Technical and Bibliographic Notes / Notes techniques et bibliographiques

The Institute has attempted to obtain the best original copy available for scanning. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of scanning are checked below.

L'Institut a numérisé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de numérisation sont indiqués ci-dessous.

- ☐ Coloured covers / Couverture de couleur
- ☐ Covers damaged / Couverture endommagée
- ☐ Covers restored and/or laminated / Couverture restaurée et/ou pelliculée
- ☐ Cover title missing / Le titre de couverture manque
- ☐ Coloured maps / Cartes géographiques en couleur
- ☐ Coloured ink (i.e. other than blue or black) / Encre de couleur (i.e. autre que bleue ou noire)
- ☐ Coloured plates and/or illustrations / Planches et/ou illustrations en couleur
- ☑ Bound with other material / Relié avec d'autres documents
- ☐ Only edition available / Seule édition disponible
- ☑ Tight binding may cause shadows or distortion along interior margin / La reliure serrée peut causer de l'ombre ou de la distorsion le long de la marge intérieure.
- ☐ Additional comments / Commentaires supplémentaires:

- ☐ Coloured pages / Pages de couleur
- ☐ Pages damaged / Pages endommagées
- ☐ Pages restored and/or laminated / Pages restaurées et/ou pelliculées
- ☑ Pages discoloured, stained or foxed/ Pages décolorées, tachetées ou piquées
- ☐ Pages detached / Pages détachées
- ☑ Showthrough / Transparence
- ☑ Quality of print varies / Qualité inégale de l'impression
- ☐ Includes supplementary materials / Comprend du matériel supplémentaire
- ☐ Blank leaves added during restorations may appear within the text. Whenever possible, these have been omitted from scanning / Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été numérisées.

CANADIAN MAGAZINE
OF
Science and the Industrial Arts.
Patent Office Record.

Vol. 13. JANUARY, 1884. No. 1.

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

The Editor does not hold himself responsible for opinions expressed by his correspondents.

No notice will be taken of anonymous communications.

1884.

During the year we have endeavoured to supply our readers with the most recent information in regard to industrial progress and scientific investigation. We have carefully avoided the introduction of theories so abstruse as to be interesting only to the specialist, but have rather tried to present the subject matter in a thoroughly popular form.

During the present year we are expecting a visit from the British Association, among whose members are to be found most of the leading scientific men of the day. As the result of this visit, we may surely anticipate with confidence a large increase of interest in practical and theoretic science throughout the Dominion of Canada. We shall hope to present our readers with accurate resumés of the proceedings of the meetings in Montreal, and purpose to give "in extenso" those papers which may seem of the greatest importance to the general public.

There is one department of this magazine which we would wish to make more of a specialty, and this can only be effectively done by the kind co-operation of those of our readers who may be personally interested in industrial operations. The department is one which we would desire to devote more particularly to a record of the most recent improvements and advances in machinery or in any branch of industry. We shall therefore be much gratified to receive such information from any correspondent.

This would be a most desirable supplement to the information now contained in the valuable Patent Office Record, which is issued with every number of this magazine, and to the illustration of which the greatest care and attention are devoted.

ECONOMY IN HIGHWAY BRIDGES.*

BY PROF. J. A. WADDELL C.E., B.A.S.

(Continued from Last Number.)

Satisfactory investigations as to economy in combination bridges cannot well be made, for the best depths of trusses and best panel lengths will depend upon the ratio which the cost of lumber bears to the cost of iron.

By increasing the depth, the posts and batter braces are made longer and larger, the chords lighter and the diagonal ties heavier or lighter, according as the angle which they make with the vertical recedes from or approaches forty-five degrees. If wood be cheap, and long and large timbers be easily procured, it will be cheaper usually to make the depth tolerably great so as to save iron in the lower chord and diagonal ties, as the angles which the latter make with the vertical usually exceed forty-five degrees in single intersection bridges which are not longer than one hundred feet, and in all ordinary double intersection bridges. In deep trusses the large section required by the batter braces causes to be adopted for the sake of appearance an unnecessarily large section for the top chord. This difficulty can be overcome by using batter brace stiffeners, which permit of the batter braces being figured for half length for bending in the plane of the truss thus, greatly reducing their sectional area: these stiffeners, however, do not add to the beauty of the structure.

The outer and inner timbers of each upper chord should span two panels, therefore the best number of panels will depend upon the price and the supply of long timbers. This last is a very important consideration; for enough time might easily be lost in obtaining long timbers to counter-balance ten times the value of the material saved by using long panels.

The weight of the upper chord castings increases with each dimension of the chord, therefore, for this consideration alone, the section should be as nearly square as possible; but this would give an impracticable section for the batter braces, and might cause the exterior joints of the chord to open, when the empty bridge would be subjected to the maximum wind pressure; this is a point which should always receive attention.

The weights of some portions of combination bridges are not affected by a change of depth, nor those of others by a change in the number of panels, the principal ones that are affected can be seen by examing Table V.

---

* A paper presented to the Engineers Club of Philadelphia.

TABLE III.

SPAN.	NO. PANELS.	DEPTH.		
		SING. INT.		DOUB. INT.
Ft.		Ft.	In.	Ft.
80	5	16	5	
90	5	18		
100	5	20		
110	6	21		
120	6	21		
130	7	22		
140	7	23		26
150	8	23		26
160	8	24		27
170	9	26		29
180	8	28		30
190	10			32
200	10			33
210	11			34
220	11			35
230	12			36
240	12			38
250	13			39
260	13			40
270	14			41
280	14			42
290	15			43
300	15			44

TABLE IV.

80	5	16	5	
90	5	18		
100	5	20		
110	5	21		
120	5	22		
130	6	22		
140	6	23		26
150	7	24		27
160	7	25		28
170	8	27		32
180	8	28		32
190	8			34
200	9			35
210	9			36
220	10			37
230	10			38
240	10			40
250	11			41
260	11			42
270	12			43
280	12			44
290	13			45
300	13			46

TABLE V.

INCREASING THE DEPTH.		INCREASING THE No. OF PANELS.	
INCREASES THE COST OF	DECREASES THE COST OF	INCREASES THE COST OF	DECREASES THE COST OF
Posts. Batter Braces. Vibration Struts. Postal Struts. Vibration Rods. Hip. Verticals. Post Sockets.	Upper Chords. Lower Chords. Chord Pins. Up. Chd. Pan. Connections.	Floor Beams. Vibration Struts. Posts. Lower Lat. Struts Lateral Rods. Lower Chords. Vibration Rods. Diagonal Ties. Pins. Bolts. Post Sockets. Top Chord Panel. Connections. Lat. Angl.'Blocks Packing Washers	Upper Chords. Batter Braces. Joists. Hip. Verticals.

A simple inspection of Table V, will show the advantage of using long panels when long timbers can be procured, but as most American mills do not readily furnish sticks over forty feet long, it will be necessary to limit the panel length to twenty feet, and to reduce it, when necessary, to one of half the length of the longest suitable timber that can be obtained, without delaying the work.

The economic depths will not usually differ much from those found for iron bridges, and so Table III. can be used for combination bridges, remembering that when the number of panels is increased, the economic depth is a little reduced.

There seems to be an unfounded prejudice against long panels in the minds of many county commissioners and supervisors. Practically they make a better bridge than short panels do, for the members are fewer and larger, and therefore less affected by flaws, besides being less subject to vibration, and less liable to inaccuracy of construction.

The floor-beams and joists being larger, there is less probability of often receiving their maximum working loads. The only real objection to long panels is the extra cost of the joist timbers when they are to be replaced. In addition to what precedes, the following general economic considerations should always receive attention.

Field riveting should be avoided as much as possible, and designs should be made so that all the parts will come together readily during erection.

Rivets should be spaced with some regularity, so as to facilitate the punching of the holes by riveting machines.

In heavy bridges the sizes of the hip pins can be reduced by using four end diagonals instead of two—this fact was pointed out in my paper on "Bridge Pins—Their sizes and Bearings."

It is generally better in through bridges to pack all but the end chord bars, outside the posts, and to reduce the width of the top chord plate to its minimum limit.

It is not always better to employ the apparently most economical depth of channels. For instance if there be a choice of using eight-inch or nine-inch channels for the upper chords and batter braces, and if the *sections alone* would indicate a saving of say one hundred and fifty or two hundred pounds of iron by the use of the nine-inch channels, the others would be more economical, for the nine-channels require larger stay plates, lattice bars, splice plates and re-inforcing plates; generally they would require a wider top chord plate, which would increase the weight of the cover plates, chord pins, post latticing, post stay plates, shoe plates, etc., and even add a little to the lengths of the floor beams.

The results given in Table I are reliable, although the calculations by which they were obtained were not checked, because in each truss the weight of each member was compared with the weights of the corresponding members in other trusses, so that no error of any magnitude can have crept into the work. The calculations have been long and tedious, occupying over three hundred hours of steady work, and the objects attained have been few; still the writer will feel well repaid for his trouble, if this paper prove an assistance and a saving of time and labour to even a few members of the profession.

◆

SEWER VENTILITAON.—(*Building News.*)

The Borough Engineer of Cardiff, Mr. Harpur, has reported to the council of his town a proposed new system of sewer ventilation, and his remarks are of sufficient general interest to be worth reproducing in our columns. Mr. Harpur says: "The importance of this subject is apparent by the fact that not only in Cardiff, but in many towns throughout the United Kingdom, and in the metropolis itself, is the cry being raised against the offensive and dangerous character of the gases emanating from the sewer ventilators placed in the centre of the public streets. For many years past it has been thought sufficient, in constructing a system of sewers for a town, to make provision only for properly disposing of the sewage, and to place ventilating shafts at intervals along the lines of sewers to enable the sewer gas to escape into the streets. This is undoubtedly a false idea, and is fast being dispelled from the minds of sanitarians. There is now no disguising the fact that much disease is created in our towns by the germs which emanate from the sewer ventilators, and the truth of this statement being generally admitted, it becomes evident that to thoroughly destroy any germs of disease emanating from the sewers of a town is equally as essential to the health of the inhabitants, as the proper deodorization and disposal of the sewage. It is therefore manifest that some improved mode of sewer ventilation must ere long be brought into general use. There is even more necessity for this in the case of Cardiff than in most towns, for daily, while the tide valves are closed, the sewage which temporarily accumulates in the sewers, drives out through the ventilators, an amount of sewer gas equal to the quantity of sewage stored during high water. The same thing also applies when the sewers are being flushed, for, though flushing is of the greatest importance in cleansing and sweetening the sewers, yet there is the fact that for every cubic foot of water sent down the sewers, the same quantity of sewer gas is made to ascend into our streets. The only other method of sewer ventilation of importance, in addition to the usual method above referred to, which has been adopted to any great extent, is that of constructing ventilating pipes from the sewers up the sides of buildings to a level somewhat above the roof, and upon some of these ventslating cowls of various designs have been placed. But the results are not satisfactory, for upon calm, warm days, when the extraction of foul gases from the sewers is most needed, the cowls do not act. But even supposing that the ventilating pipes, with or without cowls, were perfect in their working, there still remains the fact that the sewer gas is being discharged, unpurified, and containing germs of disease, into the atmosphere we are breathing, occasionally to descend with a beating wind and enter the open windows of bed rooms, &c., at an elevation slightly below the tops of the ventilators, and at all times to be wafted through the windows of adjacent buildings at a greater elevation. This being so, I would not recommend you to seek powers in the Bill now about to be presented to Parliament, which would enable you to construct such ventilators in any positions which you may deem fit, but would respectfully draw your attention to another method which, I believe, would prove effectual, and thoroughly destroy all germs of disease emanating from the sewers. There can be no doubt that germs of disease made to pass through fire, or heat of a sufficient degree, will be entirely destroyed, and that heat is one of the best powers that can be used for drawing or extracting air. For many years I have held the opinion that ere the ventilation of sewers would become perfect heat would, in some way or other, be brought into use for the purpose. Several methods have presented themselves, but the difficulty has been in suggesting a mode that would be inexpensive in its application, both as to construction and maintenance. A system has very recently been patented by a Manchester firm, which consists of the ordinary ventilating shafts, heated to upwards of 600 deg. Fah., with a consumption of eight or ten cubic feet of gas per hour. The sewer gas, having to pass through the furnace so heated, all germs of disease are destroyed, while the currents of air are greatly increased, and the ventilation of the sewers thereby vastly improved; but taking the average consumption of each apparatus as eight cubic feet of gas per hour, with the present price of gas in Cardiff each ventilator would consume gas to the value of nearly £10 per annum, and to apply this to the whole of your sewers would mean a very large outlay annually, irrespective of the first cost of the apparatus, &c. I am, however, of opinion that equally good results may be obtained at a much less cost than by the patent furnaces above referred to. I would propose a manhole and ventilating shaft combined, as constructed upon the lines of your sewers. By shortening the charcoal cage some four or five inches at the bottom, and standing it upon legs to that extent, there would be a sufficient space underneath for the air to pass through, and also for placing a gas jet underneath. The manhole side of the cage would be entirely covered by a piece of sheet iron, while, on the opposite side, the space below and half-way up the cage would be also covered by sheet iron. This would necessitate the air passing underneath and through the cage, which, being filled with asbestos or other incombustible material, and ignited by the gas jet below, would act as an air extractor, while, at the same time, all germs of disease would be destroyed. The advantages which I claim in this suggestion over the patent furnace referred to are (1) the saving in the cost of the furnaces, which would not be required, and (2) that the quantity of gas necessary to keep sufficient heat in the incombustible material would be considerably less than that required by the other method. However, upon this point I am, as yet, unable to speak with certainty. But if you think the suggestion worthy of further consideration, I shall be glad if you will instruct the borough analyst to ascertain, by experiment, whether the idea is practicable, and, if so, the minimum amount of gas that would be required in order to destroy all germs of disease. I am reluctant to suggest to you a scheme which will necessitate so considerable an outlay annually in working; but I do so on the conviction that no other method as yet adopted will satisfactorily dispose of the difficult question under consideration. Should you approve of the suggestions herein contained, it will be advisable to ascertain whether it will be necessary to apply the method to every ventilator. I am of opinion it will not; but this can only be decided by experiment." We understand that the Cardiff Town Council, acting on Mr. Harpur's suggestion, are about to carry out some experiments in sewer ventilation.

◆

NOTES ON INDICATOR DIAGRAMS.

The Indicator, (for illustrations see pages 4 and 5,) an instrument invented by James Watt, for studying the action of a fluid of variable volume, has been gradually perfected and is now capable of tracing at every part of the stroke, the action of the steam (or other fluid) in the most rapidly working engines. Fig. 1 represents Richard's well-known parallel-motion Indicator. Fig. 2, a section of the Thompson Improved Indicator, and Fig. 3, a section of the Crosby Indicator. It consists of a small cylinder containing a piston, and is fixed at one of the ends of the cylinder of the engine, communication between the two cylinders being effected by means of a cock. When the cock is opened the steam enters the indicator cylinder, raises the piston and presses it against a spiral spring, so constructed that its displacements are proportional to the pressure on the piston. The piston carries a pencil which indicates the movements upon a sheet of paper wrapped round a cylinder capable of motion about its axis. This cylinder is connected with the piston of the engine, or with some part moving with it, and is thus made to oscillate through angles which are always proportional to the distance through which the piston travels. The pencil will therefore describe a closed curve, of which the abscissæ are proportional to the displacement of the piston, the ordinates to the pressures, and the area to the work done by the steam in one stroke of the engine. If the indicator is fixed to a pump, the pencil point moves round the curve in an opposite direction, and the area of the curve is proportional to the work done on the fluid in one stroke. When the speed of the engine is very great, oscillations may be induced in the Indicator piston, which will cause the pencil to trace a wavy curve and thus tend to neutralize the efficiency of the diagram. In order to obviate this evil as far as possible, the momentum of the moving parts in some indicators is diminished by giving the piston a travel less than that of the pencil.

Errors in the diagram are often due to imperfect fixing, and it is therefore advisable to provide permanent and suitable taps in the cylinder. These taps should be fixed if possible in the cylinder covers, and in any case should never be placed in or near the ports, as such a position would make the indicated pressure of the rapidly-moving steam too small.

The indicator having been fixed in position with the pencil touching the paper upon which the diagram is traced, the engine makes one or two revolutions before any communication is established between the

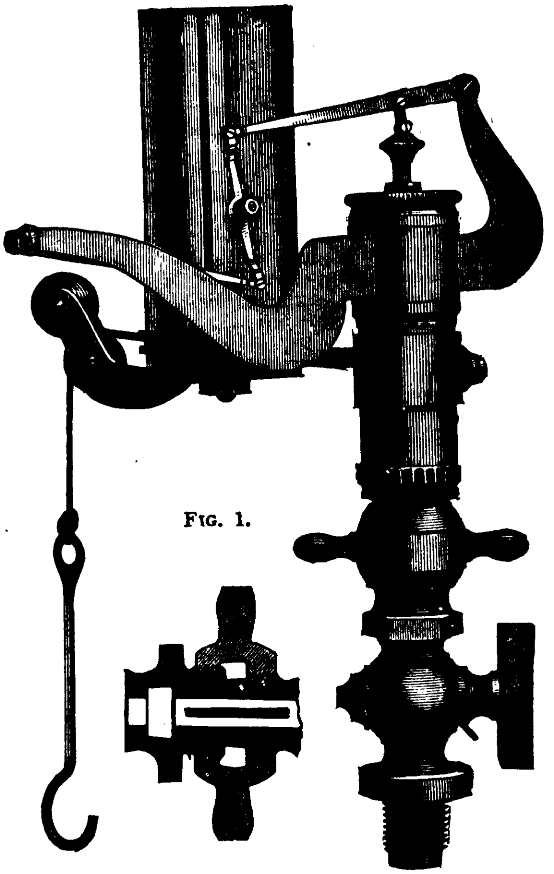


FIG. 1.

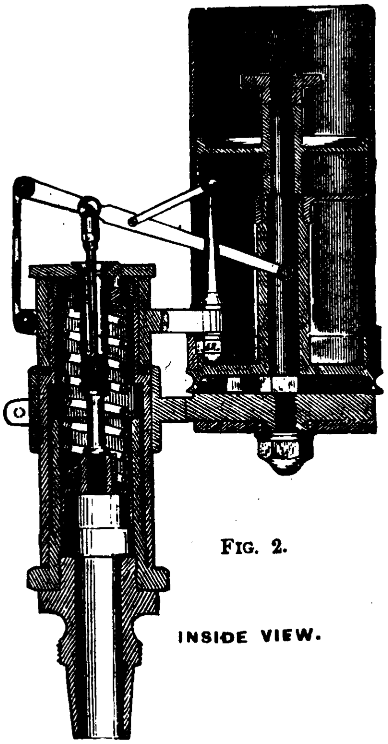


FIG. 2.

INSIDE VIEW.

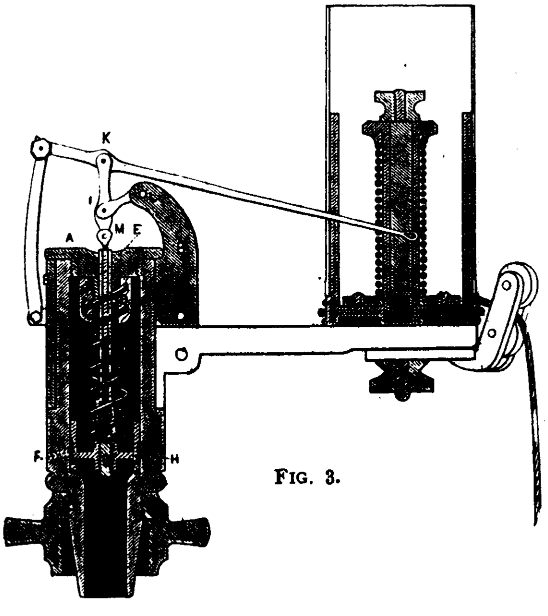


FIG. 3.

SECTIONAL VIEW

steam and indicator cylinders. A horizontal line, called the *atmospheric* line, is traced upon the paper, and corresponds to a state in which the pressure above and below the piston are equal. This line represents the pressure of the atmosphere and its length is the oscillating cylinder's travel which bears a certain fixed ratio to the stroke of the piston. A *datum* line of *no pressure* can now easily be drawn by ascertaining the barometric pressure at the given time and place.

Let O V, be the datum line of no pressure, and suppose that the indicator cock is opened when the piston is at the bottom of its stroke, *i. e.*, when the pencil point is at D. The steam rushes in and raises the piston so that the pencil traces the vertical line D A,, A defining the point at which the pressure of the steam is equilibrated by the resistance of the spring. The steam is still being admitted into the cylinder of the engine and the pencil traces the horizontal line A B as the paper cylinder moves round its axis. At B the slide valve cuts off steam and further work can only be done by the expansion of the steam already within the cylinder. The pressure consequently falls and the pencil traces the expansion curve B E. At E an opening is made into the exhaust, the pressure at once falls, and the pencil traces the vertical line E E′, E′ defining the end of the upward stroke. During the downward stroke the exhaust port continues open, and the pencil traces the horizontal line E′ D.

The three essential elements in the diagram are, the absolute pressure of the steam at admission (= A F), the absolute pressure at exhaust (= E′ G or D F), and the rate of expansion $\left\{= \frac{D\,E'}{A\,B}\right\}$

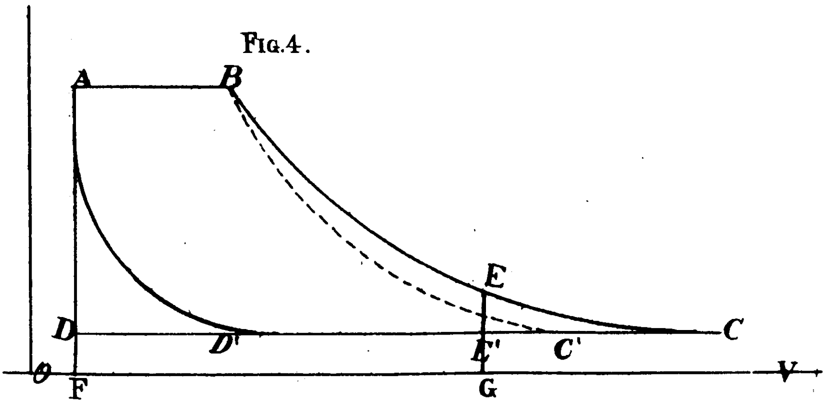


FIG. 4.

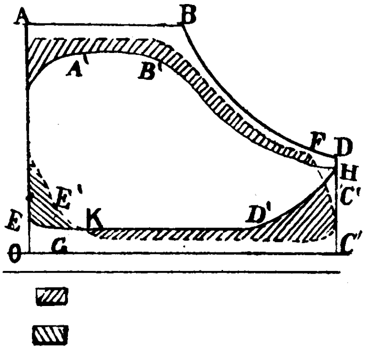


FIG. 6.

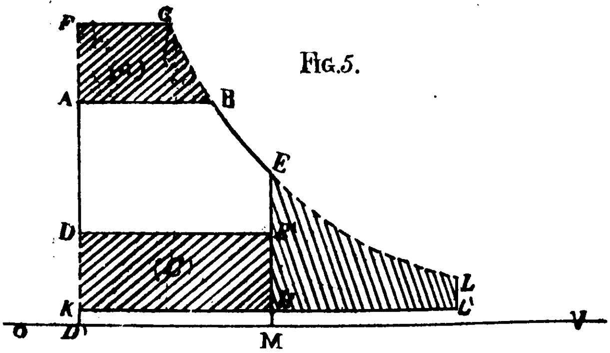


FIG. 5.

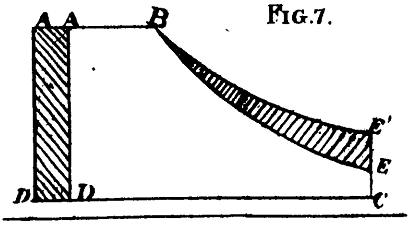


FIG. 7.

The above diagram, or cycle, differs from that of a molecule of water. A molecule taken from the condenser at the pressure defined by B is forced along D A into the boiler, evaporates along A B, and expands along D C to the pressure in the condenser. The molecule is then liquefied under this pressure along C D. In a Carnot's cycle A D and B E are replaced by the two adiabatics A D' and B C'.

Advantages of condensation, high pressure, and a high rate of expansion. Fig. 5.

Let O V be the *datum* line.

Let A B E E' D be the diagram of a non-condensing engine.

E' M is the atmospheric pressure.

The effect of adding a condenser to the engine is to change the exhaust pressure from E' M to H M, so that there is a gain of work proportional to the area D E' H K, without a theoretically greater expenditure of steam. The degree to which condensation can be carried is sometimes limited by the difficulty of procuring cold water and also by the weight and volume of the necessary apparatus.

The effect of using steam at a high pressure is to change the pressure at admission from D' A to D' F. There is consequently a gain of work represented by the area A F G B, G B being a prolongation of the expansion curve B E, and it is evident that the expenditure of steam is the same as before. The employment of high pressures is limited by practical considerations as to the size or strength of the engine. The advantage of a high pressure is more especially felt in the case of non-condensing engines.

Theoretically the expansion gives a *net* gain of work without any further consumption of steam, and it would seem expedient to prolong the expansion indefinitely. A first limit, however, is fixed at the point at which the pressure of the steam falls below that of the condenser. Again, as the expansion increases so also does the stroke and therefore the size of the engine. Hence, from a constructive point of view, expansion is only practicable within certain limits. Indeed, the advantages arising from exceedingly high rates of expansion are comparatively so small that many engineers prefer a low rate, and even to wire-draw the steam.

The gain of work by prolonging the expansion to *n* is proportional to the area E L L' H.

Loss of head. The ports open gradually and therefore all the angles or the diagram will be rounded.

When the ports open the steam rushes through at a very high speed depending upon the area and velocity of the piston. There is a consequent *loss of head* which is still further increased by the friction and bends in the ports. This loss of head is approximately proportional to the square of the velocity of the steam in its passage through the ports, and therefore rapidly increases (especially at exhaust) as the area of a port opening diminishes. It also slightly increases with the pressure, and is greater with wet than with dry steam.

The effect is to lower the pressure during the forward stroke and to raise it during the return, so that the theoretic diagrams (Fig. 6), A B D C O will be replaced by A' B' H' D' E' and the difference between the areas of the two diagrams will represent the corresponding loss of work. But the density of the steam in A' B' is evidently less than in A B. Hence, the consumption of steam is less in A' B' than in A B, and this, to some extent, compensates for the loss in the forward stroke.

Again, the loss is diminished by introducing a *lead* at admission and exhaust. The exhaust port being opened at F, a little before the end of the stroke, the pressure rapidly falls to C', and the return is made along E' K. The exhaust port is closed at K, a little before the end of the return stroke, and the admission port is opened, so that the *clearance* becomes filled with steam which is compressed by the piston, and attains a high pressure. The increase in the pressure lessens the necessary consumption of steam, and although a small amount of work is absorbed in the compression it is almost wholly restored during the expansion.

The effect upon the diagram is to raise the curve as shown by the dotted line. The work gain is represented by the *scored* areas, the work lost by the *darkened* areas.

The lead at the opening of the exhaust should be greater than at admission and both leads should increase with the speed of the engine, and as the ports diminish in area.

The lead at the closing of the exhaust should be greater in condensing than in non-condensing engines, and should increase with the clearance.

Clearance, Fig. 7. The effect of the clearance may be observed from the accompanying diagram D D' being the volume of the clearance, the area A D represents a lossof work. The work during the full pressure in A B remains unchanged, but the curve of expansion B E is raised to B E' E' which gives a gain of work represented by the area B E' El E. This, to some extent, compensates for the loss A D, and, if the rate of expansion is sufficiently high, may more than counterbalance it. B

◆

THE ores of manganese, fused with borax or salt of phosphorus, enter into the production of the beautiful "violet-coloured glass." The finely powdered mineral, spread on stoneware as a paste, will afford a permanent glazing, which will have a "black" colour, if laid on thick, and a deep violet blue if quite thin. The oxide heated with muriatic acid gives off fumes of chlorine, and is employed for bleaching purposes. One of its ores also affords the gas "oxygen" to the chemist. Manganese ores also receive a fine polish and are employed for "inlaid work." Pulverized, it may be used for umber paint. The sulphate and chloride of manganese are used also in "calico printing," the sulphate producing a fine chocolate brown.

THE NEW EDDYSTONE LIGHTHOUSE.

By William Tregarthen Douglass, Assoc. M. Inst. C.E.

The necessity for the construction of a new lighthouse on the Eddystone rocks had arisen in consequence of the faulty state of the gneiss rock on which Smeaton's tower was erected, and the frequent eclipsing of the light by heavy seas during stormy weather. The latter defect was of little importance for many years after the erection of Smeaton's lighthouse, when individuality had not been given to coast-lights; but with the numerous coast and ship-lights now visible on the seas surrounding this country, a reliable distinctive character for every coast-light had become a necessity. The tower of the New Eddystone was a concave elliptic frustum, with a diameter of 37 feet at the bottom, standing on a cylindrical base 44 feet in diameter, and 22 feet high, the upper surface forming a landing platform 2 feet 6 inches above high water. The cylindrical base prevented in a great measure the rise of heavy seas to the upper part of the tower, and had the further advantage of affording a convenient landing-platform, thus adding considerably to the opportunities of relieving the lighthouse. With the exception of the space occupied by the fresh-water tanks, the tower was solid for 25 feet 6 inches above high-water springtides. At the top of the solid portion the wall was 8 feet 6 inches thick, diminishing to 2 feet 3 inches in the thinnest part of the service-room. All the stones were dovetailed both horizontally and vertically, as at the Wolf Rock Lighthouse. Each stone of the foundation-courses was sunk to a depth of not less than 1 foot below the surface of the surrounding rock, and was further secured by two Muntz metal bolts 1½ inch in diameter, passing through the stone and 9 inches into the rock below, the top and bottom of each stone being fox-wedged. The tower contained nine rooms—the seven uppermost having a diameter of 14 feet and a height of 10 feet. These rooms were fitted up for the accommodation of the light-keepers, and the stores necessary for the efficient maintenance of the lights; they were rendered as far as possible firepoof, the floors being of granite covered with slate; the stairs and partitions were of iron, and the windows and shutters of gun-metal. The oil-rooms contained eighteen wrought-iron cisterns capable of storing 4,300 gallons of oil, and the water-tanks held, when full, 4,700 gallons. The masonry consisted of two thousand one hundred and seventy-one stones, containing 62,133 cubic feet of granite, or 4,668 tons. The focal plane of the upper light was 133 feet above high water, its nautical range was 17½ miles, and in clear weather it overlapped the beam of the electric lights from the Lizard Point. The lantern was of the cylindrical helically-framed type adopted by the Trinity House, The glazing was 2 feet 6 inches higher than usual for first-order lights, this addition being necessary to meet the requirements of the special dioptric apparatus. For the white fixed light exhibited from the three lighthouses of Winstanley, Rudyerd, and Smeaton, at the Eddystone, the Trinity House determined on substituting, as a distinction, a white double-flashing light at half-minute periods, showing two successive flashes, each of about three and a-half seconds' duration, divided by an eclipse of about three seconds. It was also decided to show from a window in the tower, 40 feet below the flashing-light, a sector of white fixed light, to cover the Hand Deeps, a dangerous shoal 3½ miles north-west from the lighthouse. It was further arranged that a large bell should be sounded during foggy weather, twice in quick succession every half-minute, thus assimilating the character of the sound-signal to that of the light. Two bells of 40-cwt.. each were mounted at opposite sides of the cornice, in order that a windward bell might be sounded during fog. The optical apparatus for the main light consisted of two superposed tiers of lenticular panels, twelve in each tier. Each lens-panel subtended a horizontal angle at its foci of 30°, and a vertical angle of 92°, being 47½° above the central plane of the lens, and 44½° below it; and was composed of a central lens and thirty-nine annular rings or segments, there being twenty-one above and eighteen below the central lens. The twelve panels in each tier were fitted together so as to form a twelve-sided drum, each lens having its focus in a common centre at a distance of 920 millimetres. These lenses subtended the largest vertical angle of any yet constructed for coast-illumination, the increased angle and consequent additional power being obtained by the adoption of heavy flint glass for the six highest and the three lowest rings of each panel. The light was derived from two six-wick "Douglass" burners, one being placed in the common foci of each tier of lenses, the illuminant being colza oil. With a clear atmsophere, and the light of the Plymouth Breakwater lighthouse (10 miles distant) distinctly visible, the lower burner only was worked at its minimum intensity of 450 candles, giving an intensity of the flashes of the optical apparatus of 37,800 candles; but whenever the atmosphere was so thick as to impair the visibility of the Breakwater-light, the full power of the two burners was put in action, with the aggregate intensity of 1,900 candles. This intensity was about 23.3 times greater than that of the fixed light latterly exhibited from Smeaton's tower, and about 3,282 times that of the light first exhibited in the tower from tallow candles. The new tower was built at a distance of 130 feet from Smeaton's lighthouse, a large portion of the foundation being laid below the level of low-water spring-tides. The estimate for the work was £78,000, and the cost £59,255. The first landing at the rock was made in July 1878, and the work was carried on until December. Around the foundation of the base of the tower a strong coffer-dam of brick and Roman cement was built for getting in the foundations. By June, 1879, the work was sufficiently advanced for the stones to be laid in the lower courses, and everything was arranged for H.R.H. the Duke of Edinburgh, Master of Trinity House, who was to be accompanied by H.R.H. the Prince of Wales, to lay the foundation-stone on the 12th of the month; but the weather being stormy the ceremony was postponed until the 19th of August, when the lowest stone was laid by the Duke of Edinburgh, assisted by the Prince of Wales. On the 17th of July, 1880, the cylindrical base was completed, and the 38th course by the early part of November. On the 1st of June, 1881, the Duke of Edinburgh, when passing up Channel in H.M.S. "Lively," landed at the rock, and laid the last stone of the tower. On the 18th May, 1882, the Duke of Edinburgh completed the work, by lighting the lamps and formally opening the lighthouse. The edifice was thus erected and fitted up within four years of its commencement, and one year under the time estimated. The whole of the stones, averaging more than 2 tons each, were landed and hoisted direct into the work, from the deck of the steam-tender "Hercules," by a chainfall working between an iron crane fixed at the centre of the tower, and a steam-winch on the deck of the "Hercules," which was moored at a distance of 30 fathoms from the rock.

The Town Council and inhabitants of Plymouth having expressed a desire that Smeaton's lighthouse should be re-erected on Plymouth Hoe, in lieu of the Trinity House sea-mark thereat, the Trinity House made over to the authorities at Plymouth the lantern and four rooms of the tower. For taking down and shipping Smeaton's masonry, the "Hercules" was moored at 10 fathoms from the rock, and the stones were shipped, after the removal of the lantern, by her steam-machinery, by a process exactly the reverse of that by which the stones of the new tower were landed. After the removal of the structure to the floor of the lower room, the entrance doorway and well staircaise leading from it to the lower room were filled in with masonry, and an iron mast was fixed at the centre of the top of the frustum.

◆

MOTION CURVES OF CUT-OFF VALVES.*

BY A. WELLS ROBINSON, M.E., MONTREAL.

(*For Illustrations See Pages* 8, 9 *and* 17.)

Among the many forms of diagram illustrating geometrically the movement of slide-valves by eccentrics, none have come under the writer's observation which will satisfactorily represent the distribution of steam effected by that class of valve gear in which a main slide-valve actuated by link motion constitutes a moving seat for double cut-off valves.

Looking at the slide-valve in its simplest form, operated directly by a single eccentric, the effects produced by certain proportions of lap, lead and travel are comparatively well known and easily understood; but when a link motion is introduced for effecting expansion within certain limits, as well as reversing the direction of motion, the action becomes extraordinarily complicated. Put, now, on the back of this motion double variable expansion valves, and it becomes a subject affording an unlimited field to engine designers and mathematicians for study and investigation.

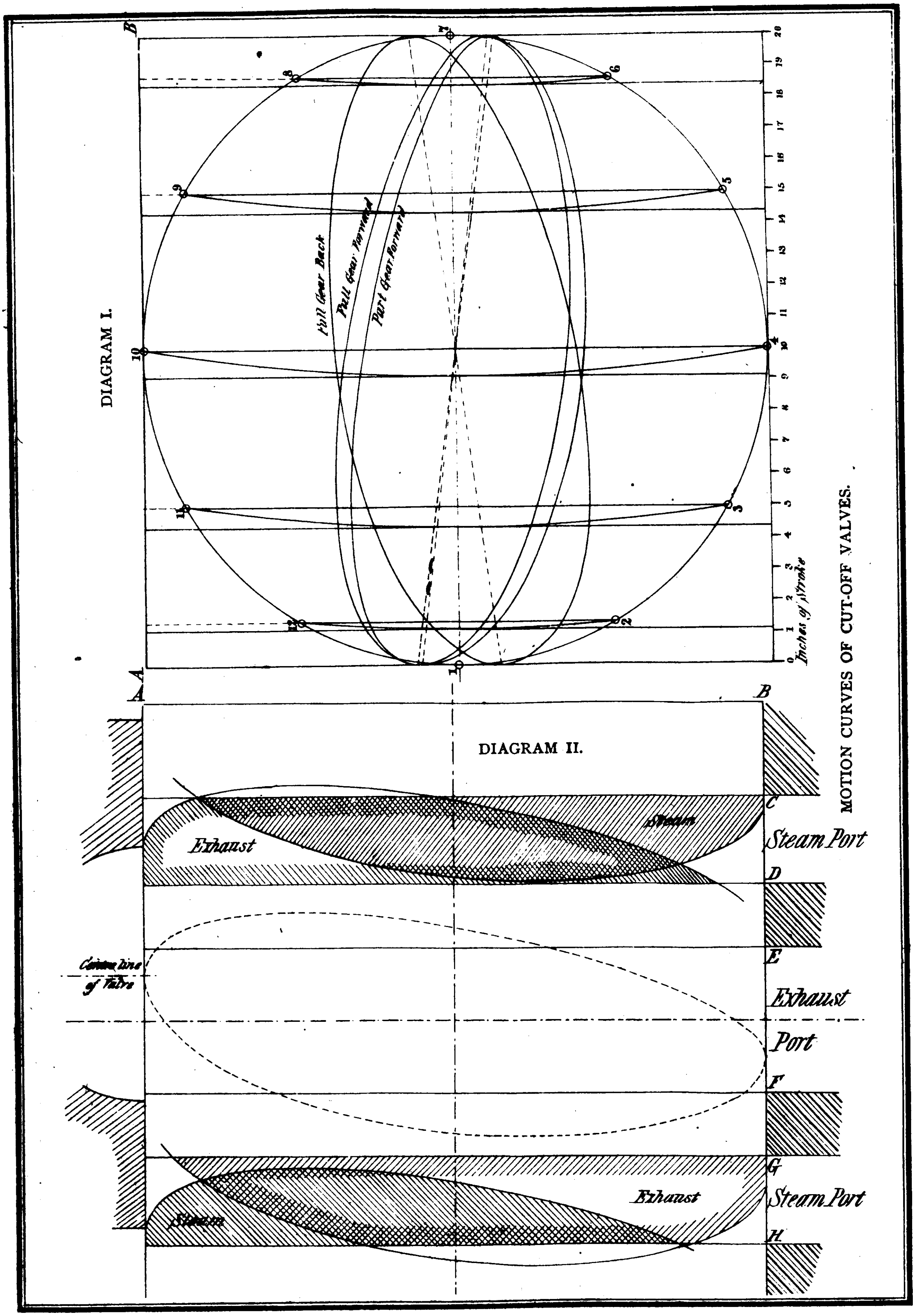
The form of diagram about to be described is a modification of one already known to some engineers, and the idea of adapting the principle to link motions and variable cut-off valves, so as to show the extent and duration of the port opening, occurred to the writer while designing a small condensing marine engine recently, the dimensions of which are selected for the present illustration.

In the diagram No. 1, the large circle representing the path of the crank-pin is divided into a number of equal parts—12 in this case; these points of division are projected up to the line A B, which represents the stroke of piston, the points on which thus obtained are the piston positions corresponding to the numbered divisions of the crank-pin circle. The motion of the valves must now be considered to take place at right angles to the line A B, so that distance horizontally represents piston movement and distance vertically represents valve movement. Now, suppose the diagram to be moved horizontally a distance equal to and corresponding with A B, or the stroke of piston, in a similar manner to the movement of an indicator diagram, while the valve, receiving its relative motion from the link, moves vertically on it; then a point in the centre of the valve would trace a curved line of an elliptic form. This motion curve may be taken to represent the path of the centre of the main valve, and it may be drawn for various positions of the link, those shown in the diagram Fig. I being full gear forward, second notch forward and full gear back. They are laid down by ordinates derived from diagrams Fig. 4, which shows the journeyings of the link through its successive positions corresponding to the before-mentioned divisions of the crank-pin circle. A curve showing the exact movement of the main valve being drawn in this way, we can now draw parallel curves to represent the movement of its edges over the ports in the valve seat, as shown in diagram Fig. 2. The ports are projected across the diagram from C D, &c., and the extent to which they are opened during the stroke for steam or exhaust is shown by the curves of the outer and inner edges of the valve respectively. Referring to Fig. 2, it will be seen that the steam opening commences with 3-16 lead at C; then, widening rapidly, reaches its maximum at about 38-100th of the stroke, after which it gradually closes, cutting off at 9-10ths of the stroke.

Proceeding now to consider the movement of the cut-off valves, it will be seen that, if we draw parallel curves representing the moving parts in the main valve, we may lay down the movement of the cut-off valves over them in a similar manner, and thus trace the events between them. The position of the cut-off eccentric being diametrically opposite the crank-pin, the movement of the cut-off valves, if we suppose it to be traced in a similar manner to the main valve, will be represented on the diagram by straight lines K G and L D, Fig. 3, and the variable positions of their edges to effect any desired cut-off will be straight lines parallel to K G and L D. In the example the shaded areas of the part terminated by these lines represent the port opening up to their respective points of suppression by the cut-off valves. The various proportions of the cut-off valves for any desired range of expansion may now be determined by direct measurement from the diagram. For example, if the range of cut-off is to be from 1-5th to 3-4th, the distance, J M, between these two positions is 2 inches, which is the limit of adjustability for each valve. In like manner the necessary width in order to cover at extreme travel will be equal to N P, plus a small amount for cover; and if at the latest limit of cut-off the inner edges of the valves are shown to overlap each other, the ports in the back of the main valve must be separated by that amount in order to allow space for the adjustable movement.

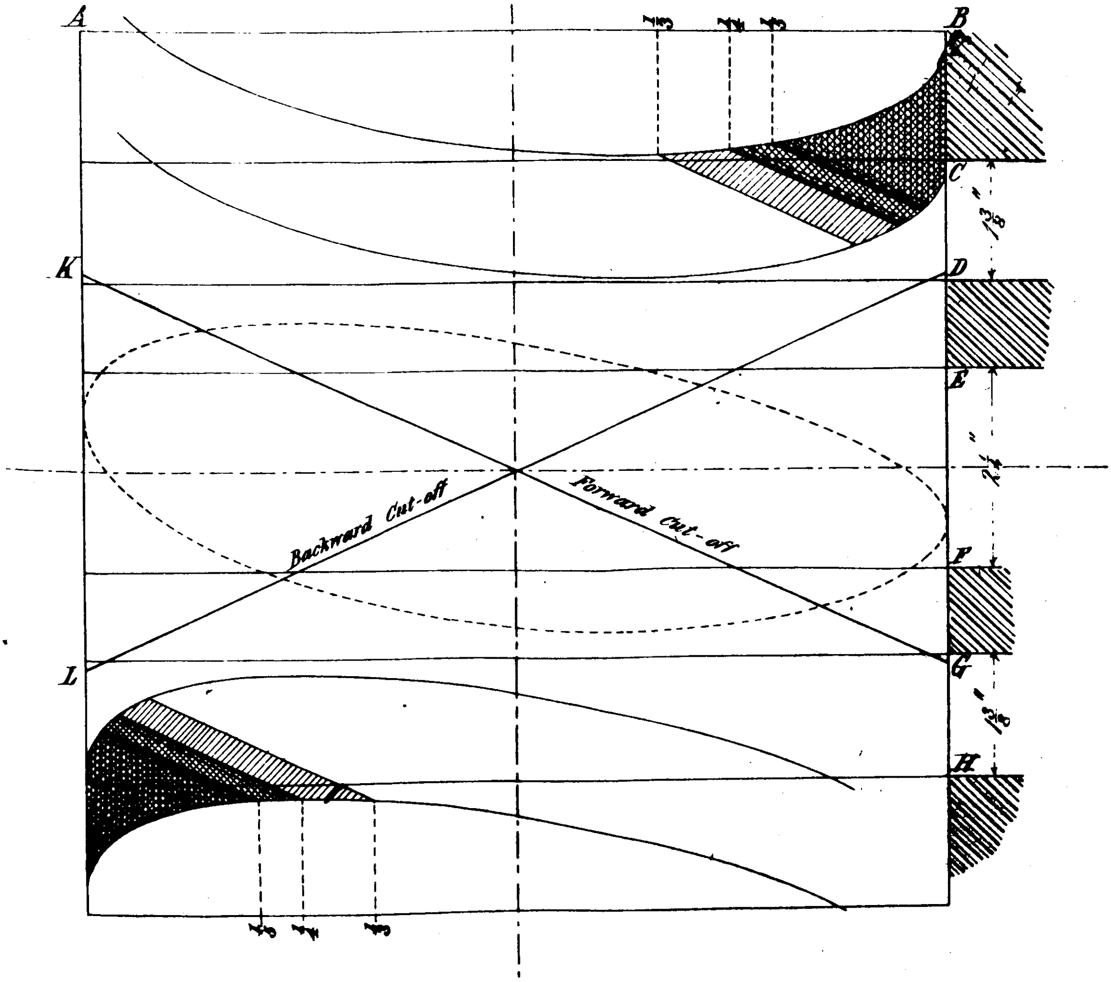
---

* Read at Annual meeting of the American Society of Mechanical Engineers, New York, November, 1883.



MOTION CURVES OF CUT-OFF VALVES.

MOTION CURVES OF CUT-OFF VALVES.



As before stated, the piston positions O R S T, Fig. 1. are projected by straight ordinates from the divisional points of the crank circle. The positions thus obtained, however, would only be correct were the connecting-rod of infinite length. The effect of the obliquity of the connecting-rod is always to draw the piston nearer to the crank-shaft than it would be if the connecting-rod were infinitely long. In order, therefore, to apply a correction to this effect, we join the divisional points of the crank circle by circular arcs, the radius of which is equal to the length of the connecting-rod. The ordinates of the motion curve are then laid off tangent to these arcs, the result being that the port openings measured at any point on this curve correspond to the fractional parts of the stroke at which they were taken. As before mentioned, the usual position of the cut-off eccentric on the shaft is diametrically opposite the crank pin, in which case, if it be a reversible engine, and the two eccentrics of the link-motion have an equal angular advance, the admission will be equal both for forward and backward motions. Under some conditions, however, it may be desirable to give a greater admission during backward motion than during forward, in which case the position of the cut-off eccentric may be shifted toward the backward eccentric, giving it a later movement, and thus prolonging the admission, while for the forward movement its angular distance in advance of the forward eccentric is increased, thus producing an earlier movement and a greater relative travel. Its movement in this case, instead of being a straight line, K G (the valve going and returning upon that line), would be an open curve, similar to, but flatter than, those of the main valve, according to the position of the eccentric.

The movement of the cut-off valves (curve or straight line, as the case may be) may be plotted direct from the eccentric circle, as shown in Fig. 1. The eccentric circle is divided to correspond with the crank-pin circle, and the points of division of the former are projected horizontally and those of the latter perpendicularly, as before; the intersection of like numbered lines are then points in the curve (or straight lines) K G and L D.

It will be borne in mind that while the absolute travel of the cut-off valves is constant, we change the relative travel, for a given position of the link, by shifting the position of the cut-off eccentric in the manner before described, for it is manifest that the relative travel of the two valves would be zero if the position of the eccentrics imparting motion to them coincided (or equal to the difference of their throw, if any), and greatest when diametrically opposite. In these illustrations the diagram has been divided into three parts, for the sake of clearness, and many lines have been introduced which would be dispensed with in practice. The desired results may be easily obtained by sliding a tracing of the central curves over the diagram of steam ports.

It is not supposed that this form of diagram will displace or supersede the ordinary methods of designs in vogue in the drawing office, but it is thought that the method employed, of drawing the ports and graphically representing the extent of their opening, at once appeals to the eye, and a clearer idea of the valve movement is conveyed to the mind than if certain geometrical constructions bearing a conventional, but no apparent, relation to the movement were employed. It also admits of every variation of its elements, and furnishes the means of comparison and of judging the effects of such variation, while at the same time its strict accuracy in neglecting no disturbing influence, such as obliquity of the connecting-rod or varying positions of the link, will perhaps render it valuable for purposes of investigation.

◆

Interspaces Brick-work.—The influence of interspaces in ordinary brick walls in preventing the percolation of moisture has been frequently observed by experienced sanitarians and builders. But the value of such spaces in reducing the temperature in summer and increasing it in winter, has never received a more forcible illustration than in the report of Superintending Engineer Mussey as to the officiency of the device in preventing the contents of the flush tanks of the system of sewerage recently finished in Keene, N. B., from freezing. The sides of the tanks are composed of an external brick wall, an air space, and a lining wall, also of brick. No other precautions have been taken; and yet, during the coldest nights of last winter, not a single tank was frozen up; while, during the summer, the water was several degrees cooler than in cisterns and wells adjacent. Builders of dwelling houses in this climate may find a valuable hint in the experience of the little city of Keene as to double-walled flush tanks.

◆

[*]NOVA SCOTIA DIVISION OF THE GREAT AMERICAN AND EUROPEAN SHORT LINE RAILWAY.

BY H. V. THOMPSON.

(For illustrations see pages 12 and 13.)

By an Act of the Parliament of Canada, passed May 7th, 1882, the Great American and European Short Line Railway Company was incorporated for the purpose of constructing a Trunk Air Line from Montreal through Quebec, Maine, New Brunswick, Nova Scotia and Cape Breton. With the object of obtaining the shortest possible route for the conveyance of mails and passengers to and from Europe, the Company proposed run a line to Cape North in the Island of Cape Breton, to maintain a service of steamers thence to Cape Ray, the nearest point in Newfoundland, and to construct a railway from the latter point to Bonavista on the extreme east of the island, thereby reducing the ocean travel to a minimum and making the time of passage from Montreal to Liverpool very much less than by any existing route. The Cape North portion of the road will necessarily be difficult of construction, and the undertaking of this and the Newfoundland portion has been deferred until further investigations are made as to the practicability of the route. At present the Cape Breton Division is being located between the Straits of Canso and Louisburg, which port is to be the eastern terminus of the road. The Straits of Canso at the site of the proposed crossing are about 2,700 feet wide, and through cars are to be taken over on boats built for the purpose, similar to those used at different points in the United States.

The total length of the line from Montreal to Louisburg is about 764 miles, and of this about 278 miles are now in operation, and to be acquired by the Company. The approximate lengths of the different portions already in operation and of those yet to be built are given on the accompanying map (I). The railway when completed, by giving much shorter communication than any other route between Montreal and the sea ports of the Maritime Provinces, is likely to become the great through line for passengers and freight between the Western and Eastern parts of the Dominion, and between Western Canada and Europe. The advantages of the route in respect to distances will be seen from the following table :—

BETWEEN	Via Shortest Present Route.	Via G. A. & E. S. L. Railway.	Miles Saved.
Montreal and Fredericton	561	373	188
" " St. Andrews	544	385	159
" " St. John	585	410	175
" " Moncton	566	476	190
" " Charlottetown, P.E.I. (Cape Tormentine)	784	543	241
" " Pictou	834	581	253
" " Halifax	845	653	192
" " Louisburg	994	764	230

Distance between St. Andrews and Liverpool	2,730	miles.
" " St. John "	2,740	"
" " Halifax "	2,480	"
" " Louisburg "	2,240	"

The main line of the Nova Scotia Division extends from Bay Verte, on the Straits of Northumberland, eastward through the Counties of Cumberland, Colchester, Pictou and Antigonish to the Straits of Canso, and is about 170 miles in length. A branch line of about 21 miles which is to connect with the Intercolonial Railway on the south at Oxford Station, and with the harbour of Pugwash on the north, crosses the main line about 15½ miles from the Oxford Junction. A branch has also been located to the town of Pictou which has one of the best harbours in the Province. It was at one time proposed to run the main line through the town of Pictou, and several preliminary surveys were made with this object in view; but it would have necessitated a somewhat circuitous and difficult route, and a very expensive iron bridge across the harbour, so the idea was abandoned, though the town offered $50,000 for the purpose of securing the railway.

That part of the Division between New Glasgow and the Straits of Canso, about 80 miles, is now in operation, forming the Halifax and Cape Breton Railway, which is at present under the control of the Nova Scotia Government. The first three miles of the Oxford-Pugwash Branch are also in operation, having been built by the Dominion Government as a branch from the I. C. R. to Oxford village. The part of the Division in process of construction comprises the remaining 18 miles of the Pugwash Branch and that part of the main line extending from Pugwash Junction to the Middle River Coal Shoots, which are within 10 miles of New Glasgow. From Middle River there are two coal railways (II.) either of which will give connection with the Intercolonial Railway and the Halifax and Cape Breton Railway, and one of which it is proposed to be purchase in whole or in part, and to repair and make part of the main line. The Division west of Pugwash Junction is not yet located.

In June, 1882, shortly after the Company had received its charter and secured a subsidy of $3,200 per mile on the line between Oxford and New Glasgow, location was commenced on this part of the road.

---

[*] Abstract of Summer Report for 1883, Faculty of Applied Science, McGill University.

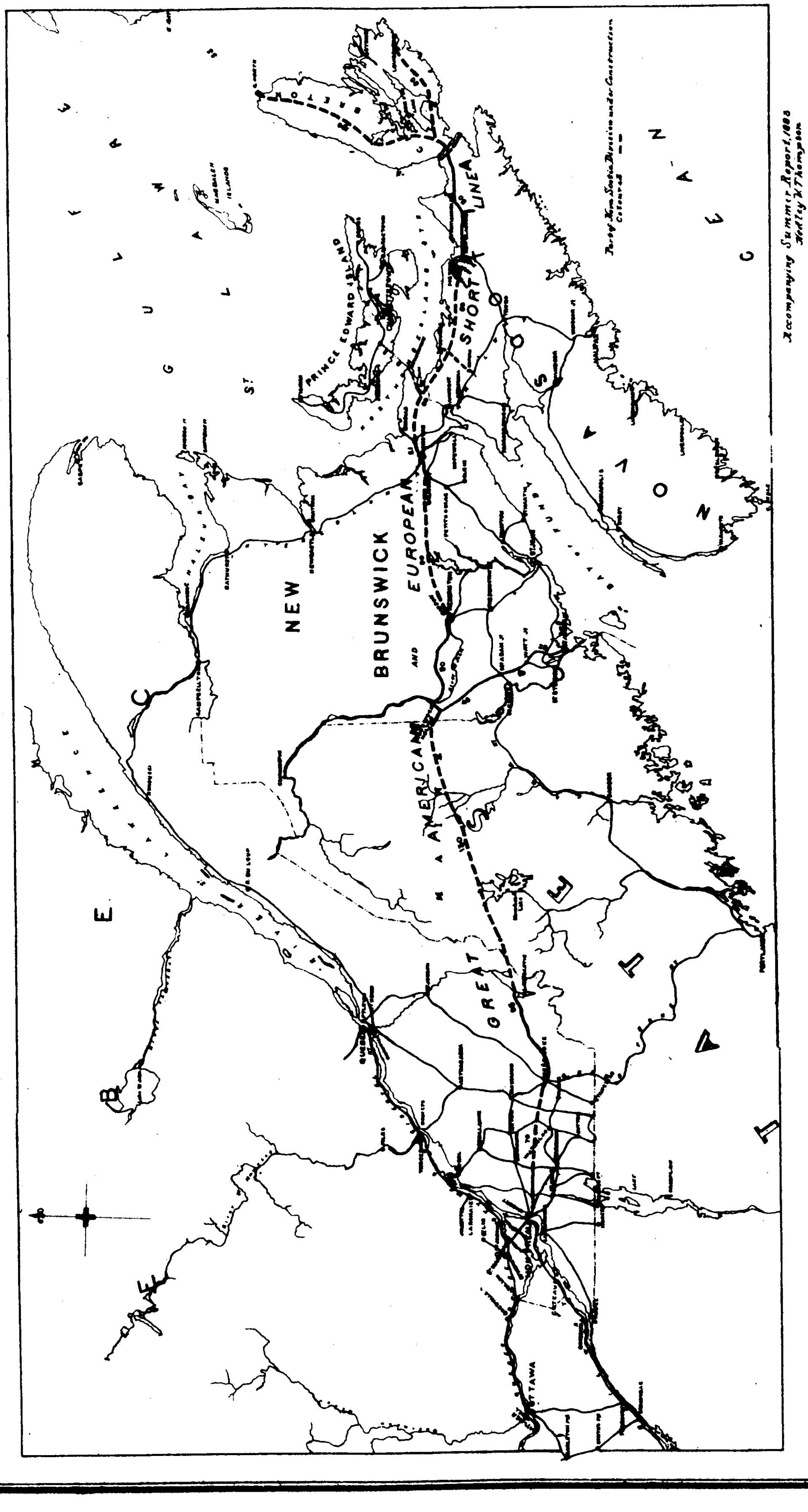
Construction on the branch was well advanced by the close of the season, and grading was nearly completed to Pugwash when operations were suspended on the 26th of July, 1883. There are two bridges on the branch line, viz: a 50-feet span Howe Truss bridge over Pugwash River, and a pile trestle bridge about one quarter of a mile in length across Pugwash Basin, both of which are nearly completed. The piles for the latter were driven in the winter when the Basin was frozen over. The branch for the most part is easy of construction. No difficulties were met with except at Pineo's Lake, about 9 miles from Pugwash. At this place the road crosses a bog, the nature of which was not understood until after construction had been commenced, as precautions were not previously taken to obtain proper soundings. Thus a mistake was made which has led to unnecessary expense, as a good, though less direct location might have been obtained a little to the left. There is a light fill over the bog, and a pile trestle with two piles to a bent has been built for a distance of 1,350 feet. The usual distance between the bents is 10 feet, but in some places on the curve they are only 4 feet apart. The piles had to be driven to a very great depth, in some cases more than 70 feet, before solid bottom was reached. They were driven down one upon another, the only splice being a two-inch pin inserted in the ends which had been previously sawed off square and bored to the depth of a few inches. The locality has proved to be a floating bog. The dumps on the approaches to the trestle work settle rapidly as they are filled out and the sides of the road are raised up in ridges. The hammer of a pile driver was lost in the bog and sounded for in vain, thus showing that the bog is of soft nature for a great depth. Considering this be the case the method of splicing the piles, I think, is not a good one, as the material in which they are driven can give but little resistance to their bulging out sideways, and the material of the bog is about the only resistance to this tendency, as the pin is of wood and fits loosely in the top pile, being made simply to guide the pile in its descent. The momentum of trains passing over the trestle will introduce couples which will act about the middle points of the top piles and in different directions, according to the direction of the moving load, which will tend to loosen the piles, and make the trestle very unstable, especially on the curve. Further, when a joint is out of the straight line joining the extreme ends of the pile, the weight of the train will tend to budge it out still more, and thus the trestle will gradually get out of its proper position. The track, as well as being unstable, must become very uneven and irregular owing to the unequal settling of the trestle, which will evidently depend upon the number and lengths of the pieces spliced together in each pile, the straightness of the pile timber, the straightness of the line in which the pieces have been driven, and the difference in consistency of the bog at the different places. Further the straightness of the spliced pile must depend upon the squareness with which the butted ends have been sawed to the longitudinal section, as well as upon the straightness of the timber itself. In driving the piles there will be a tendency to bring the shoulders flat together, but in crooked piles the chief tendency must be to follow a circular path.

In order to stiffen the piles, slabs have been laid between the bents and covered with earth. But the structure cannot be made so stable in this way as if the piles had been first rigidly spliced.

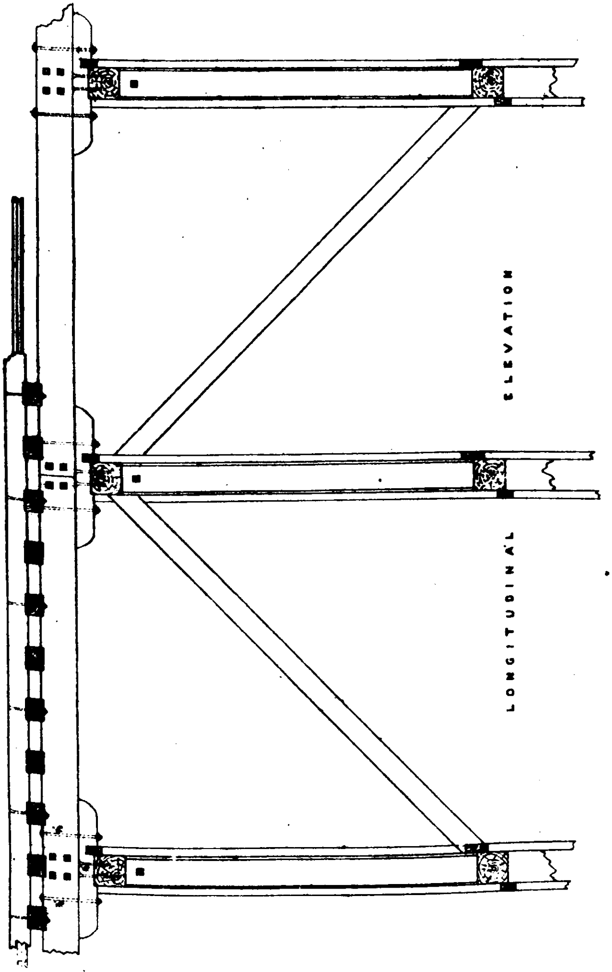
The Company having secured during the last session of Parliament, a further subsidy of $3,200 per mile on other parts of the throngh line, including the portion in Cape Breton between the Straits of Canso and Louisburg and a part of the New Brunswick Division, commenced construction on the main line of the Nova Scotia Division in June, 1883, and in the following month began location in Cape Breton and New Brunswick. The grading and masonry on the Nova Scotia Division were to be completed in the following November. The work was being pushed rapidly forward with every propect of being completed within the specified time, when all at once operations were suspended on the 26th of July, 1883. That part of the Division under construction is subdivided into six Residencies. The branch line comprises Residency No. 1, and includes 4 contract sections. The Residencies on the main line, with the exception of No. 6, are each about 10 miles in length, and comprise two contract sections each, the length of a section being as near five miles as practicable. Residency No. 6 is about eleven miles in length and includes three sections, the last one being less than one mile in length. The road for the most part passes through a good and well settled farming country. The site of the railway being near the sea and parallel with the general direction of the coast, a succession of streams and intervening ridges have to be crossed. If the road had been located farther inland, the constructiou would have been much more difficult and costly. The bridges might have been less expensive, but would not have been fewer in number, and the country to the south, as it approaches the cobequids, becomes much more hilly. In a few places, especially on the eastern part of the line, where the country is quite hilly, there was some difficulty in obtaining a good location. A locating party was occupied for a while during the summer in making changes in those places where a good location was not obtained by the former party, and they were usually successful in finding not only a much improved, but a remarkably good location. The object of the change made at Tatamagouche was not as much to avoid difficulty in construction, as to convenience the people of the village. It may be at once observed that the new location surpasses the old inthis respect and (shewn in the profile book,) profiles show the advantages of the new over the old location at Saw Mill Brook. At Middle River, it was first intended to cross the Nova Scotia Coal Railway *on the level*, and for this purpose to build a high trestle bridge across the river, similar to that shown on page 13; but it was finally decided to build a lower trestle across the river and to pass under the Nova Scotia Coal Railway. For this purpose a slight change had to be made in the former location, making the junction with the Intercolonial Mining Company's Railway a few stations farther on. Among other changes to improve the location, two were made on Residency No. 2, the curvature of which is given in the profile. The object of one of these changes was to avoid crossing a swamp, in which pile driving would be impracticable.

The rock formation belongs to the Carboniferous period, and quarries of excellent freestone have been

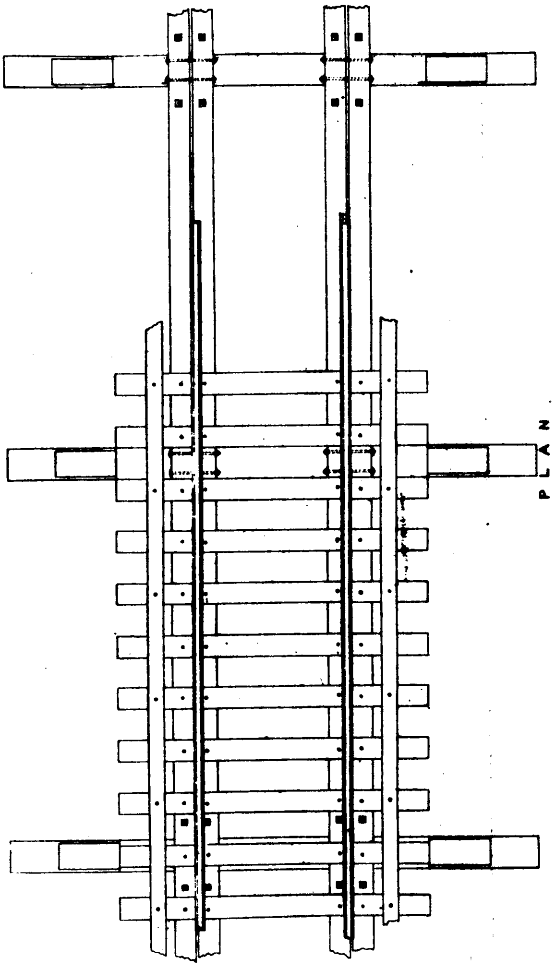
AMERICAN AND EUROPEAN SHORT LINE RAILWAY.



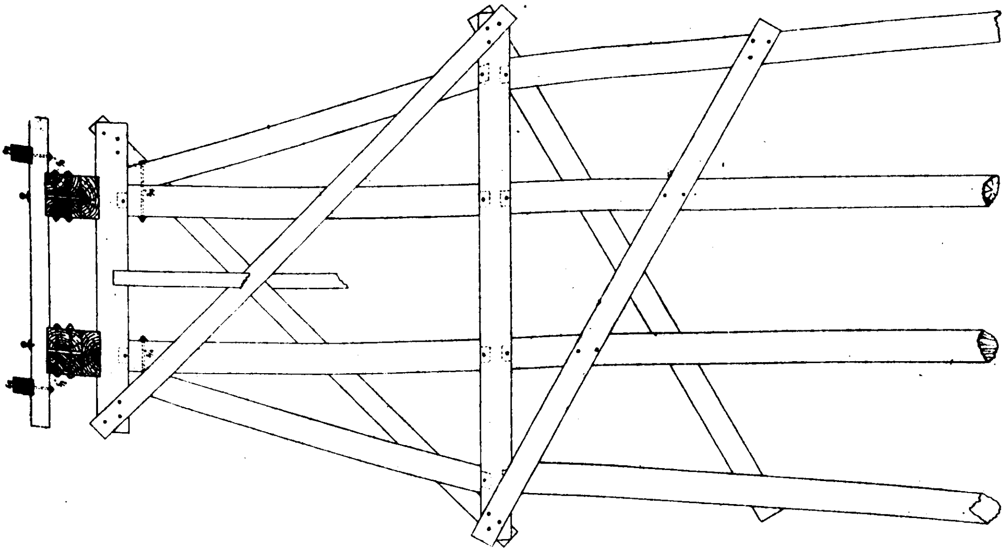
AMERICAN AND EUROPEAN SHORT LINE RAILWAY.



LONGITUDINAL ELEVATION



PLAN



TRANSVERSE ELEVATION

PLAN OF PILE TRESTLE.
G. A. AND E. S. L. RY.

stripped and derricks raised at several points along the line, so that good stone for the bridge and culvert masonry is obtained without a lengthy haulage. The site for the Wallace River bridge, which is to be of four spans, and the highest and most important bridge in the Division, is in the immediate vicinity of a good freestone quarry. The earth to be removed in grading is usually of a clayey nature, and soon forms a very hard and compact road-bed.

The usual method of proceeding with excavations, and the one adopted to a greater or less extent by all the contractors is, first, to plough the surface between the slope stakes, and to keep repeatedly ploughing and casting off until the cut is out to rock or formation grade. After the top lift has been taken off, the earth becomes so hard by the carting over it that it requires four horses and about as many men to work the plough. Besides this, the plough and carts are often in one another's way and time is lost. The centre stakes, gullet stakes, and sometimes the slope stakes, are removed at the first ploughing, and when the cuts are of any considerable depth it becomes difficult to tell exactly where the road-bed should be. There can be little doubt that in very shallow cuts this method is the most practicable and economical, but in deeper cuts, where a fall can be obtained, its utility is doubtful, especially when the earth to be removed is of the character already described. Moreover, the work is very much more neatly and accurately done when the gullet is first taken out to grade without using the plough, and the slopes made afterwards. The cuts are then, without any trouble, taken out to their proper depth, and the gullet stakes are there to show the exact place for the road-bed.

The bridges, culverts and other structures, in so far as they have been decided upon, are indicated on the accompanying profile.

The bridges to be built may be tabulated as follows:

Stream.	Sta.	Kind of Bridge.	Remarks.
Doherty Creek	12	25 feet span (truss)	Abutment completed. Masonry 2nd class.
Wallace River	264	Deck bridge of 4 spans. End spans 80 feet each. Middle spans 125 feet. (Howe trusses.)	One abut. completed. Masonry 1st class.
Dewar River	603	80 feet span. Howe truss.	One abut. completed. Masonry 1st class.
Waugh's River	1039	Pile trestle	
West River	2490	Pile trestle	
Middle River	2630	Pile trestle	

French River (sta. 968) will probably be crossed by a pile bridge, with a draw over the channel, as there is a shipyard and wharf just above the crossing. No pile driving nor bridge superstructure has yet been commenced on the main line. The kind of trestle shown in IV. is the design for the one to be built over West River, where the grade is high compared with that at most of the other crossings, where pile bridges are to be built. In the usual form of pile trestle the upper part of the structure is dispensed with, and the track stringers lie on bolsters, which rest upon the caps of the piles. This is the style of trestle built over Pugwash Basin. The larger brooks, where the streams are too large for culverts, or where the fills are too great for embankments and culverts to be economical, are to be crossed by trestle bridges, either pile trestle or trestle on pedestals.

Abstract of specification for pile trestle:

"Pile trestle will consist of piles driven in bents, securely braced and properly capped. The track stringers will be carried on bolsters placed upon the caps, and the cross-ties and guard-rails will be notched and evenly laid and firmly connected together.

"Piles will be hemlock, spruce or tamarac, and of firm, straight timber, without wind, and at least 12in. at butt, and of sufficient length to reach solid bottom, and to allow of being cut off below all shattering effects of hammer, and to grade. If any will not permit of this they must be drawn out and longer ones driven in their place.

"Piles will be squarely cut to grade, and tenoned with a 2 x 4 in. and 6 ft. tenon, the edges of which will be levelled and the shoulders planed and even, so that the cap will fit truly.

"In all permanent structures, piles will be driven 5 ft. between centres and 12½ ft. between centre of bents. Outside piles will be driven with a batter of 1 in 12.

"The piles in each bent will be capped by a 12 x 12 in. x 17 ft. timber, properly mortised so as to fit the tenons, and notches to set evenly and closely on shoulders of caps, and they will be connected with the piles by two 1-in. tree-nails, driven from opposite sides, cut off flush and wedged at smaller ends."

TIMBER FOR BRIDGES.

"Wood for girders, main braces, counters and lower lateral bracing will be of the best Southern hard pine. Track stringers, floor beams, guard rails, and top lateral guard rails and top lateral braces may be of Canadian white pine, or other approved timber, free from wind shakes, large knots, decayed wood, sap or any defect that will impair its strength or durability."

The culverts are to be of stone.

The construction on the main line was in charge of a constructing engineer. The work on each residency was in charge of a resident engineer, whose duties were, first, to carefully check over the levels and alignment on his residency, and to establish bench marks and reference stakes throughout, and then to cross-section the ground and stake out the work. Bench marks, with their numbers and elevations above datum marked thereon, were established about every 1,000 feet, and always in close proximity to every stream or river crossing where bridges, culverts or other structures were to be built. In the case of a large stream, they would be established on both sides. Reference stakes were placed at the beginning and end of every curve, on tangents, at distances of not more than 2,000 feet, and on each side of every stream crossing, and at such a distance from the crossing as not to be disturbed during the construction of the bridge or culvert. A hub was usually tied in by four reference stakes, and the exact distance measured between the nail in the centre hub and that in the peg at the foot of the reference stake. Sometimes six reference stakes were used, the other two being put in in a line through the centre, but at right angles to the centre line. The reference hubs were put in without reversing the instrument, and in the following manner: One reference hub was established by setting the instrument over the centre hub; the instrument was then set over the one just established, and the other hub fixed in the same right line by sighting over the centre hub.

Before staking out the work, the ground was cross-sectioned, and the cross-sections plotted in books. The distance for the slope stakes from the centre-line would then be shown by the plotting books. In cross-sectioning the ground levels were taken at each edge of the road bed, and beyond these limits, at greater or less intervals, depending upon the irregularity of the surface. At the end of each week, the resident engineers walked over their residences, taking measurements and notes of progress, which they reported on forms provided for the purpose to the constructing engineer, who consolidated these reports and sent a copy to the chief engineer. From these reports the weeky progress in grading and culvert masonry was shown by painting on tracings of profiles.

It will be seen on referring to the profile, that instead of laying out vertical curves, it was usual to have a level grade for 100 or 200 feet, where the grades sloped in opposite directions. The curving will be done when the road is ballasted.

Miscellaneous Notes.

STEAMING AND BENDING WOOD.

In an address recently delivered by Mr. H. G. Shepard, of New Haven, Conn., relative to the use of wood in carriage making, he said that after a piece of wood is bent its characteristics undergo a considerable change. The wood is heavier, and its fibres have become interlaced ; it will sustain more pressure and strain than straight wood in the same directions, either across or with the grain. He said : a piece of timber that has been steamed, whether it is bent or not, has its stiffness increased. It is more brittle than it was before, and for some uses it will do as well, and yet there is a quality that the steaming process and the kiln-drying process affect in much the same way ; they both cook the gum in the timber and make it brittle and stiff. There is a kind of hickory that never becomes stiff by a natural process of drying, and one of the desirable qualities of a spoke, rim, or whiffletree, is stiffness as well as strength : you take that hickory—and it is the very best we have—and steam it, and it is better fitted for these purposes than it was before. It is difficult to tear apart a piece of bent wood ; the fibres are interwoven, one with the other. We do not perceive the change on the outside, but when we come to split the stick open we find that its character is entirely changed.

New Wire Fencing.—A new style of barbed wire fencing has lately been put before the public. The wire is single strand made with a loop at the proper intervals. The barb passing through this loop until its middle or centre part is inclosed within the loop, has its ends coiled in opposite directions around the wire next to the loop. After the barb is placed within the loop its first bend is in the direction of the strand to prevent the straightening out of the loop when strain is applied. This forms a neat, firm and compact two-pointed wire barb on a single strand.

A Useful Kind of Solder.—A soft alloy which attaches itself so firmly to the surface of metals, glass, and porcelain that it can be employed to solder articles that will not bear a very high temperature, can be made as follows : Copper dust obtained by precipitation from a solution of the sulphate by means of zinc is put in a cast iron or porcelain lined mortar and mixed with strong sulphuric acid, specific gravity 1·85. From 20 to 30 or 36 parts of the copper are taken, according to the hardness desired. To the cake formed of acid and copper there is added, under constant stirring, 70 parts of mercury. When well mixed the amalgam is carefully rinsed with warm water to remove all the acid, and then set aside to cool. In ten or twelve hours it is hard enough to scratch tin. If it is to be used now, it must be heated so hot that when worked over and brayed in an iron mortar it becomes as soft as wax. In this ductile form it can be spread out on any surface, to which it adheres with great tenacity when it gets cold and hard.

Canadian Cotton Manufactures.—It is an open question whether the gross capacity of the mills now in Canada is not about equal to the demands of the population at this time. The United States census returns of 1880 show that there was then one spindle to every five of the population, and that the annual production was about 45 yards per head of population. With the increased capacity and production since then, there would now be not less than 50 yards per head. In Canada we have one spindle to a little over nine of the population, and the annual production is about 27½ yards per head. This, it is true, is but slightly more than half that produced in the United States, but there are two facts which must be borne in mind in estimating the value of this difference. One is that our normal consumption of cottons is far less than in the United States, owing to the difference in climate. Woollen goods are much more extensively worn in this country and always will be, notwithstanding any modifying influence of the changing fashions. All things considered, our normal consumption may not be much more than one-half that of America. Then, again, America does not consume all she produces, but exports to foreign countries a considerable proportion of her cotton products.

Glass Clothing.—The ingenuity that led to the manufacture of articles of clothing from paper has been eclipsed, as similar articles are now being made from glass. A dry-goods store has on exhibition a glass table-cloth several feet square, of variegated colours, with ornamental border and fringed edges. The fabric is flexible and only a little heavier than those woven of flax, while it is claimed that it can be washed and ironed like an ordinary tablecloth. Glass has been spun and woven in Austria for some years, but it is a new undertaking in this country. A prominent glass manufacturing firm in Pittsburg, Pa., recently engaged in the manufacture of this brittle substance into fabrics, which they claim are as perfect, delicate and durable as the finest silk. A representative of this firm said lately, that they can spin two hundred and fifty-nine threads, each ten miles long, in one minute. The weaving is done with an ordinary loom, but the process is more difficult and much more interesting than the spinning of cotton or other threads. "We can duplicate in glass any costume," said this gentleman, "and can make it just as brilliant in colour, elaborate in finish, perfect in fit, and equal in its smallest details, even to the button on the original. The fabric is very strong, cannot be ripped or torn, and can be sold at a less price than linen, cotton or silk, or other fabric imitated. It is also very warm, easy-fitting, and comfortable, whether worn as dress, shawl or other garment in ordinary clothing." Among the articles already manufactured of glass are beautiful feathers, which resemble those of the ostrich ; towels, napkins, and tablecloths.

Steel for Heavy Shafts.—An engineer at a meeting of the Society of Engineers at Aix-la-Chapelle gave some facts in regard to the qualities of mild steel for heavy forged work that tend to modify the growing confidence in that material as compared with iron. He said that a Bessemer steel shaft of a high speed engine belonging to a rolling mill broke suddenly while the engine was moving slowly. The shaft was replaced by one of iron. In an engine works on the Rhine a steel shaft of 15¾ inches diameter broke, and inside was found a hole large as a man's fist containing two steel balls that during the two years of the shaft's rotation had been worn quite smooth. Another engineer said that in casting steel ingots it is more frequent to have a porous casting in mild steel than in hard steel. If steel ingots have incomplete, hollow, or porous spots, these do not become welded together by further heating and working, but, after being rolled thin, they retain their porosity, as unwelded spots are retained in wrought iron. As these porous places are generally in the centre of the ingot, the round bars, the piston rods, and axles made of it have also usually an internal weakness, which it is difficult to set right in the working, and which may cause breakages in the future. In the course of the discussion it was shown that steel that hardened on the surface on sudden cooling ought not to be deemed mild steel, and was treacherous in its character. No material capable of considerable hardening should be called iron, and, if narrowly examined, it will be seen that a great deal of the ingot iron specified as "incapable of considerable hardening," is nevertheless capable of very considerable hardening under certain circumstances, such as a sudden cooling of a heated shaft. This "inconsiderable hardening" is just sufficient to shrink the surface, produce tension, small cracks, and finally breakages.

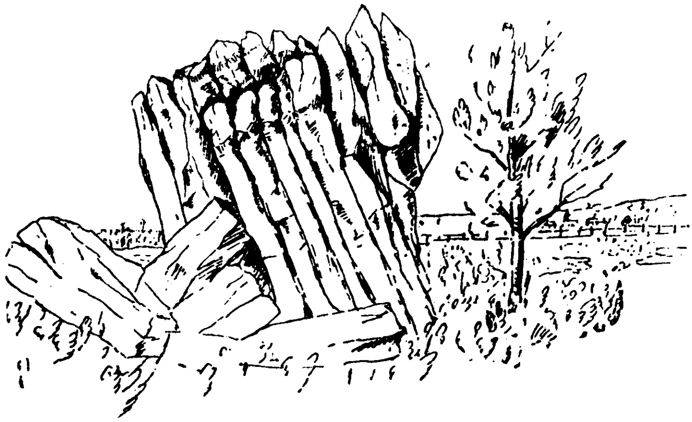


FIG. 1. — Outcrop showing weathering along the plane of stratification.

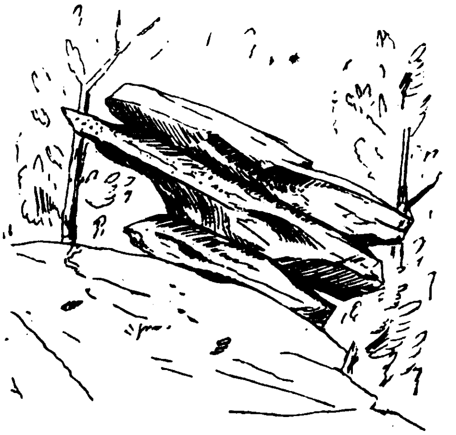


FIG. 2. — Isolated conglomerate mass showing increase of weathering along the planes of stratification on the upturned edge.

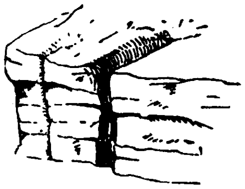


FIG. 3. — Weathering across the plane of stratification.

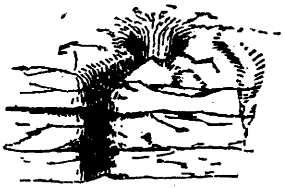


FIG. 4. — Enlargement at end of fissure.

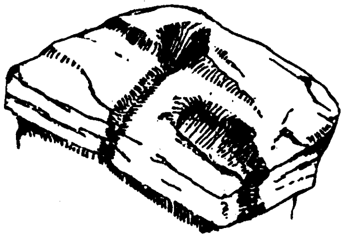


FIG. 5. — The results of superficial weathering in the plane of stratification.

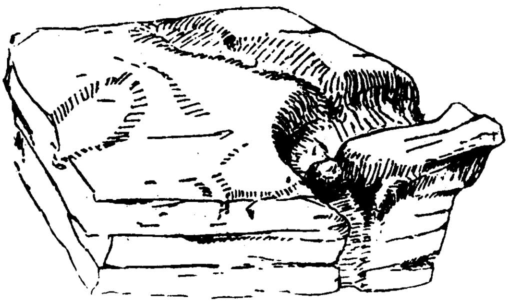


FIG. 6. — Large basin in conglomerate, with a double outlet.]

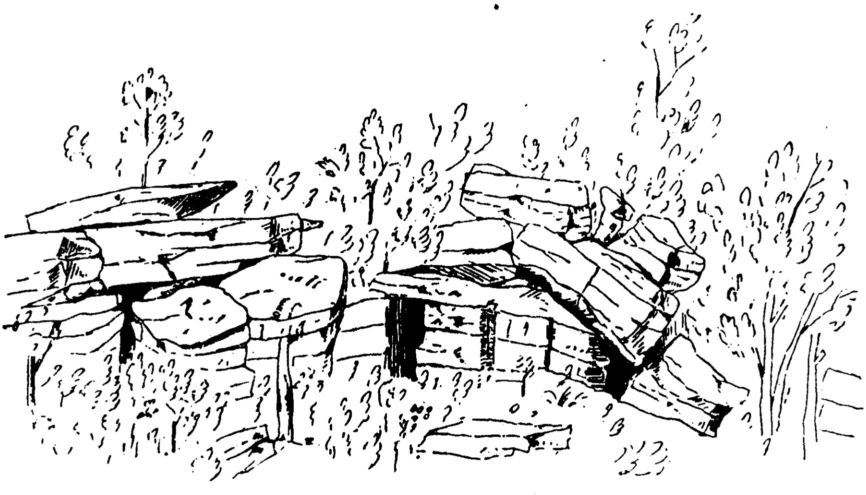


FIG. 7. — Broken conglomerate outcrop.

PECULIARITIES OF WEATHERING IN THE POTTSVILLE CONGLOMERATE.

The striking characteristics of the Pottsville conglomerate in eastern Pennsylvania are its highly siliceous composition and its solidity. Owing to a consequent great durability, it stands out prominently along the different mountain ridges which surround the anthracite coal-basins; but though, as compared with the associated rocks, its resistance to weathering is very great, the effects of this action are everywhere revealed on examination.

The surfaces of the finer and more compact varieties are frequently seen to be covered with numerous small holes, or pit-marks, resulting from the removal of separate grains. Blocks of the coarse pudding-stone have generally a very rough surface, the pebbles projecting half their thicknesses above the surrounding matrix; and fragments of this rock are sometimes so thoroughly permeated and softened by percolating water that they can be crushed to grains by the hand.

Along the planes of stratification the subaerial decay of this rock is particularly well marked. Deep clefts and gashes are found along these planes, which frequently cut entirely across large masses, dividing them into separate slabs. This action is best developed along the upturned edges of steeply inclined dips, where water has the best opportunity to accumulate and to prolong its action in incipient grooves; and, with isolated blocks only slightly inclined, the increased decay along the upturned edges, due to this same cause, is often noticeable. A somewhat remarkable fact about such weathering is, that clefts parallel to the stratification are found in an apparently homogeneous rock. In such cases a difference or deficiency of cometing-material must be the directing cause.

Weathering action across the plane of stratification is exhibited in its first stages by shallow and narrow grooves, which run sinuously across the rock. These have their origin in little streams of rain-water which flow from the surface down the sides of the rock. Once started, such a groove forms a channel whose drainage capacity constantly increases as the depression enlarges; and by degrees the fine groove grows to a decided fissure, half a foot or more across, which the continued action of rain-water cuts deeper and deeper into the rock. This fissure is generally of approximately uniform breadth; but, as it enters farther into the rock, the water drains into it from all sides, and an enlargement is sometimes formed at the end, which I have seen to result in an almost circular hole, completely penetrating the rock.

The most peculiar and remarkable of all the results of this weathering action are, however, those produced by a superficial action in the plane of stratification. Over flat surfaces of the rock, white-washed looking patches occur; but where a slight depression exists, the water accumulates and stands, and as a consequence the grains of the rock in immediate contact are loosened, and, on the evaporation of the water, blown away. Thus the depressions which were at first, perhaps, only a fraction of an inch, are deepened, and, by degrees, basins of as much as a foot in depth are eaten out. These are often so regular in outline, and with such smooth sides, that they might readily be mistaken for pot-holes; and, indeed, it was such that I first considered them, and was puzzled to account for the peculiar channel in which the waters producing them must have flown. A distinguishing feature of these depressions, however, is that each one has an outlet cut down to near the bottom of the cavity; and this is easily accounted for, on the theory of their subaerial origin, by considering, that, once such a basin started, the overflow would always pass off over the lowest edge, and as the basin increased in depth, by continued dissolving action, so would the outlet also. A further confirmation of this is furnished by the facts, that in inclined rocks the outlet is always towards the lower rim, and the bottom of these cavities is either horizontal or sloping towards the outlet. In the bottom is also generally accumulated a small amount of gravel and sand recently loosened from the bed. These basins are of all sizes, up to three feet and more in diameter. Their shapes are varied,—sometimes circular, sometimes oblong,—with gently sloping sides, or steep, even recurving ones, according to the character of the rock. They are frequently connected in strings by narrow channels, like a miniature lake system; and, with the enlargement of these channels, a simple, deep groove across the rock results, all this action combining to give the rock a very rugged appearance.

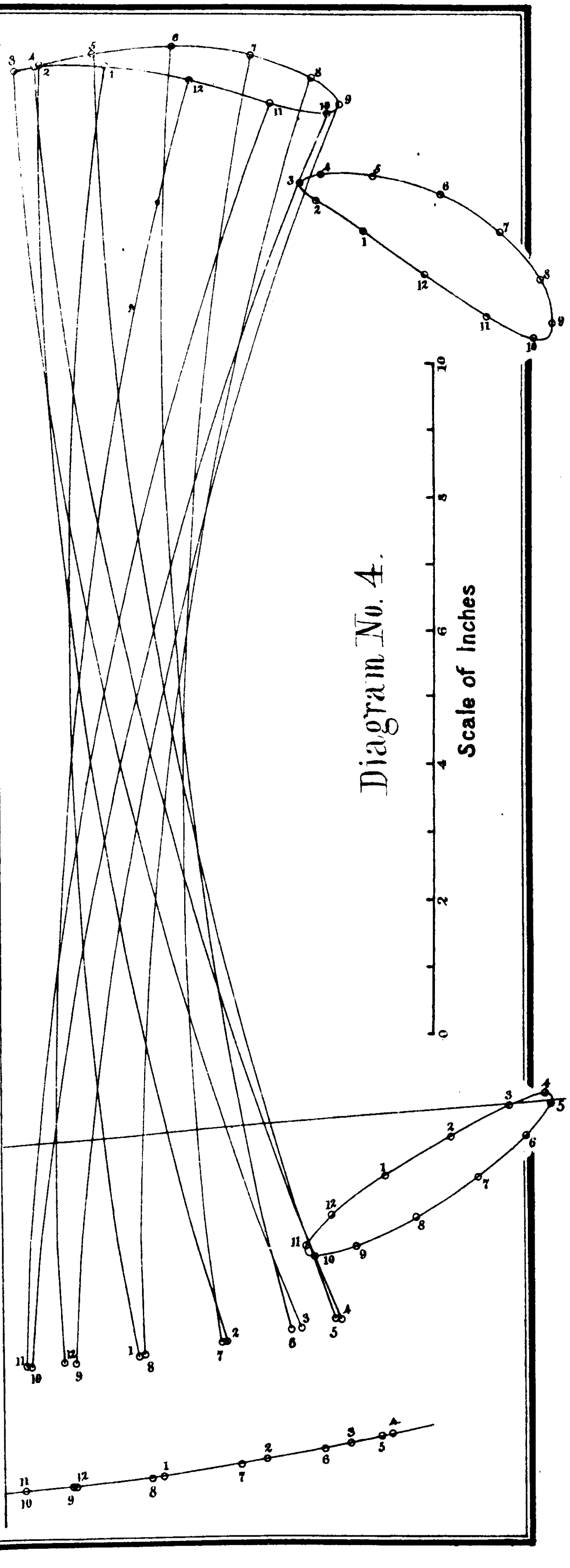


Diagram No. 4.

The very great proponderance of silica grains in this rock, to the exclusion of any good cementing-material, is probably one of the chief reasons for its decay. Rain-water is, without doubt, one of the most active agents; but the secretions from the thick growth of moss and lichens, which frequently covers the surface and penetrates into the cavities of the rock, have probably also their effects. The deep gashes produced by the action of the rain-water offer excellent opportunities for frost to continue the work of destruction; the ice forming in these clefts, and, by its prying action, completing the separation of the already partially divided mass.

As a consequence of this wide-spread weathering process, large continuous outcrops are rarely found. Collections of huge blocks generally mark their site; and the thick accumulations of smaller fragments, which are so frequently found over conglomerate areas, results, without doubts, from the futher subdivision of these larger blocks.

The products of decay either accumulate in place, are washed down by streams, or blown away by the wind. On the top of Broad Mountain, and elsewhere, the distintegration *in situ*, I am informed, is so great that the loose rock is dug out as gravel; and, in valleys watered by streams flowing down from conglomerate ridges, deep deposits of siliceous sand are found, valuable for building-purposes.

The decay of the sandstones and shales, associated with or underlying the conglomerate, is even more pronounced than in that rock. Changes of color, especially from the greenish tints to red, brown, and yellow, are the most frequent results; and this is often accompanied by a softening to a barely coherent sand or clay. Erroneous conclusions are thus frequently drawn from surface indications, as to the nature of the underlying rock.

The subject of the decay of rocks has recently been admirably treated by Dr. T. Sterry Hunt, chiefly with regard to the crystalline rocks; and it deserves to be further studied, in the case of these more recent rocks, from its evident importance in chemical geology, its interesting and well-known relation to topography, and its economic bearing.

ARTHUR WINSLOW.

THE GENERATION OF STEAM.*

BY MR. W. ANDERSON, M. INST. C. E.

The Lecturer commenced by remarking that the source of our fuel supply was derived from the rays of the sun acting upon the earth ages ago. He pointed out that those rays were of complex structure, intimately bound together and yet capable of being separated and analyzed. He remarked that it required over 1,000 H.P. to separate 1 ton of carbon from the atmosphere in twelve hours; but that, in consequence of the enormous area of leaf-surface in which the decomposition took place, the action was silent and imperceptible.

As soon as a law of definite chemical combination had been established, chemists began to suspect that the changes of temperature observed in chemical reactions were also of a definite kind, and that they were as much the property of matter as chemical atomic weights. In the last century Lavoisier and Laplace, and after them, down to the present time, Dulong, Despretz, Favre and Silbermann, Andrews, Berthelot, Thomsen, and others, had devoted much time and labour to the experimental determination of the heat of combustion and the laws which governed its development. Messrs. Favre and Silbermann, in particular, between the years 1845 and 1852, had carried out a splendid series of experiments, by means of a calorimeter, which was illustrated by a diagram. The apparatus consisted of a gilt coppe receiver, in which the substances tested were burnt by a jet of gas. This receiver was immersed in another vessel lined with swan's-down. Thermometers of great delicacy were employed to determine the temperatures, and the whole of the apparatus, used for generating the gases and for collecting the products of combustion, was constructed with the utmost ingenuity and skill. Messrs. Favre and Silbermann adopted the plan of ascertaining the weight of the substances consumed, by calculations from the weight of the products of combustion. By this means they were enabled to deal with larger quantities, and several errors incidental to the opposite process were eliminated. A Table was given showing the calorific value and the chemical composition of such substances as commonly formed the constituents of fuel.

The thermo-chemical laws relating to combustion and decomposition were then stated, and the general formula for calculating the thermic value of any kind of fuel whose analysis was known, was explained. It was pointed out that energy existed on the earth in a form which was often unsuitable for the wants of man:—for example, the water flowing down the Alps was competent to furnish the power necessary for boring through those mountains; but it was not in a form which could be used directly. The kinetic energy of the water had first to be converted into the form of steam or air at high pressure and temperature, and then, by means of suitable heat-engines, it could be used in the manner with which all were familiar. It was probably to this circumstance that the tardy development of the steam-engine was due, for its history dated back only some two hundred years—a very small proportion of the time during which the human race had existed.

A steam boiler was in reality a species of heat-engine, and its action should be investigated upon the same principles, and consequently the doctrines of Carnot were applied. According to these, the efficiency of a boiler depended entirely upon the range of temperature through which the heated gases acted, and, by means of an illustration derived from an application of water-power, it was demonstrated that the proper way to increase the efficiency of a boiler, was to raise the temperature of the furnace to the utmost degree possible, and to lower the temperature of the smoke to the lowest point practicable. Particular instances were then taken in which it was shown that 1 lb. of carbon would be capable of evaporating 14·87 lbs. of water from and at 212o. The case of the prize engine of the Cardiff show of the Royal Agricultural Society in 1872 was described in detail, and it was demonstrated that the maximum amount of work which could be expected from its boiler was equivalent to the evaporation of 13·27 lbs. of water, the actual evaporation having been 11·83 lbs., showing a duty of 89 per cent. In pursuance of the idea of treating a boiler as a heat-engine, an indicator diagram was exhibited and explained, and the laws of Carnot were stated in detail and discussed. The terms of Carnot's formula were then examined separately,—first, in relation to the temperature of the furnace, the process of combustion was explained, and it was shown that the temperature of the furnace depended upon the supply of air. A minimum supply would give the highest temperature, but it was found necessary to add an excess in order to make combustion perfect. It was pointed out that the limit to high temperature in a furnace was the imperfection of the material out of which boilers were constructed. It was shown from the fact that steel was capable of being melted in boiler furnaces, that temperatures so high as that were not injurious; but that, when that melting-point of steel was greatly exceeded, the boiler plates began to suffer severely. Next, the temperature of the chimney end of the boiler was examined. It was stated that by the adoption of feed-water heaters and by the use of forced draught, not for the purpose of augmenting the steam-production, irrespective of economy, but with a view to promoting economy, that the temperature of the smoke could be lowered to about 100_0 above that of the feed-water. The loss of 11 per cent. in the Cardiff boiler was then looked into, from which it appeared that it arose partly from imperfect combustion, which always prevailed more or less, and partly from losses incidental to the transfer of heat from substances less dense to others more dense, and *vice versa*. It was stated that this loss was common to all energy propagated by undulatory motion, such as light, heat or sound. The law of conduction through plates was then explained, and it was pointed out that even joints in a bar of uniform material interposed a certain amount of resistance, and the fact was illustrated by an experiment. The loss was much greater when there was a joint between dissimilar materials, such as between the gases of the furnace and the boiler plate, and between the boiler plate and the water. At first sight it would appear a matter of common sense that a boiler which contained its own furnace must be a better generator than one with an external furnace formed of brick-work; but brick-work was an extremely bad conductor of heat, while it was a very good radiator, absorbing heat from the gases and returning them by radiation to the boiler surfaces. This action was strongly pronounced in the case of the reverberatory furnace, and in the brick arches now commonly introduced into the fire-boxes of locomotives.

---

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

The gases forming the products of combustion were very bad absorbers, and very bad radiators of heat. Pure dry air and nitrogen were absolutely incapable of absòrbing or radiating heat. They were not in the least affected by the passage through them of the most intense heat-rays. Carbonic-acid was a somewhat better radiator while the vapour of water was a good absorber, and therefore a good radiator. It was then demonstrated that the products of combustion consisted mainly of air and nitrogen, and consequently, taken as a whole, the products of combustion were bad radiators. Little or no economical advantage was derived from making the combustion in a boiler perfect, because the colder luminous flame was a good radiator, on account of the white-hot particles of carbon it contained, while the notter and non-luminous flame was a bad radiator, and carried a great deal of the heat into the chimney. This circumstance was illustrated by an experiment, by which it was proved that an intensely-hot non-luminons Bunsen flame had very little more effect upon an air thermometer than a smoky luminous flame burning the same quantity of gas, but that the moment a spiral wire was hung in the Bunsen flame, it commenced to glow, and the radiation from the wire immediately had a powerful effect upon the thermometer. It was probably owing to this circumstance that the backwardness of the owners of steam-boilers to prevent smoke was to be attributed. Had considerable advantage been obtained by the suppression of smoke, Acts of Parliament would not have been necessary for the purpose.

A different class of boiler was required for consuming flaming fuel, as contrasted with such fuel as anthracite and coke, burning with very little flame. In the latter case, tubular boilers were preferable; but unless the combustion was perfect before the gases reached the small tubes, the gases cooled down so considerably, that the flame was frequently extinguished. This fact was illustrated by an experiment, which showed that when pieces of ½-inch gas-pipe of various lengths were placed over an ordinary gas-flame, the shorter tubes allowed the flame to pass through, while the longer ones extinguished it, and the gas could be re-lighted at their upper ends. Water, being completely adiathermanous, and a very bad conductor, could not be heated by direct radiation or conduction. The process of heating by convection was explained in detail, and a comparison was instituted between the heat transmitted from the hot gases in the furnace of a boiler to the water, with the reverse effect of warming by the transfer of heat from hot water pipes to the air of a room. The two being reverse operations, agreed very closely together in accordance with the theory of exchanges. The proper heating-surface to be allowed in a boiler to effect a given amount of evaporation was then dwelt upon. The mode of calculating the sectional area of tubes and flues was given, the heat of the chimneys and their area was considered, and finally the thermodynamic theories relating to the formation of steam were investigated. It was stated that, of necessity, the molecules of steam which became emancipated from the water through the energy of heat, carried with them particles of water, and that these particles constituted priming, the amount of which depended upon the velocity with which the steam escaped from the water. A table was exhibited of a large variety of boilers ranged in order of the velocity and disengagement of steam from the water-surface; and from this it appeared that those in which the velocity was highest were also those most subject to priming. The doctrine of the viscosity of liquids and gases was next dealt with, and applied to account for the manner in which particles of water and of very minute solid impurities were carried over from the water of the boiler into the steam. The same theory was adduced to show that from the slowness with which smoke fell in the atmosphere, it must be composed of exceedingly small particles, and that they were not very numerous compared with the volume of the gases with which they were associated. It further went to show how it was that complete combustion did not produce any marked economy, because the absence of the white-hot particles of carbon from the gases caused a loss of radiating power. It was thought that no great improvement was to be expected in the economy of boilers, for the limit had been already almost reached.

The honour of having first pointed out the true principles on which the duty of boilers should be estimated, namely, by comparing the work actually done with the potential energy of the fuel used, was due to the late Professor Rankine.

The Lecturer concluded by a tribute of respect and admiration to the late Sir William Siemens, whose name was closely associated with the subject of his lecture. At the time of his death, Sir William Siemens was engaged in perfecting a pyrometer, intended to indicate accurately temperatures above those of melting steel. In addition therefore to the many causes of regret for his lamented decease, was to be added this, that the production of a trustworthy pyrometer would be indefinitely postponed. The impulse which Sir William Siemens had given to the study and elucidation of thermodynamics would not cease with his life, but this and succeeding generations would long profit by his example and his labours.

◆

TORPEDO BOATS.—(*Engineering.*)

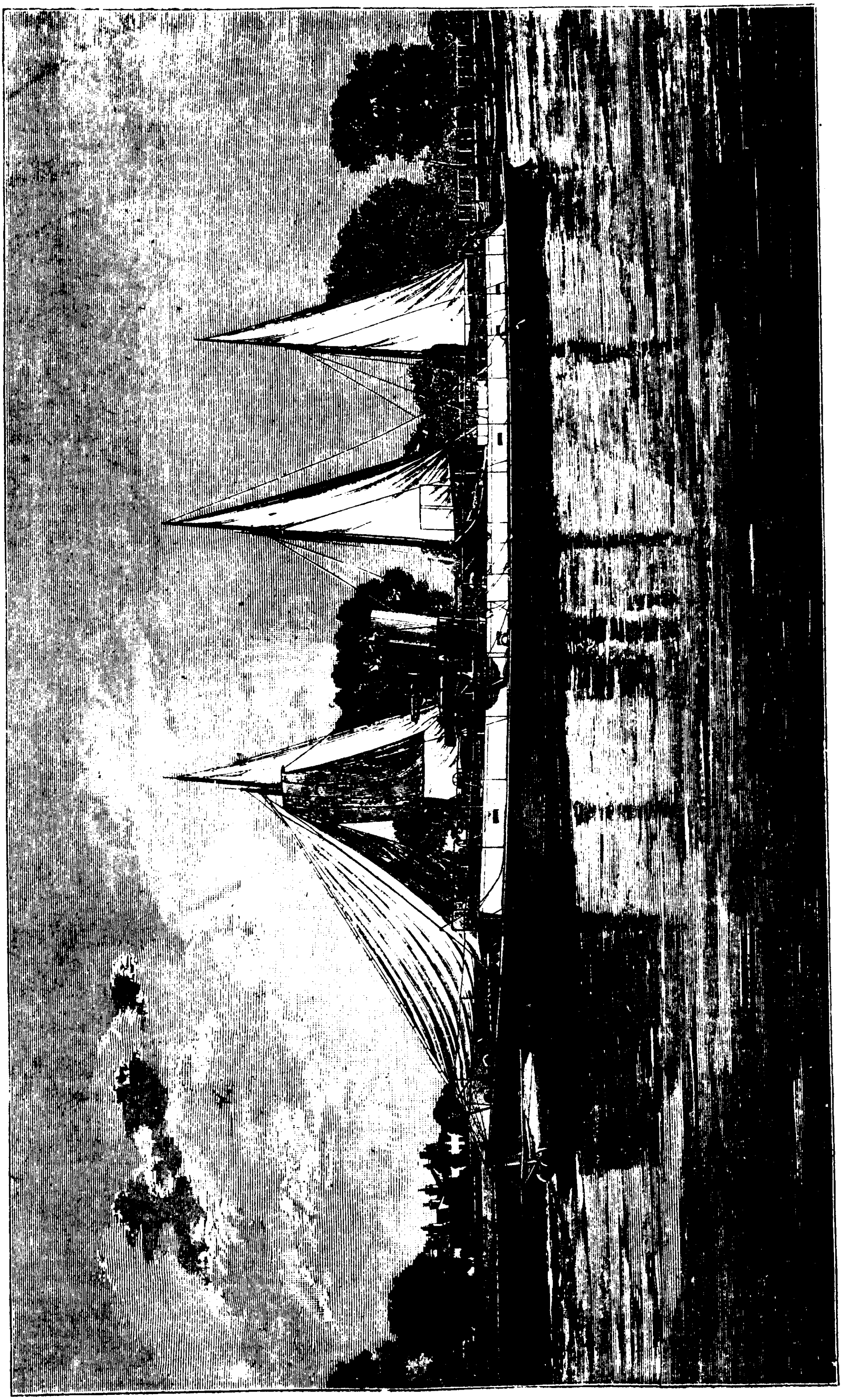
On pages 20 and 21 of the present number are illustrations of the two latest types of the first-class torpedo vessels built by Messrs. Thornycroft and Co. The Russian boat (see page 21) is of the following dimensions: Length on water-line, 113 ft.; beam (moulded), 12 ft. 6 in.; depth, 6 ft. 6 in.; draught forward, 2 ft. 6 in., aft, 6 ft.; displacement, 60 tons. The hull is built of galvanised Bessemer steel, and is divided into eleven compartments by eight water-tight bulkheads and two half bulkeads in the manner introduced by Mr. Donaldson. The boat will float with any one of these compartments filled. Six powerful bilge ejectors are fitted. Two of these are placed in the boiler compartment, and are capable of ejecting 40 tons of water per hour each with a boiler pressure of 75 lb. In addition to the ejectors a bilge pump is worked off the main engines, and hand pumps are fitted for pumping the bilge from on deck. A separate steam donkey is provided, and the circulating pump, which is arranged with suction branches both in the boiler and engine room, as well as from the sea, is guaranteed to throw 45 tons of water per hour.

The main engines are 14½ in. and 24¼ in. in diameter, by 15 in stroke, and were guaranteed to develop 750 indicated horse-power. They are of the now well-known Thornycroft type of torpedo boat engines, such as described in the thirtieth volume of *Engineering*; they are fitted with a special valve by which they can be converted into non-condensing engines if necessary. Auxiliary engines are used for driving the fan blower and for the circulating pump, in addition to which there is the steam donkey referred to; the former are placed in the engine compartment, and the donkey in the boiler room, but both fan and donkey can be regulated from either compartment. A striking feature is these boats is the steam steering gear which is fitted in the forward part of the conning tower.

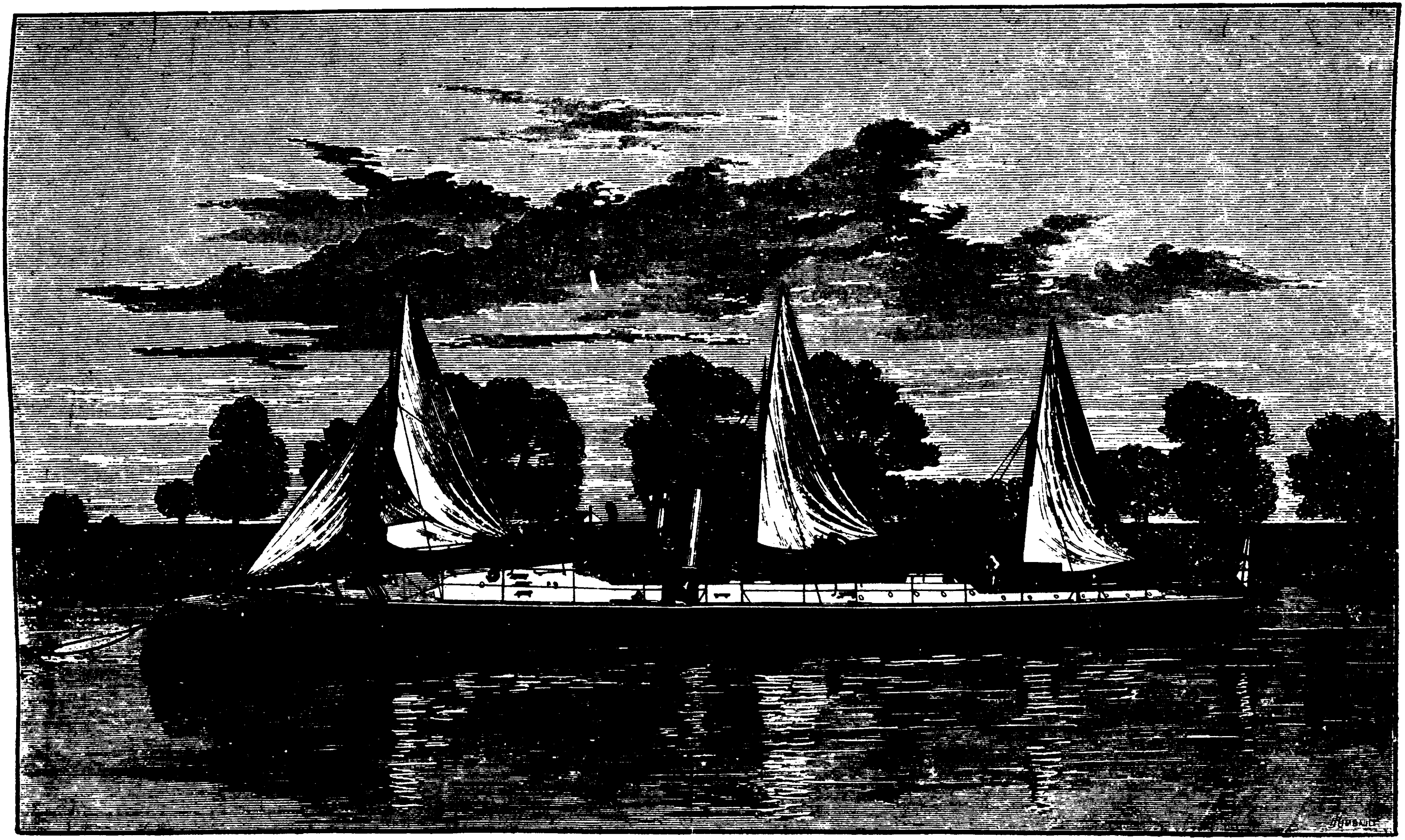
The condition which a steam steering gear for torpedo boat work has to fulfil, are somewhat trying, both weight and space having to be reduced to the lowest points. In order to meet the necessities of the case Mr. Donaldson has designed a gear expressly for such requirements. This is lighter and more compact than any yet introduced; indeed, so far as regards weight no other steam steering gear at present in use can be said to approach it. During the trials of the Russian boat the helm was put from hard-a-port to hard starboard by the steam gear in four seconds. Still smaller vessels than these first-class boats also now being supplied with the Donaldson gear. These are no doubt the smallest craft in the world steered by steam, and indeed we should think are likely to remain so. In the first-class boats the bow rudder, which has been described in these columns, is provided; when used it is worked in connexion with the main rudder, either when the steam or hand in the conning tower, or by hand by means of the wheel further aft, which may be seen in the engraving on page 21. In the forward compartment is a Brotherhood air-compressing pump, the engine and pump being self-contained on one baseplate. By this machine air is compressed to 1500 lb. to the square inch for the purposes of charging the torpedoes and ejecting them from the impulse tubes.

In the forward compartment is also the electric light machinery, consisting of a Brotherhood engine and an M. Gramme dynamo. A Mangin projector is used, by the aid of which objects are rendered visible at a distance of 1¼ to 1¾ miles.

The boiler is of the usual Thornycroft torpedo boat type, which has already been illustrated and described in these pages. The total heating surface is 1119 square feet, of which 1032 square feet are supplied by the tubes, and 87 square feet are contained in the firebox. The grate area is 30 square feet; the area of tube section is 4,74 square feet. It will be seen that in this small vessel, of only about 60 tons displacement, there



TORPEDO BOAT.



TORPEDO BOAT.

are no less than seven separate steam engines, and the main engines alone are guaranteed to indicate 12½ horse-power per ton of displacement on full power runs.

The propeller is one of Thorncroft's patent ; it has three blades, and is made of forged steel. The diameter is 5 ft. 7 in., and the pitch 5 ft. 8 in. As may be seen by the illustration on page 21, the end of one blade is considerably out of the water when the vessel is a trest, but even at a very slow speed the boat settles sufficiently by the stern to immerse the screw immediately on the engines being started ahead.

Both the Russian and the Danish (pe lo) boats are rigged in the manner shown in the engravings for the purpose of making long voyages ; they spread 1000 square feet of canvas. The three jib-headed fore and aft sails are hoisted by a sliding gunter. The masts can be readily unstepped and stowed away or left ashore. The armament of the Russian vessel consists of four 19 ft. Whitehead torpedoes, each 15 in, in diameter. Each of these carries a charge of 80 lb. of guncotton, and is capable of propelling itself for a distance of 1000 yards at a speed of from 18 to 19 knots per hour. Two single-barrelled 37 mm. Hotchkiss machine guns are placed on the gunwales on either side of the conning tower. The Danish boat carries one five-barrelled 37 mm. machine gun on the top of the conning tower.

There are three contract trials for all the first-class torpodo boats that Messrs. Thonycroft and Co. now built. A three hours' speed is run ; a 100-mile coal trial, and a six-knot speed trial. The following are particulars of the mean results of the Russian boat's trials.

Three hours' full power trial : Mean speed 18.97 knots ; boiler pressure 129.5 lb. ; vacuum 24.16 in. ; air pressure for blast in stokehold, 2.21 in. of water ; revolutions per minute 404. Six-knot full speed trial made on the measured mile in Long Reach. Mean speed of the six runs with and against tide at the rate of 19,506 knots per hour. Boiler pressure 130 lb. Revolutions 413 per minute, vacuum 27 in. Air pressure in stokehold 2.83 in. The slip of the screw was 17.13 per cent. of the speed. These and the following were tne official trials made by the Russian naval authorities, and were conducted accordingly to the Admiralty regulations.

In the one hundred-mile trial, made to test the coal consumption, run between the Nore and Purfleet, the vessel steamed 103.8 knots in 9 hours 20 min. One ton of Nixon's navigation was weighed on board for this run, and at the end a few pounds still remained. It may be said therefore that the vessel run 104 knots at eleven knots speed on a ton of coal. These boats are guaranteed to run a thousand miles at eleven knots on their own coal.

On all the above trials the regulation official weight of stores and gear was on board amounting in all to 16 tons 14 cwts. and 26 lbs. The includes coal, armament, ammunition, fresh water in tanks, crew, &c., bnt not the water in boiler.

The trials made to test the manœuvring powers of the boat resulted as follows :

Turning Circles at Trials Draught.

Speed.	Time in Making Circles.		Diameter of Circle.	Direction of Circle.	—
knots.	min.	sec.	fathons.		
18	1	20	84	To port	
	1	35	120	" starboard	both rudders
5	3	5	63	" starboard	
	2	40	55	" port	"
Astern ¾ speed	2	54	86	stern to starboard	
	7	30	358	stern to port.	"

◆

ELECTRICITY AND MAGNETISM.

BY PROF. W. GARNETT.

(Continued.)

As in the case of gravitation, the zero of electric potential (or level) may be arbitrarily selected. For our zero of level we selected the Trinity high-water mark, a purely arbitrary zero. For the practical zero of electric potential it is usual to take the potential of the earth, which for many purposes may be regarded as sensibly uniform. In purely theoretically treatises the zero of electric potential is that of a point *infinitely* distant from all electrified bodies. Taking the potential of the earth as the zero of electric potential it follows that:—

The potential of a point is the number of units of work (ergs) done by electric forces on the unit of (positive) electricity in passing from the point to the earth.

This is, of course, equal to the number of units of work done against electric forces by an agent bringing the unit of electricity from the earth to the point, for otherwise "*perpetual motion*" could be shown to be possible.

It is very important to observe that *level* is an *attribute of a point* in the neighbourhood of the earth whether there be any *matter* at the point or not. Thus, in our foot pound system of measurement, if we say that the level of a point is 1,000, we imply that 1,000 foot-pounds of work would be done on a pound in falling from the point to the sea level, but we *do not imply* that there is a pound or any other quantity of matter in the *immediate* neighbourhood of the point, whose situation with respect to the earth is alone sufficient to confer upon it the attribute of level.

Similarly, in the case of electricity, *potential* is an attribute of a point in space, and it does not follow that there is any electricity *at*, or *in the immediate vicinity of*, the point. Of course, there must be electricity somewhere in the neighbourhood, or there could be no electric potential, but the potential of a point is due to the electrification of all bodies which are sufficiently near to exert any electrical action at the point. Thus, a conductor may be at a high potential while its charge is zero, in consequence of other bodies positively electrified in its neighbourhood, and it may, and it often does happen, that a body is at a high *positive potential* and is, nevertheless, *negatively* charged. This will happen when its own negative charge is insufficient to neutralize the positive potential due to positively electrified bodies in the neighbourhood.

When work is done by electric force on the unit of [positive] electricity in passing from the earth to any point, work will have to be done *against* the electric forces in bringing the unit of electricity from the point to the earth, and the potential of the point [like the level of points below Trinity high-water mark] is reckoned as negative.

When a positively electrified body tends to go from A to B a negatively electrified body will tend to go from B to A, so that, while positively electrified bodies tend to go from places of high to places of low potential, negatively electrified bodies tend to go in the opposite direction.

It is convenient to employ the term *electric field* for any portion of space in which electric forces act.

If a body which is a non-conductor [or insulator] be placed in an electric field, so that some points of the body are at places where the potential is higher than at other points, [positive] electricity will tend to pass from the places of higher to those of lower potential, and this being resisted by the insulator stresses will be exerted on the substance of the insulator itself, which will thus be thrown into a state of strain. Thus, any non-nonductor, or dielectric, placed in an electric field, will experience a state of strain, resisted by the elasticity of the substance, and it is to this state of elastic strain of the dieletric that the *energy* of an electrified system is due. Sometimes the electric stresses exceed the elastic limits of the substance, and discharge takes place, which may be of a disruptive character, and causes the fracture of the dielectric.

If a conductor be placed in an electric field, positive electricity will flow from places of high, to places of low potential, causing the latter to become electrified positively, and therefore raising their potential, while the former becomes negatively electrified with a consequent lowering of potential. This action will go on until the potential at every point of the conductor is the same, and the distribution of potential throughout the field, as well as in the conductor itself, will, in general, be changed. This action is known as electric *induction.*

If a body be charged with positive electricity, and there be no other charged body in the neighbourhood, the body will thereby be raised to a positive potential, depending on the size and shape of the body, and the amount and distribution of its charge; for a unit of positive electricity in the neighbourhood of the body will be repelled by it, and work will therefore be done upon it as it goes away to the earth.

Similarly, a body charged with negative electricity and removed from the influence of all other electrified bodies will have a negative potential, for there will be a tendency for positive electricity to come from the earth to the body in virtue of the attraction of its negative charge.

But when a number of bodies are near together some charged positively and some negatively, the potential of any one of them will not depend on its own charge only, but in part on the charges of all the others, and thus it may happen, as indicated above, that a body with a negative charge may have a positive potential, and a body with a positive charge may have a negative potential.

Any conductor in communication with the earth must be at potential zero if there is electric equilibrium; for if its potential were above that of the earth, electricity would flow from the conductor to the earth until equality of potential was produced, while electricity would flow in the opposite direction if the potential of the conductor were below that of the earth.

Thus, a conductor in communication with the earth, and placed near to a positively electrified body, will itself be electrified negatively in order that the potential due to its own negative charge may neutralize the positive potential due to the charge upon the positively electrified body, and thus reduce the potentiel of the conductor to zero. Similarly, a conductor in communication with the earth, and placed near a negatively electrified body, will itself be electrified positively.

In connection with every electrified surface a series of *equipotential* (or level) surfaces may be drawn such that the work done on the unit of electricity in passing from any point in one surface to any point in the next in order is equal to one *erg.* Such a set of surfaces would be analogous to the set of level surfaces described above, and as in the case of gravitation, the *electric intensity* at at any point will be inversely proportional to the perpendicular distance between successive equipotential surfaces in the neighbourhood of the point.

DEF. The electric intensity at any point is the force which would act on the unit of electricity placed at that point.

Electric intensity is frequently called electromotive force *at* a point. Maxwell called it electric intensity in analogy with magnetic *intensity* and the *intensith* of gravitation. Instruments intended to *detect* differences of potential are called *eleclroscopes.* Instruments designed for the *measurement* of differences of potential are called *electrometers.*

It should be borne in mind that electroscopes and electrometers do not serve primarily to detect or measure *charges* of electricity, but simply the difference between the *potentials* of two points connected with each instrument, and called its electrodes, and hence of conductors in communication with the electrodes.

The gold-leaf electroscope consists essentially of two gold leaves suspended from a brass plate or knob by means of a brass rod, and protected from currents of air by a bell glass, through the neck of which the brass rod passes. The gold leaves should be surrounded by a wirs-gauze cage placed within the bell jar, and having a wire attached to it which passes out through the stand of the instrument. The brass plate or knob then forms one electrade, and the wire attached to the gauze cylinder the other. If no gauze cylinder is employed, the walls and other objects in the room take its place.

◆

MOVEMENTS OF THE EARTH.—(*Nature.*)

(*For illustrations see pages* 25, 28 *and* 29.)

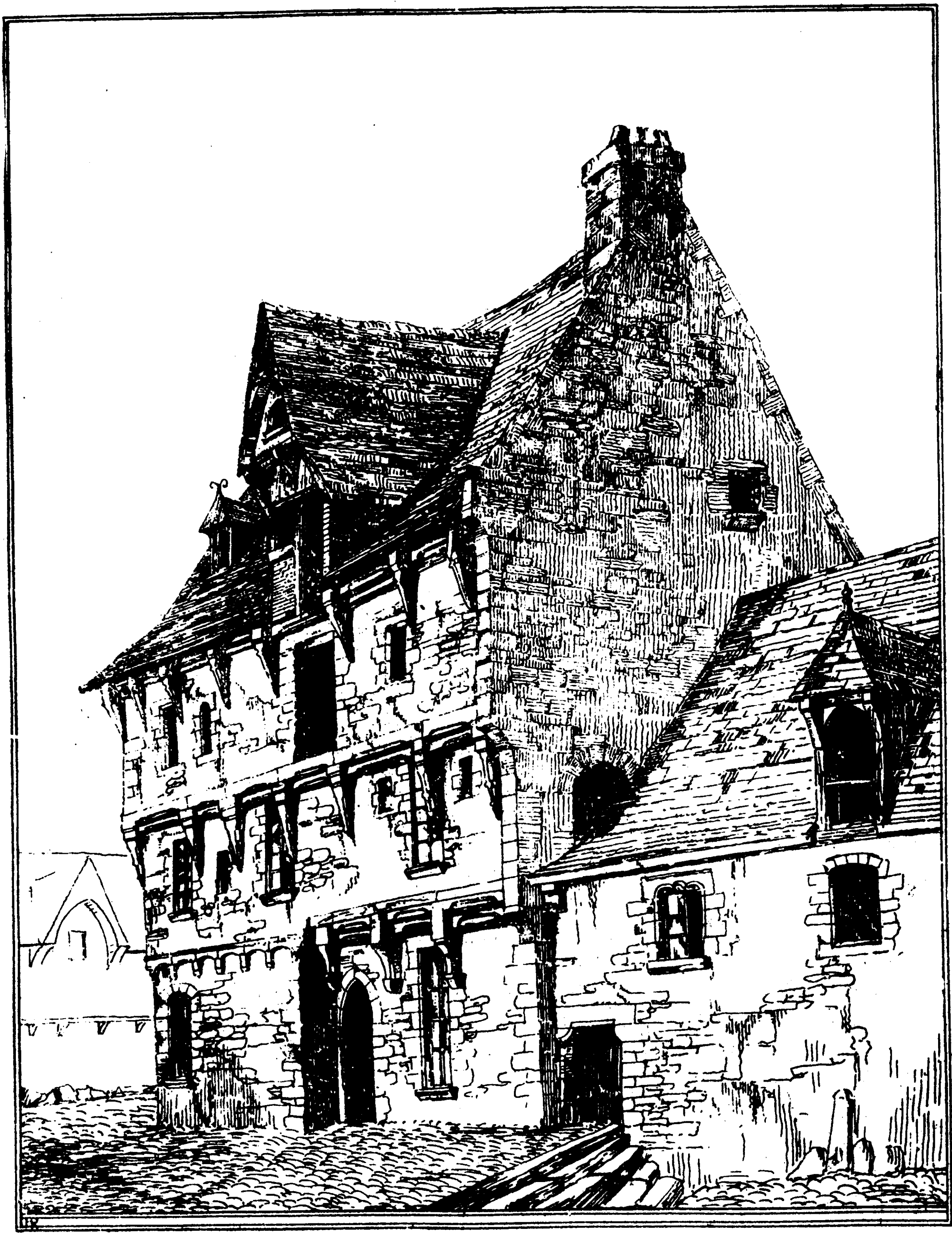
It will perhaps be convenient at this stage to compare the fineness of the division of time given by a clock of this description with the fineness of the division of the second of arc we have already discussed. There is, however, a little difficulty about this, because at present there seems to be no special reason why any particular unit of tine should be selected. Ordinarily a day is divided into twenty-four hours, each of these twenty-four hours is subdivided into sixty minutes, these again being each divided into as many seconds. The origin of this division of time will be seen later on; for the present let the fact remain that it is so.

Now a modern clock beats practically true seconds, and astronomers after a little practice gain the power of mentally breaking that second up into ten divisions, each of which is of course one-tenth of a second, so that we can say that a day may be divided into 864,000 parts, and in this way institute a comparison of the fineness of the division of time with those minute measurements of angular space with which we so recently dealt.

It is a familiar fact that the length of a pendulum which vibrates seconds is some thirty-nine inches, and it is easy to understand that there are many conditions in which a clock of this kind, with its pendulum of more than a yard long, cannot be used. Not only indeed is there this inconvenient length of the pendulum, but it is necessary that the clock to which it belongs should be rigidly fixed in an upright position. The question therefore arises, is this clock which deals out seconds of such accuracy the only piece of mechanism that can record and divide our time, or is any other time-measuring instrument avaiable? Fig. 21 shows part of such an instrument, known as the Chronometer, in which, whilst the principles necessary to be followed in the construction of the clock have been adhered to, the pendulum has been dispensed with, and the perfect stability and verticality of position so important to the clock, are here unnecessary.

In this instrument the pallets of the dead-beat escapement have been replaced by a detent, D. Let us consider the action. The escape-wheel, S, is advancing in the direction of the hands of a clock. One of its teeth meets the detent, and the wheel is locked. Then what happens is this: when the balance-wheel, P_1, swings, the circle, P_2, centred on it shares its motion. This, it will be seen, is armed with a little projection.

We left the escape-wheel locked. Now assume that the balance-wheel is swinging in the direction of the arrow. It carries the small circle with it, and the piece, P_1, in its motion, coming into contact with the end of the spring, seen projecting beyond the arm of the detent, raises it and the detent so releasing the tooth of the escape-wheel. The slight retardation which the balance receives in consequence of this action is im-



AN OLD HOUSE AT DINAN, BRITTANY.

MOVEMENTS OF THE EARTH.

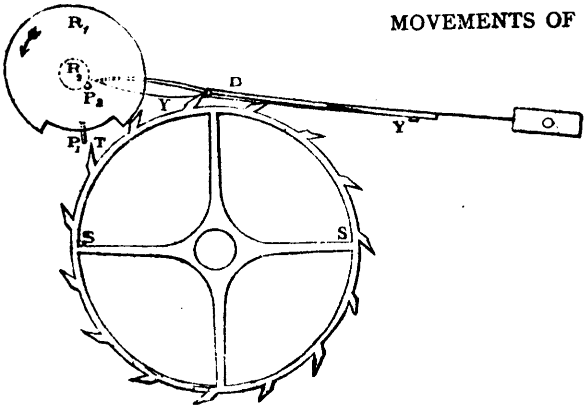


FIG. 21.—Chronometer Escapement.

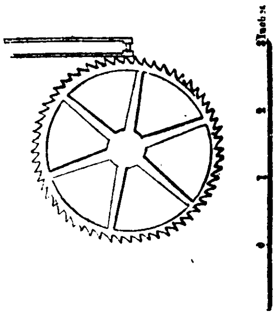


FIG. 22.—Electrical contact apparatus at back of clock.

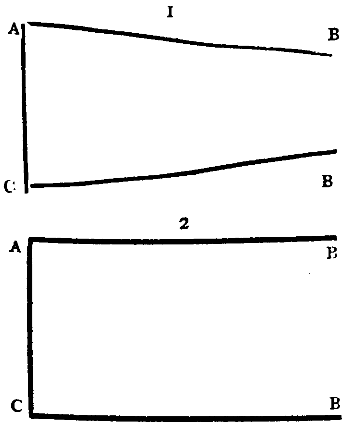


FIG. 23.—Model to illustrate parallax.

FIG. 24.—Diagram to show how the inclination of the horizon of London will change with the rotation of the earth.

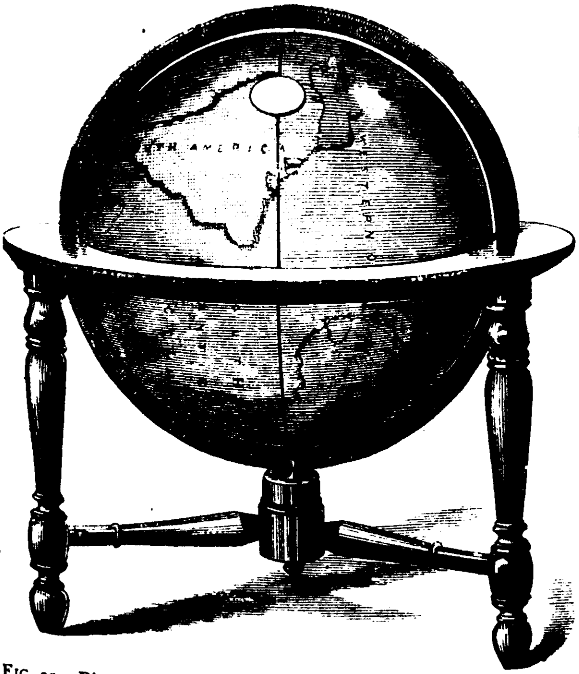


FIG. 25.—Diagram to show how the inclination of the horizon of a place on the equator changes in one direction only.

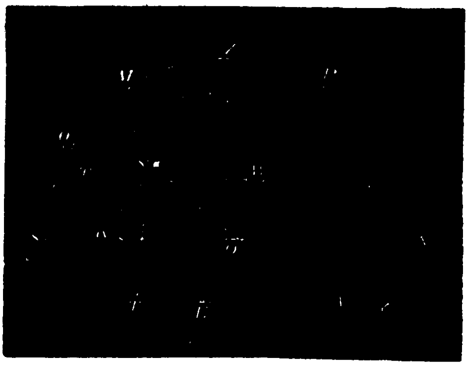


FIG. 26.—Observing condition at London.

mediately compensated. The moment the escape-wheel moves on again, one of its teeth meets the projection, P_1, and the balance-wheel receiving this fresh impulse goes on to complete its swing. Then it returns and swings in the opposite direction, this time without acting in any way on the detent. When the balance-wheel made its first swing and the point P_2, met the projecting end of the spring, the latter could then only bend from the end of the arm with which the detent is provided and against which the point B_2 forced it. But on the return swing the spring is found capable of bending from the more distant point of its attachment to the shank of the locking-piece. It is therefore easily pushed aside; there is no change in the position of the detent, nor is any resistance offered to the motion of the balance-wheel, which goes on to complete its swing. Then another tooth is caught, the escape-wheel is again locked, and again released by the lifting of the detent. So the action goes on, the teeth of the escape-wheel being constantly detained and as constantly released by the action of the point B_2. The balance wheel, it will be noted, receives its impulse only at every alternate swing, whereas in the clock the pendulum receives its impulse at each vibration.

Time then can be divided down to the 1-10th of a second, or as we expressed it, down to the 864,000th part of a day, not only by a clock, but also by this chronometer. Having obtained this 1-10th of a second by these instruments, the question arises as to whether it be possible to get a still finer division. It will be seen that a very much finer division than this can be obtained, the 1-100th part of a second being a measurable quantity; not that such a small fraction of time as this is ever necessary in astronomy, nor will it be until the present astronomical methods have ceased to exist. If it were possible to get all observations made by photography, then it would be worth while recording with such minuteness, because photography would always behave in the same way, whereas two observers never have the same idea as to the time of occurrence of any phenomena which they observe. Yet, although so great an accuracy as this is not attempted, it will be quite worth while to consider the means by which this exquisite fineness of the division of a second of time has been arrived at. We shall see that just in the same way as an appeal to mechanical principles resulted in an improvement in the construction of our clock, so this fineness in the division of time has been obtained by an appeal to the principles of electricity. Let it be assumed that the seconds pendulum of our clock swings with perfect accuracy and with absolute uniformity from second to second, in spite of changes of temperature and other perturbing influences; and having assumed this, let us see how electricity can be made to aid in the measurement of time. The instrument used is called a chronograph. It consists of a metal cylinder revolving by clock-work and covered with cloth, over which a piece of paper can be stretched. Below the cylinder and parallel with it is a track along which a frame carrying two electromagnetic markers or prickers is made to travel uniformly by the same clock that drives the cylinder. Wires connected with a battery lead from one of these magnets to a clock and from the other to a key, which can be depressed whenever an observation is made, and a current so sent to the magnet. The effect of this is to cause it instantaneously to attract its iron armature and cause the pricker with which it is connected to make a mark on the paper above.

The connection of the chronograph with the clock is as follows:—The bearing shown in the middle of the diagram (Fig. 22) is a continuation of the bearing on which the seconds hand of the clock is supported, and there is a little wheel which does its work quietly at the back of the clock in exactly the same way that the seconds hand does its work quietly in front of it. What that wheel does is this. Every time that each of its teeth—and there are sixty of them—comes to the top of the wheel it touches a little spring. That little spring then makes electrical contact, and a current is sent flowing through parts of the apparatus already described. Now the teeth in that wheel, being regularly disposed around its circumference, always succeed one another after exactly the same interval of time, and there is no difference or distinction from second to second, or from minute to minute. But suppose that before the clock is started one of these teeth is filed off, and so filed off that when the seconds hand points to o seconds, and the minute hand to a completed minute, this part of the wheel shall be at the top, and there shall be no electrical contact established, for the reason that the tooth of the wheel is not there to act on the spring. In that way it is easy to manage matters so that the beginning of each minute shall be distinguished from all the other fifty-nine seconds which make up the minute. Let the cylinder, covered with paper, revolve once in a minute. In that case, the electrical current will make a hole or a mark on that paper every second, and as matters are so arranged that the prickers shall be travelling along at the time that the dots are made upon the revolving paper they are thus made along a continuous spiral, and since we have supposed the cylinder to revolve once in a minute, the beginning of each minute will be in the same line along the spiral. Then, according to the length of the cylinder, a second of time will be obtained written in dots, sixty of them round the cylinder representing sixty seconds. Suppose now that a man with a perfect eye makes an observation, recording it by sending a current through the apparatus and making a dot on the paper. He will then have an opportunity of observing on the paper the precise relation of the dot which represents the time at which the observation was made to the other dots which represent the various seconds dotted out by the clock, and not only the exact distance of the observation prick from the nearest *second*, whether it be ½, or 1-10th, or 1-100th of the distance between that second and the next, but the omission of the record of the first second in the minute will give the relation that observation has to the nearest *minute*.

For the sake of simplicity the case of one observer making one observation has alone been considered; but if the work be properly arranged, then not only one electromagnet, but two or three, or four, may be at work upon the same cylinder at the same time, each making its record, and that is how such work is being done at the Greenwich Observatory.

This power of measuring and dividing time then having been obtained, we seem to have reached our subject, "The movements of the Earth." Yet even now there are one or two other matters which require to be discussed before we consider the movements themselves. The first of these is the important fact that the earth is spherical in its form. There have been many views held at different times as to the real shape of the earth, but the only view we need consider is that stated. In going down a river in a steamboat, or, better still, in standing upon the sea-shore at some place, such as Ramsgate, where there are cliffs, and where, consequently, one may get from the sea-level to some height above it, it is observed that when any ship disappears from our view by reason of its distance it seems to disappear as if it were passing over a gentle hill.

It does this in whatever direction it goes. This familiar fact is a clear proof that the earth is a sphere, and is so obvious that it may seem unnecessary to mention it, but it was well to do so for a reason which will appear shortly. Besides this argument in favour of the spherical shape of the earth there is the argument from analogy: the moon is round, the sun is round, all the known planets are round. The stars are so infinitely removed from us that it cannot be determined whether they also are spherical, but doubtless they are as round as the earth. This point of the tremendous distance of the stars is an important one to bear in mind. Their distance cannot be conveniently stated by thousands, nor even by millions of miles, it is something far greater than that. It may be asked why it is that such a statement can be thus positively made. For this reason: the stars have been observed now for many ages, and the historical records of ancient times show that the chief constellations, the chief clusters of stars visible in the heavens now, were seen then. In the Book of Job, for instance, there is a reference to the well-known constellation of Orion, and there is very little doubt that for thousands and thousands of years that constellation has preserved the familiar appearance of its main features, the constellation called Charles's Wain, or the Great Bear, was also known to the ancients. If the stars were very near to the earth this could not be. If they were close to us the smallest motion either of earth or star would at once change their apparent position, and would prevent this fixity of appearance, and the skies would be filled, not with the constellations with which we are so familiar, but with new and ever-changing clusters of stars. This constancy of the constellations, not only from century to century, but from era to era, clearly proves then that the stars of which they are made up must be at an infinite distance from the earth.

Let us consider the question of distance a little further. If two pieces of wood (see Fig. 23) joined together by a cross-piece be taken, a moment's thought will make it obvious that the angles which A B and C B make with the cross-piece A C, will vary with the distance of the body, which can be seen first by looking along A B and then by looking along C B. If these pointers be directed to a very near object in the room, they must be greatly inclined (as in 1). If something more distant be taken, there is less inclination, and if it were possible to sight St. Paul's by looking first along A B and then along C B, there would be still less. And if something at a still greater distance were sigted, say St. Giles's at Edinburgh, the inclination of A B and C B would be still smaller than it was in the case of St. Pauls, because St. Giles's is at a much greater distance. It follows then that in sighting an object so infinitely removed from us as a star, the light from it will be in a condition of parallelism, and A B and C B consequently be placed quite parallel in viewing it (see 2). That is another reason for saying that the stars are at this infinite distance from the earth. Why it is so important to insist on this point will appear very clearly by and bye.

Now suppose that in the centre of this lecture-theatre a little globe were hung to represent the earth, the walls of the theatre and the people in it representing the heavens surrounding the earth. Now in such a case it is clear that the appearances presented would be the same whether the heavens moved round the earth or the earth itself were endowed with motion. Let us, without making the assertion, assume that the earth does move. It is perfectly obvious, since the apparent motions of the heavens are so regular, that if that be so she must move with wonderful constancy and regularity; she does not first move in one direction and at one inclination, and then at another; that would be very serious.

If she rotates she must rotate round some imaginary line called an axis. This introduces an important consideration because, whether the earth itself rotates on an axis or the heavens move round the earth—and in the latter case the heavens must also move round an axis—in either case the motion must be an equable one; so that if the matter is thus limited to a constant axial rotation or a constant revolution, as it would be called in the case of the stars, several things will happen. Let us take the former case, in which the earth itself moves. Then the motion of the surface of the earth will be least at those points which are nearest the ends of the axis on which it turns. Take the case of an observer at such a point, he will be carried a very little distance round during each rotation; similarly, if the stars move, a star near the ends of the axis on which the stars move will be carried a very little distance round during each revolution of the celestial sphere.

Change the position of the man on the earth from the pole to the equator. Then he will be carried a very considerable distance round in each rotation of the earth: similarly with the stars; if they move, a star in the celestial equator will be carried round a very great distance during a revolution. That is the first point. Another point is that if we assume the earth to rotate we must carefully consider the varying conditions which are brought about by the different positions of an inhabitant of the earth under these circumstances. For instance take the case of a man at the equator,, he looks at things from an equatorial point of view, and in the rotation of the earth he plunges straight up and straight down. Similarly, if the stars' daily revolution belongs not to the earth but to the stars, to an observer at the equator of the earth they would appear to move straight up and straight down; and now in dealing with this question and endeavouring to ascertain whether it be the earth or the stars which move it is most necessary to consider the relation of the movements or apparent movements of the stars to the place from which they are observed, and in so doing it is found that there is an immense difference between the conditions which obtain at the poles and at the equator with reference to the phenomena which are observable in each case.

Let us take a globe to represent the earth, and let London be considered the central point for our observations. Now at all places on the earth, in whatever direction we look, we see an apparent meeting of earth and sky; and supposing our observation to be made on an extended plain or at sea, the surface of the earth or sea may for simplicity's sake be considered as a plane bounded by the circle where the earth and sky seem to meet. This is known as the circle of the horizon. To represent this a piece of paper may be put over London on our globe (see Fig. 24), and London may be brought to the top. When that has been done, remembering that the stars are placed at so infinite a distance, the horizon which cuts the centre of the earth, and which is called the true horizon, may be considered as being practically the same thing as the small sensible horizon of London, represented by our piece of paper, when at the top of the globe, because the two planes will be parallel. For, whether a star be seen from the equator or from London, owing to its tremendous distance it will appear to occupy the same position in space. Now let the globe be made to rotate, then the inclination of the plane of the horizon of any place, of our horizon of London for instance, is continually changing during the rotation (Fig. 24). An exception, however, must be made with regard to the poles of the earth. At these two points the inclination will be constant during the whole of the rotation.

If now a point on the equator be brought to the top of the globe, it will be seen, as the globe is rotated, that the observers's horizon rapidly comes at right angles to its first position (see Fig. 25). This will show that the conditions of observation at different parts of the earth's surface are very different, and this whether it be the earth or the stars which move.

Let us now consider with a little greater detail the conditions which prevail in the latitude of London. Let London be again brought to the top of the globe. Let O (Fig. 26) represent an observer in the middle of the horizon, S W N E. Let Z be the zenith, which, of course, would be reached by a line starting from the centre of the earth, and passing straight up through the middle of the place of observation. S' is a star, and we want to define its position. How can this be done? Imagine first a line drawn from the observer to the zenith. Imagine next another line going from the observer to the star, or, what is the same thing, from the centre of the earth to the star. Then the angle inclosed by these two lines will give us the angular distance of that star from the zenith, or similarly we may take the angle included between imaginary line joining observer with horizon and star, and thus obtain the star's altitude.

Again its position may be stated not only with regard to the zenith and to the horizon, but to some other point, say the north point. In that case a line or plane, Z E W, is imagined passing from the zenith through the observer, and the distance between E and N will give the star's angular distance from the north point of the horizon. Again, suppose it be desired to define the star's position with reference, not to the zenith, but with reference to the pole of the heavens, that point where the earth's axis if prolonged into space would cut the skies. In that case since P in our diagram marks the position of the pole, a line P S' will give what is called the polar distance of the star; and lastly, if the angular distance of the star from the equator of the heavens be required, since the prolongation of P S' would cut the equator, the distance from S' to the point of intersection will give the angular distance of the star from the equator; in other words its declination.

We have taken London, but of course each place on the earth has its sphere of observation with its zenith and the north, east, south, and west points. With regard to the axes of the earth and the heavens, they both possess north and south points, and in the heavens as in the earth, the equator lies midway between them.

The several ideas concerning the movements of the earth which were introduced in the last lecture will in the present one have to be dealt with in greater detail.

It was then agreed that if the whole expanse of the heavens were to travel with a perfectly equable motion in one direction, such a motion for instance as would result from all the stars being fixed to a solid transparent substance like those cystal spheres that the ancients really believed to exist; or if, on the other hand, the earth herself, instead of being free to turn as she listed with varying velocity in any direction, really went with perfect constancy in the direction opposite to the apparent motion of the stars, the visible effects would be the same in both cases, so that an appeal in our eyes would not suffice to enable us to say whether the earth moved or whether she remained at rest while the celestial sphere revolved around her.

Under these circumstances what is to be done? It has been seen how, both with regard to the measurement of space and the measurement of time for astronomical purpose, those interested in the physics and beauties of the various classes of celestial bodies outside our own earth have picked and chosen now one bit of physical science and now another to help them in their inquiries; and with regard to this very important question, "Does the earth move or is she at rest?" we shall see how very beautifuly and perfectly the question has been answered by the application of certain mechanical principles.

The majority of people, I suppose, have some acquaintance, however slight, with machinery—with steam engines for instance; and it is a familiar fact how very important a part is played in the steam-engine by the flywheel. Why should that be? Why should this flywheel be so important that it is only quite recently that mechanicians have learned to do without it? For this reason: if a mass of matter such as a flywheel is once made to revolve, it will retain that motion for a long time, resisting any tendency to an increase or decrease of its velocity. It is in consequence of this property which the revolving flywheel possesses that an engineer is able to get over the dead points in his engine, whilst it also acts in preventing the engine making too sudden a start. In addition to this, when we have a mass of matter in the condition of the revolving flywheel it has some very peculiar qualities, only observed when such a mass of matter is in motion. If, then, we have a wheel so arranged that a very rapid rotation is being imparted to it, it does not behave as it would when at rest. These properties possessed by a rotating body can be well shown by an instrument known as the gyroscope, of which we shall speak more fully later on. It consists essentially of a disk to which a very rapid rotation can be imparted by a train of wheels or by other means. If the disk be set rotating, it is found to possess those curious qualities of which I have spoken. If whilst rotating at a high velocity it be placed in the position shown in Fig. 27, it will not fall, but will take on a movement of revolution round the stand.

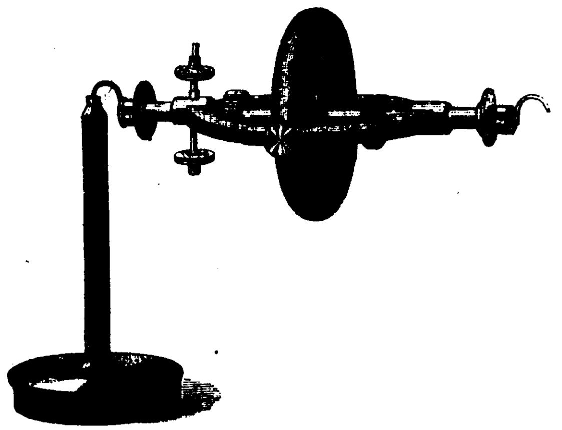


Fig. 27.—Rapidly rotating wheel supported at one end of its axis.

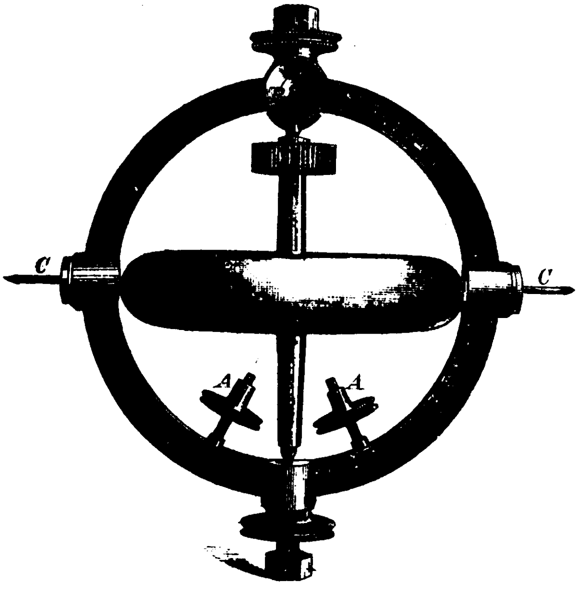


Fig. 28.—Rotating disk of gyroscope. C C, knife edges; A A, B B, adjusting weights.

From considerations suggested by this and other similar experiments, Foucault pointed out that it might be demonstrated whether the earth moved or whether she remained at rest. It struck him that the problem should be attacked somewhat in this manner:—

Suppose the earth to be at rest, and that either at the north or south pole a pendulum, suspended so that its point of support had as little connection with the earth as possible—so that it should, in fact, like the rotating flywheel, be independent of external influences, were set vibrating. Then an observer at the north or south pole would note that the swinging pendulum (the earth being considered as at rest) always had the same relation to the objects on his horizon. But, said Foucault, suppose that the earth does move. Then the swing of such a pendulum would not always be the same with regard to the places on the observer's horizon. Let the earth be represented by a globe. Suppose it to rotate from west to east. Place it with the north pole uppermost, and set the pendulum, whose point of support is disconnected from the rotating earth, vibrating. Then the pendulum will appear to travel from left to right as the earth rotates from right to left beneath it. Now suppose the pendulum to be suspended in the same way at the south pole, right and left now being changed. The earth of course rotates in the same direction as before, but the pendulum now appears to change the plane of its swing from right to left. At the equator the earth simply rotates straight up and straight down beneath the swinging pendulum.

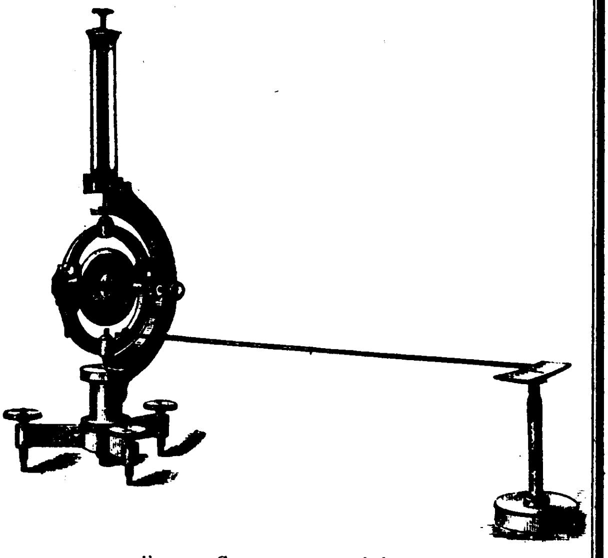


Fig. 29.—Gyroscope; general view.

From these considerations it became evident to Foucault that, if there were any possibility of demonstrating the movement of the earth by means of the pendulum, the demonstration would take this form. Provided it were possible to swing a pendulum so that it should be as free as possible from any influence due to the rotation of the earth, and take that pendulum to the north pole, it would appear to make a complete swing round the earth in exactly the same time that it really takes the earth to make a complete rotation beneath it. At the south pole exactly the same thing would happen except that the surface of the earth would appear to move in the opposite direction to what it did at the north pole. Now it will be perfectly clear that if we thus get a pendulum appearing to swing one way on account of the true motion of the earth at the north pole and in the opposite direction on account of the true motion of the earth at the south pole; at the equator, as we found in dealing with our model earth and model pendulum, it will not change the plane of swing either way, that is to say, the time taken by a pendulum to make a complete swing will be the smallest possible at the poles, whilst at the equator it will be infinite.

At all places, therefore, between either pole and the equator the period of swing will be different, and the time taken to make a complete swing will increase or decrease as the equator is approached or receded from. So much for theoretical considerations. Can they be put to the test of experiment, and an answer obtained from nature herself? The fact is that this idea of Foucault's is so beautifully simple that anybody can make the experiment providing he has the means of using a very long pendulum. This pendulum must be rigidly, but at the same time very independently, supported.

Beneath the pendulum, in contact with the earth, and therefore showing any movement of rotation which the latter may possess, is a board, on the centre of which the pendulum nearly rests. From the central point of this board lines are described showing so many degrees from the central line over which the pendulum bob swings. These preliminaries being arranged, let the pendulum be started. This is done by drawing it out of the vertical and tying it by a thread which is burnt when it is desired to start the experiment.

Then, in consequence of that quality the existence of which was revealed to us by the rotating disk and which is possessed by this vibrating pendulum, and in consequence of the precautions which have been taken to prevent its swing being interfered with by the motion of the earth or other perturbing influences, it should be found, if Foucault's assumption be correct, that the earth is moving beneath the pendulum. And if all the conditions of the experiment have been complied with it is found that the pendulum moves over the scale as the earth rotates beneath it. That then is one demonstration of the existence of the earth's rotation.

The question now arises whether there be any other method of determining the same thing. There is, but in answering the question in the affirmative it must be said that this second method is neither so simple nor so satisfactory as the first.

We owe it also to the genius of this same man, Foucault. It depends upon the same principles and is connected with the same series of facts as the other. But before proceeding to discuss this second experiment it will be well to consider these two tables, which have been taken from Galbraith and Haughton's "Astronomy," because they show not only what the swinging pendulum should do if it behaves properly, but also what the gyroscope, the instrument used in the second experiment, should do if it behaves properly.

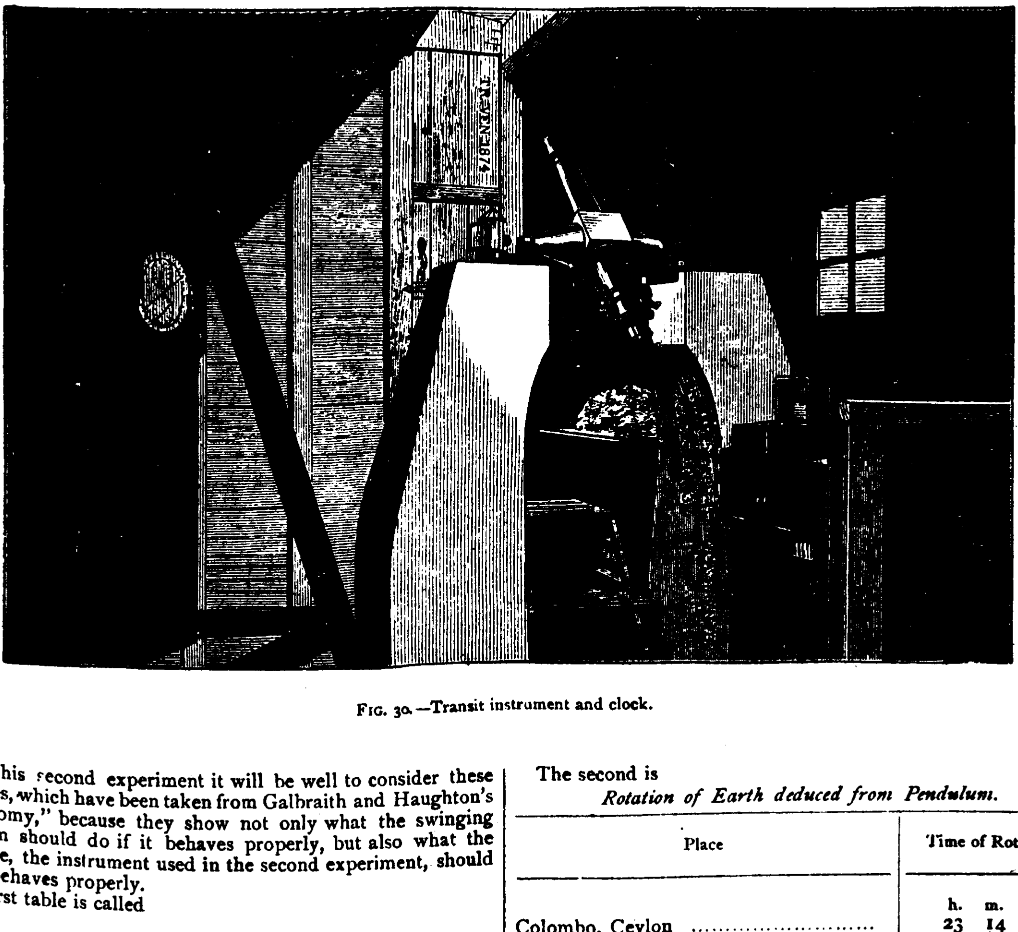


FIG. 30.—Transit instrument and clock.

The first table is called

Hourly Motion of Pendulum Plane.

Place	North Lat.	Observed motion per hour	Calculated motion per hour	Observer
Ceylon	6° 56′	1°·870	1°·815	Schaw and Lamprey.
New York	40 44	9·733	9·814	Loomis.
Providence, R.I..	40 49½	9·955	9·833	Carswell and Norton.
New Haven, Ct...	41 18½	9·970	9·929	
Geneva...............	46 12	10·522	10·856	Dufour and Wartman.
Paris..................	48 50	11·500	11·323	Foucault.
Bristol...............	51 27	11·788	11·763	Bunt.
Dublin	53 20	11·915	12·065	Galbraith and Houghton.
Aberdeen...........	57 9	12·700	12·636	Gerard.

The second is

Rotation of Earth deduced from Pendulum.

Place	Time of Rotation		
	h.	m.	s.
Colombo, Ceylon	23	14	20
New York...	24	8	9
Providence, R.I..............................	23	38	29
New Haven, Ct.	23	50	7
Geneva	24	41	39
Paris	23	33	57
Bristol	23	53	2
Dublin	24	14	7
Aberdeen	23	48	49
Mean value..................	23	53	9

The pendulum plane is of course the plane in which the pendulum swings. The first column in Table 1 gives the place where the pendulum was set swinging, the second the latitude, the third the observed motion per hour, and the fourth the calculated motion. The table has been so drawn up that it begins with places nearest the earth's equator and passes gradually to others further away, going from Ceylon at 6° N. lat. to New Yerk at 40° N. lat,, New Haven at 41°, and ending with Aberdeen at 57°, At the first-named place it will be seen that the pendulum swings through less than 2° per hour, whilst at Aberdeen it swings through nearly 13°, which is an approximation, at least, to the statement I have made, that, since the rotation of the pendulum plane will be most rapid at either pole, the further from the equator we swing it the greater will the number of degrees passed over per hour.

J. NORMAN HOCKYER.

(To be continued.)

GALTON'S INQUIRIES INTO HUMAN FACULTY AND ITS DEVELOPMENT.

BY R. W. BOODLE.

The significance of Mr. Galton's last work upon Human Development will be understood by all who have watched the changes of public opinion upon the evolution theory. Victorious from the first in the scientific world, for few names of any eminence were bold enough to oppose it, it gradually won its way among the great mass of intelligent readers, with whom the practical application of scientific theories rests: and its victory almost immediately dealt the last blow to the fables and fancies, upon which pre-scientific ages had constructed their religious and social ideas, and which had lingered between life and death ever since the days of Gibbon and Hume. Thus though the evolution theory was by no means in itself a theory of negation (for it told a tale of the ascent of man from lower organisms, a conception as ennobling as the story of his degredation which it displaced), it was possible for the supporters of the old faith to confuse it with its negative side, to insist that this negative side was its important side, to deny that it gave any grounds upon which a religion and morality might be constructed, in short to identify evolution with agnosticism.

The importance of such works as Spencer's "Data of Ethics" and George Eliot's "Theophrastus Such" and the present volume lies in their expounding, each in a different way, the positive side of the new faith, and in their thus being the best answer to the charge, so constantly brought against modern science, of being merely agnostic and destructive. "The chief result of these Inquiries," writes our author in the summary with which he concludes his book, "has been to elicit the religious significance of the doctrine of evolution. It suggests an alteration in our mental altitude, and imposes a new moral duty. The new mental altitude is one of a greater sense of moral free dom, responsibility and opportunity; the new duty which is supposed to be exercised concurrently with, and not in opposition to the ones upon which the social fabric depends, is an endeavour to further evolution, especially that of the human race."

The new mental attitude that Mr. Galton desires to emphasize will be best understood from the following passage: "While recognising the awful mystery of conscious existence and the inscrutable background of evolution, we find that as the foremost outcome of many and long birth-throes, intelligent and kindly man finds himself in being. He knows how petty he is, but he also perceives that he stands here on this particular earth, at this particular time, as the heir of untold ages and in the van of circumstance. He ought therefore, I think, to be less diffident than he is usually instructed to be, and to rise to the conception that he has a considerable function to perform in the order of events, and that his exertions are needed. It seems to me that he should look upon himself more as a free-man, with power of shaping the course of future humanity, and that he should look upon himself less as the subject of a despotic government." Man's duty in the world follows from his mental attitude, viz., "to awake to a fuller knowledge of his relatively great position, and begin to assume a deliberate part in furthering the great work of evolution. He may infer the course it is bound to pursue, from his observation of that which it has already followed, and he might devote his modicum of power, intelligence, and kindly feeling to render its future progress less slow and painful. Man has already furthered evolution very considerably, half unconsciously, and for his own personal advantages, but he has not yet risen to the conviction that it is his religious duty to do so deliberately and systematically."

Such are the results of the work before us, which is occupied in detail with the attempt to found the science of "Eugenics," or the science of improving the human stock. With this view, Mr. Galton shows by a number of separate lines of investigation, such as the history of the lives of twins and of the races of domesticated animals, that nature is superior to nurture; and that if we wish to better the human stock through voluntary effort, we must study and improve ancestral influences. To this end the formation of public sentiment tending to discourage marriage where its results would be bad from the sanitary stand-point should be fostered. Of course, there is a large element of visionariness, in Mr. Galton's theories just as in the Republic of Plato, and in other Utopias that have been given to the world at different epochs of speculation. But ideals like these show us the objects at which we should aim, they bring vividly before us the corollary of our accepted scientific theories; and Mr. Galton's volume will not be without its value if it leads people to think seriously about the future of civilization when evolution is no longer an unrecognized process, but a law of life that has forced itself upon the consciousness of the world.

Scientific Notes.

AN ELECTRIC GUN.—At a recent lecture by Colonel Fosbery at the Royal United Service Institution, he exhibited a new gun bought from Liège, which is fired solely by electricity. The lock mechanism is dispensed with entirely, the firing apparatus being a small accumulator, which can be placed either in the stock of the gun or in the vest pocket of the gunner. This accumulator, the construction of which was not described, is said to be capable of firing 2,000 rounds. It is probably a chloride of silver cell.

CURE FOR THE COTTON PLANT WORM.—Experiments have been made in Georgia to save cotton from the ravages of the worms which have hitherto done so much damage to the plant. London purple was the poison used to kill the worms. This was dissolved in water, half a pound to 50 gallons, and was sprinkled over the cotton by means of a pump. The first application succeeded in driving away the worms. A stronger solution was then thrown upon the plant, and this caused the death of the eating worms. Where a solution of one pound in 60 gallons of water was used it was found that where it collected in drops it injured the leaves. The proper strength is in a solution of one pound of the poison in from 80 to 90 gallons of water.

A New Explosive.—A French chemist named M. Eugène Turpin has, it is stated, discovered an explosive of tremendous power which he terms "Panclastite," and for which he claims a maximum of force with a minimum of risk, the two materials of which it is composed being innocuous until mixed. M. Turpin recently made experiments at Chatham before the military authorities, and they pronounced the explosive to be very satisfactory.

Railways in the Caspian region — General Chernaieff, the governor of Turkestan, has recently gone over the route from Kungrad to the Caspian in person, and finds it well suited for vehicles. Even a railway between the delta of the Oxus and the Gulf Mertvi-kuttuk has been talked of. The connection of Tiflis and Baku by rail is completed, and the journey can now be made between the Black and Caspian seas in thirty hours without change.

Limit of Hearing.—This subject has recently been studied by M. E. Panchon, and his results have been communicated to the French Academy of Sciences. The notes were produced by a powerful siren of the kind invented by Cagniard-Latour, and actuated by steam. The highest audible notes produced in this way had 72,000 vibrations per minute. M. Panchon has also vibrated metal stems fixed at one end, and rubbed with cloth powdered with colophane. In diminishing the length of the stem the sharpness of the note is increased. Curiously enough he finds that the length of stem giving the limiting sound is independent of its diameter; and for steel, copper, and silver the lengths are in ratio to the respective velocities of sound in these metals—that is to say, as 1,000 for copper, 1,002 for steel, and 0.995 for silver. Colophane appears to be the best rubbing substance. When the acute sound ceases to be heard, the sensitive flame of a gas jet is still affected by it.

While upon the subject, we may mention that Mr. Francis Galton has recently invented a "hydrogen whistle," which enables him to obtain notes far above the upper limit of human hearing, its object being to test the hearing powers of insects, which, as is now known, have very very acute ears. The number of vibrations produced by a gas in a whistle is universally proportional to the density of the gas, and as hydrogen is thirteen times lighter than air the sounds produced by it in a given whistle are thirteen times shriller—that is to say, the pitch is thirteen times higher. Mr. Galton has made a whistle 0·14 inch long and 0·04 inch in diameter, which with hydrogen gas gives a sound of 312,000 vibrations per second. The whistle is fitted with a piston at its base to regulate its length, and it is probable that still higher notes can be obtained with a shorter length.

Casting Electrotype Plates.—There are several ways of making wooden blocks and mounting electrotype plates upon them, but none of the methods prevent them from swelling or warping when the "forms" are washed, thereby injuring or rendering them altogether useless. An invention by which all danger of such damage is prevented has been devised by C. Baecler, of Portland, Ore, U.S.A. When an electrotype is to be made, the matrix is put in the casting-box in the ordinary manner, and the core of wood is set in place by supports, two of which are in the lower end of the box and one at the upper end. When an electrotype plate is already cast and is ready to be mounted on a block, another mode of working is followed. The electrotype is "backed" in the usual manner and straightened or planed. Then, laying the face against the bottom of the casting-box, the core is placed on the back and strips of tin foil put around the edges, and the strips are fused when the metal is poured. Then some pieces of fusible metal, just thick enough to fill the space between the core and the lid of the casting-box, are placed on the back of the core, and the enclosing side and end bars are set as in the first case, when it is ready to receive the molten metal. If the electrotype plates are old or long cast or corroded in any way, the edges around the outside of the core where they are to fuse with the new flow of metal are usually scraped bright and the tin foil placed in the joint as before. If the metals to be joined are similar in alloy, it is not always necessary to use tin foil; but any of the common acid fluxes may be employed, and the result is the same—a good joint. A block made in this way is waterproof, is not affected by the air in any manner, and has other valuable features. They also require less metal than those of partially enclosed cores with ends or sides open to dampness; and in the case of electrotype plates previously made ready for mounting, the inclosing metal may be of a commoner and cheaper sort, and barely thick enough to flow and cover the cores, greatly reducing the expense. By this method even the largest plates can be mounted and used with safety and durability, a feature not obtained by any other method.

◆

SIR WILLIAM THOMSON'S QUADRANT ELECTROMETER.—(*Engineering.*)

The quadrant electrometer is one of Sir William Thomson's many and beautiful contributions to electrical science. This instrument illustrated under, is invaluable to the electrician, enabling him, as it does, to measure, with great precision, resistances and differences of potential, the insulation of condensers, and the capacity of submarine cables.

It derives its name from the four brass quadrants, which are so arranged around a common centre as to enclose a small cylindrical box-like space. The opposite quadrants are joined together by a fine wire, and the two pairs thus formed are separately connected with the electrodes of the instrument, Fig. 1. page 32. It is essential that the quadrants be placed symmetrically with respect to the needle. Three of them are movable along radial slots and adjustable by hand, whilst the fourth is susceptible of very fine adjustment by a micrometer screw, fixed on the main cover, Fig. 1.

The "needle," which is somewhat paddle shaped. is of thin sheet aluminium. It is freely movable about a vertical axis consisting of a stiff platinum wire. The upper part of this wire carries a short horizontal cross-piece to which are attached the two threads (unspun silk) of the bifilar suspension.

The needle is charged and kept at a high potential by being in permanent connexion with the inner coating of a large Leyden jar. This coating consists of strong sulphuric acid which, besides being an excellent conductor of electricity, has a remarkable affinity for water, so that the inner working parts of the electrometer are kept dry and well insulated. The outside coating of the jar is formed of strips of tinfoil, sparsely arranged in order that tne interior of the instrument may be seen.

The dielectric is the glass of the jar, which is of white flint, and carefully chosen as to quality and insulation.

A charge is given from (say) a small electrophorus to the acid by means of the charging rod which is seen in Fig. 2 projecting from the upper semi-cylindrical part of the electrometer, technically known as the "lantern." A stiff platinum wire is rigidly connected to the needle, and carries, at its lower extremity, a small weight of the same metal which dips into the sulphuric acid. In this way, the needle is always at the same potential as the inner coating of the jar; its oscillations are, moreover, partly checked by the resistance which the acid offers to the rotation of the terminal weight. The wire is protected against surrounding influences by a narrow metallic cylinder, called the "guard tube."

As the needle is completely enclosed by the quadrants, it is thereby screened against extraneous electrification and is, besides, kept in a constant field of electrical force. Hence the angular deflection of the needle will be constantly proportional to the difference of the potentials of the quadrants.

This deflection is measured by the displacement over a finely divided scale of the image af a narrow slit, through which rays from a lamp are admitted that are afterwards reflected from a mirror in rigid connexion with the needle. This mirror is a light disc of fine microscope glass, silvered and slightly concave. It is surrounded by a sort of brass hood to protect it against the influence of neighbouring electrified bodies.

It is easily seen that the sensitiveness of the electrometer varies with the potential of the needle. Hence measurements are comparable *inter se* only inasmuch as the potential is maintained constant. This condition is attained by means of the *replenisher*, which accessory is merely a small but ingeniously contrived induction machine. By twirling a milled head, Fig. 1, the potential of the jar may be raised or lowered according to the direction of rotation; and, as the increments or decrements are very small, a definite charge map be accurately reproduced. This is indicated by the *idiostatic gauge*.

This gauge is itself an attracted disc electrometer. It is known that the jar has reached its normal charge when the sighting hair lies evenly between two black dots, Fig. 2, which are made on a small white porcelain plate. Errors of parallax are avoided by viewing the air through a plano-convex lens, taking care to keep the line of sight perpendicular to the centre of the lens.

SIR WILLIAM THOMSON'S QUADRANT ELECTROMETER.

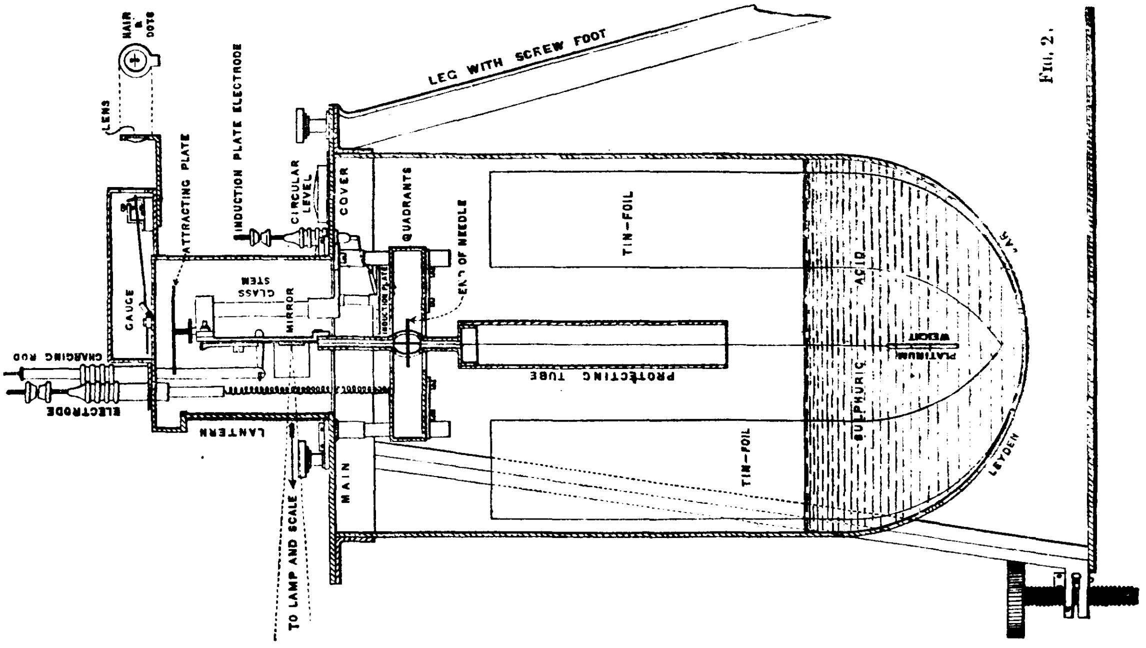


FIG. 2.

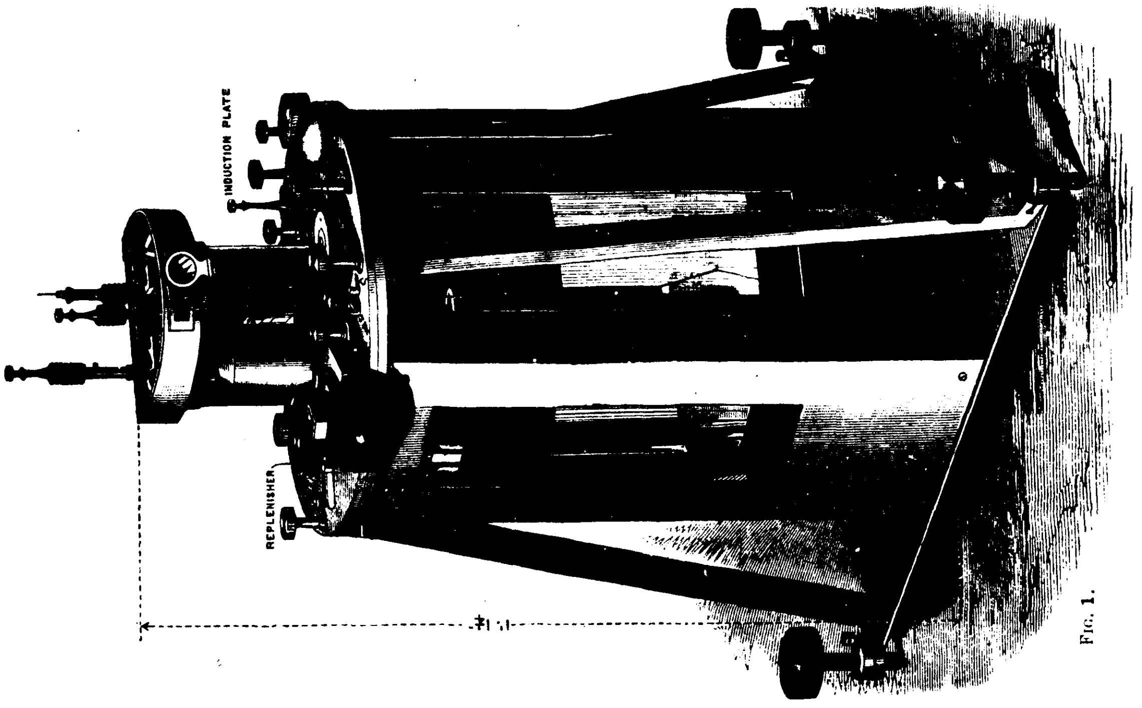


FIG. 1.

When the difference of potentials to be measured is comparatively great the light spot may be sent off the scale. To obtain a reading in such a case it is necessary to reduce the sensitiveness of the instrument, and this is effected by means of an oblong brass strip, called the *induction plate.*

This plate is fixed immediately over one pair of quadrants, so that if one point of an electrified conductor be connected with it, instead of with the underlying quadrant, the charge in the latter will be less than if direct connection had been made, and the deflection will be correspondingly reduced.

Fixed on the main cover, Fig. 2, is a small circular spirit-level which, together with the three foot-screws, permits of the instrument's being accurately levelled.

The readings of the quadrant electrometer may be converted into absolute measure when the *constant* of the instrument has been, once for all, determined by comparison with an *absolute* electrometer. When this determination has been made it is evident that the position of the quadrants must not be altered, and the normal charge of the needle must always be exactly reproduced before a measurement is made.

Another means, and one of frequent use as well as of easy application, consists in comparing the obtained deflection with that given by a known difference of potential, such as that of a Latimer Clark's cell, or Sir William Thomson's standard Daniell.

The quadrant electrometer is also (at Kew) advantageously used as a self-recording instrument for registering, by means of photography, the variations in kind and degree of atmospheric electricity, and in this connection it has already rendered important services to meteorology.