestion of food*, for the middle coat of the stomach and intestine, not to speak of the gullet, is muscular, and serves by its movement to mix the food with the digestive fluids. I need hardly add tha, muscles give to the varied regions of the body their contour and outline. It is the business of the sculptor to delineate with precision the form which the various muscles give to limbs and body under the varying attitudes of action and repose.

There are two distinct classes or kinds of muscle in our bodies. The first of these is the group of *voluntary muscles*, whilst the second group is that of *involuntary muscles*. The former derive their name from the fact that we can move them when we like, and the muscles of face, head and neck, arms, trunk, and legs—that is, the muscles of the body generally—exemplify this first set. The "involuntary" muscles are those which are outside the command of the will, and which discharge various important duties, requiring, so to speak, automatic and regular performance. The muscles of the stomach, which, by their action, mix the food with the gastric juice; the muscles which form part of the walls of bloodvessels, and which by their contraction or expansion produce pallor or blushing of the skin for example; and the muscles of the bronchial tubes of the lungs, and of the pupil of the eye, all illustrate the "involuntary" class. They act only when stimulated by some special feature of life. Light will produce contraction of the special eye muscles whose function it is to close the pupil; and food entering the stomach sets its muscles agoing. The heart is likewise an involuntary muscle, discharging, when left to itself and not interfered with by the brain, its important duty with regularity and precision.

There is a wide difference in structure between the "voluntary" and "involuntary" muscles. The former are often called *striped* muscles, and the latter *unstriped*; but it must be borne in mind that the *heart* is an exception to this classification. The fibres of the heart are *striped* like those of the "voluntary" muscles, whilst, of course, the heart is entirely involuntary in its action. In some respects the heart-fibres, however, are different from those of the striped muscles at large.

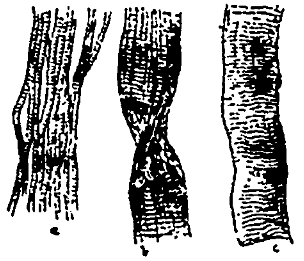

Fig. 1.

If we take a "voluntary" muscle, separate it from its surrounding neighbours, and examine it carefully, we find it to be composed of *bundles of fibres* or *fasciculi* as they are technically named. Each bundle consists of a variable number of fibres (Fig. 1. a.) which at their longest do not exceed one and a half inches in length. The average breadth of a fibre varies from the four-hundredth of an inch to the twenty-four-hundredth. In cold-blooded animals, the fibres are larger than in warm-blooded forms. When we put a fibre of voluntary muscle under the microscope, we observe that, as the light shines through it, it presents a striped appearance (*Fig.* 1. *c.*), the stripes running across the fibre. This "striped" appearance, from which the voluntary muscles derive their name, is due to the fact that a fibre is composed of two kinds of elements, thick and thin. These alternate with each other, and the thick parts, of course, under transmitted light, appear as the dark stripes, whilst the thinner parts form the intervening light bands of the fibre. The light bands refract the light singly, whereas the dark discs or parts refract the light in a double fashion. More recently, another stripe has been described cutting as it were, each dark stripe into two halves. It is evident, however, that when the ultimate structure of a fibre of muscle is considered, we might readily enough conclude that the fibre was really built up of cross-pieces or *discs*, placed end to end, like a *rouleau* of shillings. And, as a matter of fact, we can see this structure in a muscular fibre which has been allowed to soak for some time in a weak acid: As shown in Fig. 2, the fibre then breaks into cross-pieces, named its *discs* (*a*, *b*). Again, on the surface of the fibre we can detect markings or stripes running the long way of the structure. This shows us that in another sense the fibre can be divided into smaller fibres or *fibrils*; and when the extremity of a fibre is microscopically examined, we may see the ends of these fibres (Fig. 2, *c*), reminding us of a section of the separate wires which compose a thick wire rope. Last of all, we must note that each fibre is enclosed in a delicate sheath, called its *sarcolemma*.

Fig. 2.

The *unstriped* or *involuntary* muscles possess, as their name implies, a different structure from their striped neighbours. They are also composed of fibres, but each fibre is made up of long spindle-shaped cells, varying in length from the three-hundredth to the six-hundredth of an inch.

The question, finally, "how does muscle act?" faces us at the close of our brief studies. If we take the well-known *biceps* muscle, which forms the great fleshy mass of the upper arm, as a type of muscles at large, we may discover a ready reply to this question. The biceps springs from the shoulder by its two tendons (or sinews) and passes, to be attached or "inserted" also by a tendon, into the *radius* (one of the fore-arm bones) below. Now, when this muscle acts, we see that it pulls up the fore-arm and flexes or bends it on the upper arm, as in the act of bringing food to the mouth. If we place our hand over the biceps (at the middle of the upper arm) as we raise our fore-arm, we shall feel *the muscle to grow thicker* as the fore-arm approaches the upper arm. Again, we observe that only one end of the muscle moves (the lower end, or *insertion*), whilst its upper end (or *origin*) at the shoulder, remains fixed. From these facts, then, we learn, *firstly*, that muscles act by pulling together the parts between which they are attached; *secondly*, that the muscle grows thicker when it acts; and *thirdly*, that muscles perform their functions of moving the bones and body, because they possess an inherent property called *contractility*—that is, *the power of shortening themselves*. In this latter phrase is found the whole explanation of muscular action. And when we add that groups of muscles (such as those which bend the fingers), antagonise or oppose others (such as those which open the fingers); and that the muscles are ordered and governed by the nervous system, we shall have fairly started our readers on the way of becoming better acquainted from the pages of any physiology text-book with the interesting problem concerning our movements and the power of doing as we will.

THE EURYPHARYNX PELECANOIDES represents one of the most singular beings dredged from the great depths of the Atlantic during the last voyage of the Travailleur. It was found on the coasts of *Morocco at a depth of* 1745 ft. It is a fish about 18 inches long and its greatest thickness is about ¾ in. Its colour is a very deep black. The body, leaving out of consideration the mouth of which the proportions are colossal, resembles that of the Macrurus, and terminates in a point at the caudal extremity. But its altogether peculiar appearance is due to the arrangement of the jaws and the conformation of the mouth. In fact, although the head is hardly more than 1¼ ins., the jaws and *the suspensorium* are exceedingly long; the latter, composed only of two parts, measures not less than 3·7 ins. The result is, that the articular angle is very far back, and at a distance from the end of the mouth equal to about three and one half times the length of the cephalic portion. A long and slender stiletto constitutes the upper jaw, its situation should make it approach the inter-maxillary. On each of the jaws may be felt slight dental granulations; at the extremity of the mandible are seen *two* fang-like *teeth*, about ¾ in. long. The buccal orifice, in consequence of this arrangement is enormous; it leads into a cavity of still more astonishing dimensions. The upper jaw, in fact, is joined to the sides of the head and the anterior portions of the body by an extensible cutaneous fold, which allows of considerable displacement; then between the branches of the mandibles is stretched an analogous cutaneous membrane, still more elastic, formed of bundles of elastic fibres and comparable only with the well-known pocket of the pelican. In consequence of this displacement of the jaws and of the extensibility of the membranes, the mouth with the pharynx forms a vast funnel of which the body of the fish seems to be the tapered continuation, a funnel in which it seems probable that food is stored and partially digested. The organs of motion are very rudimentary. The two fins are reduced *to three small appendages,* which their position at the rear and near the bronchial orifice causes to resemble pectorals; the ventrals are wanting. At a distance from the occiput very nearly equal *to* the length of the head, commences a dorsal which is prolonged almost the whole length of the back, without however, reaching the caudal extremity; it seems to end at from 2 to 3 ins. from the latter. As to the anal, it is similarly arranged; it begins a little in the rear of the anus and finishes at the same point as the dorsal. The end of the body is surrounded by a small membraneous *fold,* like a rudimentary caudal. The slender and flexible rays of these unequal fins are neither articulated, nor, to all appearance connected by a membrane. The respiratory apparatus has a formation unique among bony fishes. There are six pairs of internal bronchial clefts, and *consequently five gills.* The latter consist each of a double series of free lamels. The water flows out on each side through a very small orifice, forming a simple cutaneous rounded perforation, situated *near the level* of the termination of the bucco-pharyngeal *infundibulum.* Finally, neither hyoid bones nor operculars are to be found, and there is a complete absence of swimming bladders.—*Revue Scientifique.*

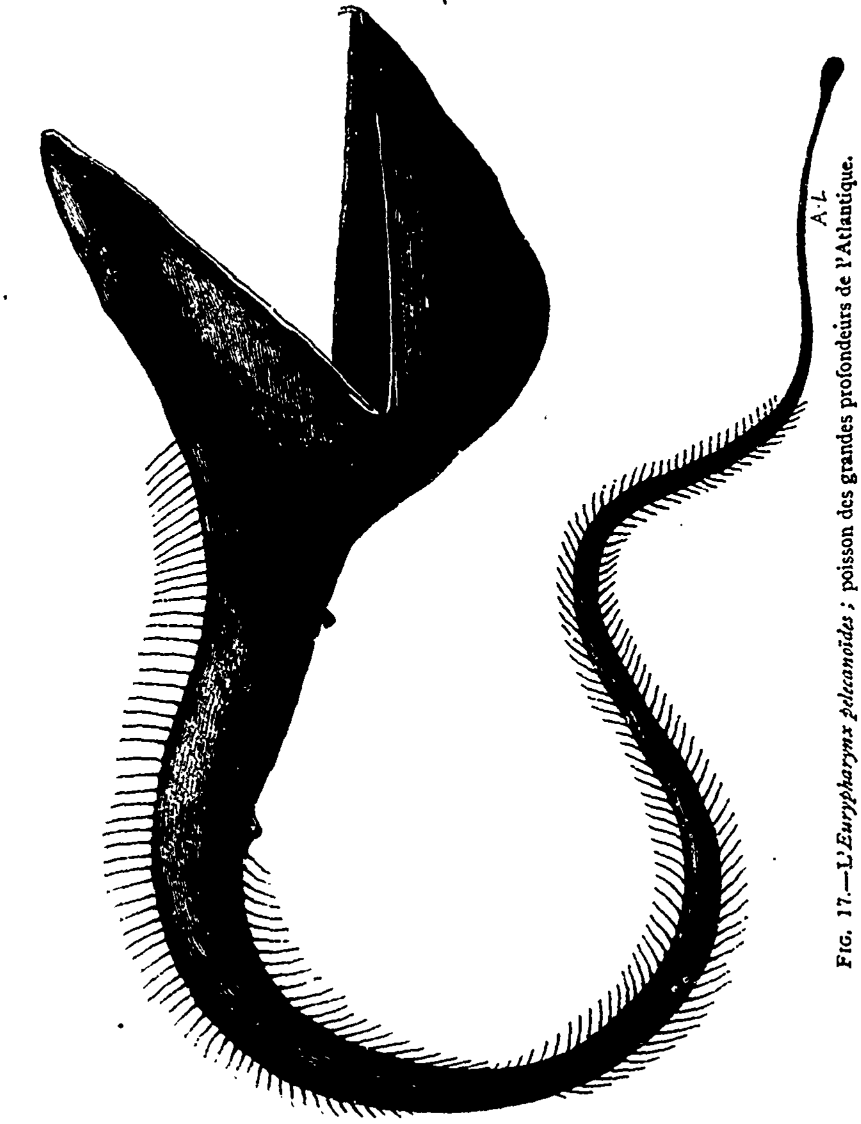

FIG. 17.—L'*Eurypharynx pelecanoïdes* ; poisson des grandes profondeurs de l'Atlantique.

THE ESTIMATION OF MINERAL OIL IN THE PRESENCE OF OTHER OILS.

BY CHARLES C. HALL, WORCESTER, MASS.

The following procedure in estimating mineral oil when mixed with vegetable or animal oils, is the result of a long series of experiments based on the method suggested by Sir William Thompson and Mr. A. H. Allen, in a paper read before the Royal Society.

Four to five grams of the oil under examination are weighed out in a porcelain capsule of 75 c.c. capacity. Thirty c.c of a 10-per cent solution of potassium-hydrate are added, and the capsule covered with a watchglass is placed in a water-bath heated to about 93° C. The mixture of oil and alkali should be stirred frequently, and after three quarters of an hour it is boiled with stirring. This will secure the complete saponification of all the vegetable or animal oil. After the boiling has been continued some time, and most of the alcohol is expelled and a thick scum of soap forms on the surface, a little bicarbonate of soda is added to convert the excess of caustic alkali into carbonate. When the contents of the capsule have become pasty an equal bulk of fine, clean sand is stirred in. This makes the soap granular, and facilitates the removal of the last traces of alcohol. The capsule is now heated for two hours more on the water-bath. After cooling, the contents of the capsule are transferred to a short-necked funnel, having a thin plug of asbestos, and washed with petroleum ether, or some other light petroleum spirit. The ether dissolves out the mineral oil from the soap, and is best collected in a quarter-liter flask having a short neck. The ether can be applied conveniently and effectively by a small wash-bottle. Care must be taken to effect a complete removal of the oil from the soap by means of the ether. This can be tested by letting a drop of the ether, as it comes through, fall on a piece of tissue-paper. If there is no greasy stain left after the ether evaporates, the solution may be considered complete.

Most of the ether is removed from the oil by distillation and can be saved. The heat of the water-bath is sufficient to boil the ether, and the fumes can be condensed by passing them into a condenser. The oil is now transferred to a weighted 50-c.c. flask which has a hole blown in its side, and dry, warm air is forced into the flask through its neck in order to remove the last traces of the ether. The flask should not be heated above the point where it can be borne in the hand; if this precaution is heeded, there is no danger that any of the oil will be volatilized. The passage of the air should be continued until the flask and oil are constant in weight.

Sperm oil cannot be separated from mineral oil by this method owing to the impossibility of completely saponifying it.

Experiments with sodium-hydrate instead of potassium-hydrate did not give good results

The following quantitative determinations of mineral oil in mixtures made for the purpose show the accuracy of the method

Kind of Fat Oil in the Mixture	Percentage of Mineral Oil in the Mixture	Percentage obtained by Analysis
Olive Oil, . .	61.11	61.10
	66.79	66.75
	25.39	25.13
	21.20	21.14
Lard Oil, . .	32.69	32.01
	43.05	42.95
Linseed Oil,	3.75	4.05
	10.63	10.68
	1.68	1.90
Neatsfoot Oil.	18.75	18.75

In a mixture of Neatsfoot and mineral oil in unknown proportions, four analyses showed the per cent. of mineral oil to be as follows 72.05, 72.00, 71.85, and 72.10

In a sample of fish oil, supposed to be pure, there were obtained the following percentages of mineral oil: 34.58, 34.90, 34.50, and 34.85.

Machine-oil, composition unknown, contained of mineral-oil 64.63 64.67.

A cylinder-oil contained of mineral-oil 71.00, 71.60.

A lubricating oil claimed to be pure animal oil was found to be adulterated with 77.25 per cent. of mineral oil —(*Trans. of Am. Inst. of Mining Engineers.*)

THE EXISTENCE OF ZINC IN A STATE OF COMPLETE DIFFUSION IN DOLOMITIC SOILS.

In 1880, M. Dieulafait shewed that zinc exists in a state of complete diffusion and in appreciable amount, throughout the whole thickness of the primordial formation and the sedimentary soils which are directly derived from it. Recently he presented a memo at the Académie des Sciences de Paris; discussing the diffusion of zinc in dolomitic soils. First of all he enunciates the following proposition, to which he has been led by his investigations:—That the bituminous substances already distinguished in some dolomites are universally present and further, *that the dolomitic rocks always contain ammonia in a proportion which often exceeds one kilogramme per cubic metre of rock* (.0624 lb. per cubic foot.) He also considers the dolomites to be sedimentary rocks which would be formed in waters rich in organic substances, i e., in gulfs which are almost closed, or even in veritable estuaries.

Again, M. Dieulafait has previously shewn that the concentration of zinc is still effected under our eyes in the estuaries of the modern period.

The conclusions resulting from these investigations are:—

(1) That zinc minerals, and specially zinc carbonate, for some time the only one worked, always bear a direct relation to the dolomitic rocks (this has been the case at the four great European centres of production.)

(2) That zinc minerals are contemporaneous with the dolomitic limestones which contain them

(3) That if the dolomitic limestones of the silurian in Sicily, of the carboniferous soil in Belgium, of the muschelkalk in Silesia, and of others still more recent, contain, in spite of their vast difference of age, zinc minerals exhibiting the same chemical composition, the same association and, even in details which are otherwise extremely complicated, the same relations to the enclosing rock, this evidently shews that, at very different periods, the same exceptional circumstances — circumstances which still remain to be discovered and investigated -- are reproduced in the case of certain sedimentations.

THE ELECTIVE POWER OF ROOTS.

The elective power of roots, i.e., the faculty which plants have of choosing in a complex medium the substances which they ought to accumulate in the largest measure in their tissues, and the substances which they should more or less completely discard, is one of the most curious phenomena of vegetable life and one of those which it would be of importance to know and understand more thoroughly in order to establish the correct use of manures. With this end in view M. Hervé-Magnon gives a few facts respecting the glacial ficoid, (*Mesembrianthemum crystallinum*)

This annual plant, a native, it is said, of the islands in the Mediterranean, but which grows very well in light soil, or in exhausted land, in Brittany and in the department of Mancha, is loaded with transparent vesicles, filled with liquid resembling small drops of frozen dew. This liquid has quite a saline taste and leaves, by evaporation when cold, besides sulphuric acid, 3.3 per cent of solid residuum formed of almost pure marine salt. The whole plant dried and burned gives an ash containing a large proportion of chlorine and alkalies, while the ashes of such vegetables as cabbage, celery, mignonette, intentionally sown by M. Hervé-Mangon about the roots of the ficoids, have always yielded their normal composition. He therefore reasonably concludes that the special constitution of the ficoid is properly due to the choice made by the roots of the elements which its development requires.

Analyses of the mineral elements of a certain number of dried ficoids, have shewn that this plant is formed by a weak solution of alkaline salts, kept in a solid state by a vegetable tissue whose weight is only 1.8 per cent of the total weight. The ashes, consisting of salts of soda and potassium, form nearly one-half (43 per cent) of the weight of the dry plant. This composition in many respects recalls that of sea-wracks.

In fine, a hectare (2.7411 acres) of land planted with ficoids has given 131,000 kilogrammes (1 kilog.=2.204 lbs.) of new plants, or 1820 kilogs. of ashes, which would contain 325 kilogs. of chlorine, as much soda and 588 kilogs. of potassium, being able to supply 864 kilogs. of the carbonate of this base. In view of such figures, M. Hervé-Mangon asks whether the cultivation of the glacial ficoid would not be lucrative in certain circumstances.

In every case, it seems probable that it might be usefully employed in removing from the saline soils of the Mediterranean coast, its native country, the excess of alkaline salts which render them unproductive.

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A NEW ELECTRIC MOTOR.—Jablochkoff has recently designed a new electric motor, which he has called the *Ecliptic* on account of its form. The motor, says M. Hospitalier in *La Nature*, consists of two bobbins, the one fixed in a vertical plane, the other movable and fixed upon a horizontal axis in an inclined position. The object of this arrangement is to counteract the effect of the magnetic masses in the part of the motor subjected to inversions of the current.

Photographic positives on paper obtained directly, by MM Cros and Vorgerand. Paper covered with a solution of 2 gr. bichromate of ammonia, 15 gr. glucose, and 100 gr. water, is dried, and exposed to light under a positive (*e.g.* a drawing). When the (yellow) bare parts of the paper have become grey, the paper is immersed in a bath of 1 gr. nitrate of silver to 100 gr. of water, with 10 gr. acetic acid. The image appears at once, with reddish tint, produced by bichromate of silver. Drying in light gives a dark brown tint.

RAPID FORMATION OF MINERAL VEINS.—*It appears from* a recent observation of Dr. Fleitmann, that the formation of mineral veins requires much less time than is generally supposed. About two years ago he filled up a pit with common clay containing iron Having had occasion to open up the pit afresh, Dr. Fleitmann was greatly surprised to find that the clay had entirely changed in character and become white. Further it was divided in numerous directions by fissures from one-twenty-fifth to one-sixth of an inch in section, which were filled with compact iron pyrites. Dr. Fleitmann supposes that the iron oxide of the clay, was transformed into sulphate of iron by the contact of water containing sulphate of ammonia.

RUPTURE OF THE TYMPANUM —Dr. Wilson, aurist to St. Mary's Hospital reports two cases of the rupture of the tympanum occurring to divers. In both cases the hearing was gravely compromised but the cure was effected in about *ten* days. Dr. Wilson explains the accident as follows :—

The water above the column of air in the external auditory tube exerts a sudden pressure on the drum, while the pressure in the middle ear remains the same as before. It is therefore necessary in diving, to take a long breath and by raising the palate to prevent the air from escaping by the nose. *This* accident, more frequent than we would imagine among bathers, is due to the want of sensibility in the ear, which is not endowed like the eye with the faculty of protecting itself by contraction or by any other means, from the dangers which may menace it.

Extract of a communication to the Academy of Sciences by M J. M. Crafts on the accuracy of measurements made with the mercurial thermometer. Depression of the Zero.—It is impossible to put a stop to the depressions which are produced when a thermometer is heated after a long period of rest ; the value of these depressions have been determined by many persons, and it is an assured fact that similar experiments give figures nearly identical with 0°.01 when the heating is carried to 300°. The only necessary precaution is to follow a method of invariable observation ; it appears preferable to let the thermometer cool in the air after an observation, and to observe the zero instantly. PERMANENT ELEVATION OF THE ZERO.—Thermometers in- tended for our ordinary laboratory experiments should be heated before the graduation and calibration, for a week or ten days in boiling mercury ; it is the only correct method for ob- taining instruments which keep the value of the degree fixed during the graduation, and the errors in thermometers which have not been treated in this manner may rise to 4° in a range of 300°. When it is intended to employ the thermometer at lower temperatures, it is sufficient to heat it to the highest temperature of the experiments for a considerable time as compared with the duration of the subsequent experiments. For example, a thermometer which indicates the temperature of the atmosphere and which is heated from time to time up to 100° in order to fix the value of the degree, is prepared for this use by being heated for three or four days at 100°. If, however, the thermometer is to be used in lengthened experiments at temperatures bordering on 100°, it should be heated throughout the whole length for three or our weeks at 100° before graduation and calibration.

The time required for the treatment may be abridged by heating the thermometer for a day in boiling essence of turpentine and afterwards for from four days to a week at 100° ; an analogous process serves for higher temperatures. The glass should not be exposed to the corrosive action of boiling water, and metal apparatus of simple construction renders it possible to effect this purpose without the escape and contact of water and mercurial vapours.

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PROCEEDINGS OF SOCIETIES.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Prof. Abel, C. B., F.R.S., reported on the present stage of his experiments relating to the *condition* in which carbon exists in steel. Preliminary trials had shown that the treatment of steel and iron by a chromic acid solution (produced by mixing a solution of potassium bichromate, saturated in the cold, with one-twentieth of its volume of pure concentrated sulphuric acid) gave great promise of success in detecting the chemical differences in the same steel, according to the treatment to which it has been subjected. When cold,rolled, and annealed steel was thus treated, it yielded considerable amounts of an insoluble residue, consisting of black spangly particles, strongly attracted by the magnet, and presenting the characteristic of a true carbide, to which was assigned provisionally the formula $Fe^5 C^8$. With hardened steel, on the other hand, but a small quantity of such particles were obtained, mixed with a lighter sediment ; and the total residue contained only about one-sixth the, carbon in the original steel, whereas in the annealed samples nearly all the original carbon was detected in the residue The theory to which this points clearly is that in soft steel carbon exists in a state of chemical combination, forming a carbide which is disseminated as a separate body through the mass of the iron ; but that in hard steel this combination is dissolved, and the carbon exists in its pure form, either merely in mechanical admixture, as in the case of grey cast-iron, or in that peculiar and not very well understood form of association which metallurgists term an alloy. It would follow that the process of tempering, or rapid cooling does not leave time for the complete formation of the carbide, and that in tempered steel all or some of the carbon still survives in its free or alloyed condition.

The fresh experiments described by Prof. Abel give, on the whole, great support to this theory. Four preparations were made of steel dissolved in chromic acid solution made as above, but of different degrees of strength. In the last only, where the strength was very high, were the results different, showing that the carbide had not been able to resist the oxidising effects of the solution. In the others, a considerable deposit was found, which, after being kept for several days, first in the original and afterwards in a fresh solution, was washed and dried, and then analysed. Another portion of the same was treated with chlorhydric acid, in order to ascertain what proportion would be converted into hydrocarbon. When this proportion was deducted from the whole, the remainder showed a most remarkable uniformity of composition, the percentages of carbon in three experiments being 5·93, 5·94, and 6·00 respectively. It seems evident that we have here a definite compound, to which Prof. Abel gives the formula Fe_3C. The deviations from this exact composition he accounts for by the presence of a certain amount of water, indicating that a carbo-hydrate had been formed, probably as a result of the action on the carbide first separated.

Prof. Hughes read a paper, which was illustrated by a series of very striking and elegant experiments, performed with the simplest apparatus, may be considered in its result, as the complement of Prof. Abel's Finding that the induction balance was equally sensitive to molecule and to chemical changes, in the metals tested. Prof. Hughes set himself to devise an instrument by which to examine the former class of phenomena by themselves. A wire forming the core of an ordinary magnetic coil, and capable of being shifted, twisted, etc., as desired, supplies what he requires. The coil is joined to a galvanometer, or better still, to a telephone ; the wire is joined to a battery, and currents are sent through it. So long as the wire is at right angles to the coil, no effect is produced ; but if we set it at an angle to the coil, sounds are instantly heard, betoken the presence of induced currents in the coil. This is the ordinary effect of electro-magneto induction, as discovered by Faraday Now, instead of shifting the wire, let us give it a slight twist, say of 40° : the sounds are instantly heard as before, and we detect induced currents, which are positive for right-hand torsion, negative for left-hand torsion. Prof. Hughes's explanation of this is that the molecules of the wire, which he regards as so many separate magnets, have been given a twist round the axis, and thus set at an angle to the coil, just as the whole wire was by the shifting in the first case. Now let us twist the wire still further, even to several complete turns. No greater strength of current is observed, showing that the angle once given to the molecules is not exceeded, and that the subsequent torsion is of the wire as a whole. Approach to the wire, thus twisted, one pole of a natural magnet, laid parallel to the wire : the sounds cease, indicating that the magnetism has spun the molecules back again into their original directions. Approach the magnet at right angles to the wire : the current returns to zero while it is still two inches distant, and when it is in contact there is a reversed current, which is then at its maximum. Lastly, removing the magnet, untwist the wire by some 40° : the current returns to zero, showing that the molecular torsion has disappeared, while the molar torsion remains almost the same as before.

In all these effects the wire has been supposed to be of soft iron a a remarkable difference appears when we turn to tempered steel. For we now fail to detect more than slight traces of molecular disturbance or rotation, no matter how many turns we give to the wire. Thus, whereas in the iron we appear to have great molecular freedom, with steel we have almost complete molecular rigidity But this molecular rigidity is found to obtain also in all alloys of steel which have been tested—*e.g.* magnetic oxide, iron and sulphur, iron and tungsten, etc. Hence we draw the conclusion that tempered steel is likewise an alloy, the associated elements in this case being, of course, iron and carbon.

Mr. Chas. Cochrane read a paper which was a sequel to one read by the same author at the Leeds meeting of the Institution, and dealt with Blast Furnace working, with special reference to the analysis of the escaping gases It was laid down at the outset that economy of fuel in blast-furnaces is governed by three conditions (1) the temperature of the blast, (2) that of the escaping gases; (3) the quantity of carbon which can be maintained in the condition, once attained, of carbonic acid, instead of being re-transformed into carbonic oxide by absorption of carbon in the fuel. On the first two of these heads there is, of course, nothing new to be said, but they were illustrated by elaborate and valuable tables, giving, in units of fuel (C burnt to Co), (a) the heat carried *in* by blast of a given weight and temperature, (b) the heat carried *out* by escaping gases of given weight and temperature. The third is dwelt on at some length, and tables are given, showing for any given consumption of C per ton of pig, the ratio of CO_2 to CO in the escaping gases, first when all the CO_2, once formed, is retained in that condition; and afterwards when ½ cwt, 1 cwt.. 1½ cwt.. etc., are afterwards reconverted into CO, or, as the author terms it, when a *transfer* of ½ cwt., 1 cwt., etc., of C has taken place From this is deduced the conclusion that the mere knowledge of the ratio of CO_2 to CO in the escaping gases, as given by analysis, is useless to indicate what is really going on in the furnace, because the same ratio may appertain to any different conditions, according to the amount of the transfer which has taken place, from CO_2 back to CO. If, however, the consumption of carbon per ton of pig iron has been at the same time ascertained, then we are at once able to refer the case to its proper position, and the knowledge of the ratio between the two cases enables us at once to see what amount of transfer has been going on, and what prospect there is of effecting an improvement. It was further pointed out that the main causes of this injurious re-conversion of CO_2 into CO were (1) the fact that the limestone, used as flux, contains a proportion of CO_2, which can only be evolved at a red heat, and therefore in contact with red-hot coke, which immediately gives up some of its B to the evolved gases, (2) the fact that the ore, especially in the larger pieces, does not get completely de-oxidised until it reaches the red-hot region, where the CO ascending in the furnace first unites with the oxygen in the ore to form CO_2, and then absorbs another equivalent of C from the coke, so returning again to the condition of CO. It is therefore suggested that both these sources of evil might be removed if (1) the limestone were *calcined* before entering the furnace, so as to have already parted with its oxygen, (2) the ironstone were broken up into pieces small enough to insure their decomposition in the higher parts of the furnace. Another means of accomplishing the latter result was to increase still further, if necessary, the height of furnaces. A sanguine estimate was made of the economy that would attend the application of these two devices, which it was expected might reach over 3 cwt. of coke per ton of pig-iron made.

The value to ironmasters of the elaborate tables annexed to the paper, and of the mode in which the problem of blast-furnace economy is presented, cannot but be very great, but grave doubts were expressed in the discussion, by Mr I. Lowthian Bell, F.R.S., whether the practical results would answer the author's expectations. As regards the use of calcined limestone, in particular, it was stated that it had already been tried, without effecting any economy, at least in large furnaces, the suggested reason being that the calcined lime, as soon as charged, re-absorbed CO_2 from the escaping gases, and that although heat was no doubt disengaged in the process, yet this was too near the throat of the furnace to have any serious effect. Moreover it is to be remembered that the previous calcining of the limestone must itself require fuel, the amount of which must be deducted from any apparent gain due to the absence of CO_2 in the lime within the furnace.

ENGINEERS' CLUB OF PHILADELPHIA, Jan. 20th, 1883 —Mr. Henry G. Morris in the chair. Mr. Wm. E. Lockwood presented a full description of the Shaw Locomotive, profusely illustrated by magic lantern, working model, etc., etc.

The Shaw Locomotive may be classed as a 37-ton soft-coal passenger engine, with two cylinders on each side, each 10½ x 24 inches; the two working in combination, being equivalent to one cylinder 14.85 x 24 inches, two cross-heads; two piston-rods; two connecting and parallel rods on each side.

Her drivers are 5 feet 9 inches; weight of engine, 67,000 pounds; coal and water, when in use, 73,000 pounds. Total, 74,300 pounds. Weight of tender, 26,000 pounds, water, 15,000 pounds, coal, 6500 pounds. Total, 47,500 pounds. Total combined, ready for use, 121,800 pounds, or 60.45 tons.

The improvement in Engines claimed in the Shaw Locomotive are

First.—No counter-balanced drivers, ergo, no hammer-blows and no nosing around.

Second.—A single movement of valve with duplex action.

Third.—Steam is the motor of balance as applied to the reciprocating parts.

Mr. Wilfred Lewis exibited a machine for the graphical determination of centre of gravity and moment of inertia of plane areas. The figure to be calculated is drawn to a suitable scale and placed in the machine, where the outline is followed by a tracing point in order to produce, upon another piece of paper, a figure whose area shall be proportional to the statical moment of the given figure about an assumed axis. If now the second figure be followed by the tracing point and a third figure be drawn, its area will be proportional to the moment of inertia, and from the areas thus drawn can be found, by simple arithmetical processes, the centre of gravity and moment of inertia.

The machine is intended for application to such figures as cannot readily be solved by the usual methods, such as decks beams, steel rails, and castings, with round corners, large fillets and curved sides which can only be approximately solved by long and tedious integrations. A planimeter is used to measure the areas and it is thought that by this graphical method, more accurate results can be obtained with less work and without so much probability of error in the operations. The machine can also be made use of to determine the contents of any solid of revolution or its radius of gyration

ENGINEERS' CLUB OF PHILADELPHIA, FEB. 3RD.—Henry C. Morris in the chair. Mr. W. S. Auchincloss exhibited and described his latest forms of Averaging Machine, which consists of an endless platform, the grooves of which represent days or distances. The various weights, representing quantities or values, are placed in these grooves and the endless platform rotated until a balance of the weights is secured, when the exact answer may be read from the accompanying scale and, by then continuing the rotation, the weights fall upon an inclined plane, reach their respective compartments in front, and are again ready for immediate use. The machine is of special interest to the engineering profession in its application to the engines, boilers and coal-bunkers in steamers, the determination of pulleys, speed of shafting and average haul of material. Mr. J. J. de Kinder described the United States Metallic Packing for piston rods, valve stems, pump rods, and throttles—exhibiting sections and model; also model with packing it is intended to supersede. The metallic packing consists of eight composition blocks, held in a brass ring, on which are horns holding the springs which regulate the pressure of the block on the rod. It is said to preserve a steam tight joint without appreciable friction or binding The vibration of the rod is provided for by a ball joint on one end and spring follower on the other, which contrivance is said to give the packing free play and preserve its tightness, notwithstanding a vibration of the rod.

THE INSTITUTION OF CIVIL ENGINEERS.—At the Ordinary Meeting on the 30th of January, Mr. Brunlees, President, in the chair, the Paper read was on "Mild Steel for the Fireboxes of Locomotive Engines in the United States of America," by Mr. John Fernie, M. Inst. C.E.

It was stated in the Paper that the use of mild steel for the fireboxes of locomotive engines was now general in the United States. Although large numbers of the outer shells of the boilers were still made of iron plates, this was simply to effect a saving of expense, and many railroad companies had the boilers wholly of steel Iron plates were first used as a substitute for copper, owing to the rapidity with which the anthracite coal wore away the soft copper When sound the iron plates gave better results, but the weldings were frequently unsound; they were apt to blister, and the plates were subject to crack near the fire-bars. Steel fireboxes, the plates being a nearly pure compound of iron and carbon, were used for the Pennsylvania Railroad engines eleven years ago. Since then, excellent steel for this purpose had been made by the Siemens-Martin open-hearth process in many places in the United States. The mode of manufacture of this steel was briefly described, as it differed from English practice. The specification for boiler and firebox steel last given out by the Pennsylvania Railroad Company was quoted. The Author next proceeded to state that in the cities of the United States, all steam-boilers of stationary engines were placed under municipal regulations, whereby a proper registration and inspection were instituted at a small cost to the user. In Philadelphia about 4,000 boilers were tested once a year, and a licence was given by the Inspector to use the boiler for one year at the pressure it was considered fit to sustain. The formulas, under which the calculations were made, were stated, and the tests employed. The highest test was when a boiler-plate, from which a portion was cut off lengthwise, showed a ductility of 20 per cent. upon a measured length of twelve thicknesses of the plate, and when cold would bend to 180° over a diameter equal to two thicknesses of the plate, or when cut crosswise would bend cold to 90° over a diameter equal to five thicknesses of the plate. In every steam-vessel navigating the lakes, rivers and seas of the United States, and sailing under its flag, a complete system of inspection during manufacture, and an examination of boilers when made, was maintained by the Government, and all boiler-plates had to be branded with the maker's name, and with the tensile strength of the plate per square inch. Makers of boiler-plates were pecuniarily liable for any failure of the material if it occurred at a lower strain than that with which it was branded. Officers for examining and testing the materials and work done were appointed, and the question seemed to be much better understood and practised in the United States than in England. With respect to locomotive engines, which were in one city one day, and in another on the next, and which might constantly be moved out of one State into another, there could be no Municipal or Government control, but there was a healthy public opinion on the subject, and heavy damages would be obtained against any company whose boilers exploded from neglect, or from the use of bad material. In America, it was stated, railroad engineers were not hampered by Government control. There was no necessity to urge railway companies to adopt improvements. Inventions were quickly examined, tested and rejected or adopted. Hence the march of improvement was more rapid than in Great Britain. The Author then proceeded to describe, first, the English type of locomotive firebox, and afterwards the various new forms of American fireboxes. In the former the strains set up by the greater expansion of the inner box over the outer, from the higher temperature, were aggravated from the material being of copper, which expanded more than iron under equal increments of temperature. Greater stress was thrown upon the stays, and by the use of copper and brass tubes a galvanic action was established in locomotive-boilers, which speedily destroyed the iron plates. The Author illustrated the American type by two examples of boilers and fireboxes in use on the Pennsylvania Railroad, and he pointed out in how far they approached the conditions of what he held to be a perfect firebox of the old and well-known form. The requirements for a firebox of this kind were, that the plates forming the outer and inner boxes should be of similar metal, that as the metal of the inner box must always expand more than the outer, it should be thin enough to bend or spring between the spaces where it was held by the round stays, that to compensate for the extra expansion, the heavy roof-beam stays should be done away with, that there should be a number of water tubes through the body of the firebox, that the fire-bars should also be water-tubes, that the areas of the firebox and grate should be large, and that the materials of construction should be cheap and easily obtainable. The Author demonstrated that in these respects the American was far in advance of the English type of locomotive-boiler. With regard to cost he showed that as steel fireboxes were only half the weight of copper ones, and as the price per ton of the former metal was about one-third of the latter, the actual cost of steel fireboxes was from one-fifth to one-sixth the price of copper ones, although the cost of workmanship would be a little more in working steel.