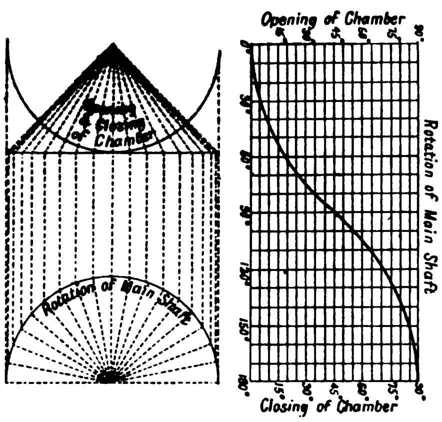
factory than if the two parts fitted together with a spigot and socket joint. The packing appeared to him to be perfect to a certain extent, but there was only one ring of it, and not two as was usual. Had it not been for the abundant lubrication he should have expected the valve face to wear out of truth, as the peripheral portions move so much more rapidly than the centre. It had been stated in the paper that the engine could be reversed by turning the steam into the exhaust passage and exhausting through the steam passage. But the steam port was arranged to cut off at half-stroke, and consequently under this arrangement, the engine would get steam, when running backwards, through the whole stroke, and would begin to cushion at half-stroke.

Mr. H. Maudslay remembered spherical engines forty years ago, and those, he said, were simple compared to this, in fact in this case the sphere was so filled with machinery that there did not appear to him to be any room for the steam. He would like to know what was the horse-power per unit of weight of the engine and to compare it with an ordinary engine. It seemed to him that there was no time for the steam to expand. It must be either full on or be exhausting. The engine certainly could not be economical.

In reply, Mr. Tower said that he made his first engine in 1878; the diameter of the sphere was 8 in. Then he made a 12 in. engine, and it was submitted to a long series of tests at the works of Messrs. Easton and Anderson. He had designed a special indicator for it, and had found that the brake horse-power was 80 per cent. of the indicated power. The peculiar form of the indicator was required because the rate of opening of the spaces in the sphere was not constant, as would be seen from diagrams 1 and 2. At that time the steam con-



sumption was 80 lb. per horse-power per hour. In the engines now made by Messrs. Heenan and Ford the consumption was 35 lb. per hour. The use of a pump for the lubrication arose from the experience he gained in carrying out the friction experiments for the Institution. He had used a large engine to drive the shaft in those trials, and as the engine was running at about one-twelfth of its power, it used a good deal of steam, and gained itself a bad name with Mr. Tomlinson. When the oil was injected by the pump there was no metallic contact of the surfaces and no wear at all. The steam was expanded from half-stroke, and, of course, as Mr. Schönheyder pointed out, the engine would not run well backwards. If, however, the steam port were lengthened by means of a clack valve which remained closed when the steam was behind it, and opened at other times, the difficulty of cushioning was avoided. There was, of course, no cut-off on the backward motion. He had found the steady pins make a more satisfactory joint between the halves of the sphere than the spigot and faucet joint, for he had tried both. The sphere was bored out with a special tool that swept it out with perfect accuracy.

Mr. Heenan explained that at each revolution a volume of steam was admitted equal to the entire contents of the sphere less the volume of the hinges between the piston and the blades. The oil was caught in a trap, and was used over and over again. It was directed principally into the main bearing, because the steam exerted a sideways action on the shaft. This bearing was stuffed with asbestos at each end, but some of the oil leaked past the inner packing into the sphere.

The President said that the first occupant of the chair of that Institution was George Stephenson, and the only paper he ever read before them was one on the fallacy of rotary engines. At that time there was a belief that the crank involved a great waste of power, and consequently there was an epidemic of rotary engines to get over the supposed difficulty. The engine before them appeared to be the first engine of the kind that had really proved successful, and next to the ingenuity of the designer, great credit was due to the manufacturers, who had brought it to such a perfect state mechanically. He had great pleasure in proposing a vote of thanks to the author.

Paddle Wheel Steam Navigation.

The last paper, "On the History of Paddle Wheel Steam Navigation," by Henry Sandham, of London, was then read in abstract, and as it was purely historical, there was no discussion.

The proceedings terminated by a vote of thanks to the Institution of Civil Engineers for the use of their premises.

THE HYDRODYNAMIC RESEARCHES OF PROFESSOR BJERKNES.

By Conrad W. Cooke.

We have in former articles* described the highly interesting series of experimental researches of Dr. C. A. Bjerknes, Professor of Mathematics in the University of Christiania, which formed so attractive a feature in the Electrical Exhibition of Paris in 1881, and which constituted the practical development of a theoretical research which had extended over a previous period of more than twenty years. The experiments which we described in those articles were, as our readers will remember, upon the influence of pulsating and rectilinearly vibrating bodies upon one another and upon bodies in their neighbourhood, as well as upon the medium in which they are immersed. This medium in the majority of Professor Bjerknes's earlier experiments, was water, although he demonstrated mathematically, and to a small extent experimentally, that the phenomena, which bear so striking an analogy to those of magnetism, may be produced in air.

Our readers will recollect that in the spring of 1882† Mr. Stroh, by means of some very delicate and beautifully designed apparatus, was able to demonstrate a large number of the same phenomena in atmospheric air of the ordinary density, and about the same time Professor Bjerknes, in Christiania, was extending his researches to phenomena produced by a different class of vibrations, namely, those of bodies moving in oscillations of a circular character, such, for example, as a cylinder vibrating about its own axis or a sphere around one of its diameters; some of these experiments were brought by Professor Bjerknes before the Physical Society of London in the following June.‡ Since that time, however, Professor Bjerknes, with the very important assistance of his son, Mr. Vilhelm Bjerknes, has been extending these experimental researches in the same direction and with the results which it is the object of the present series of articles to describe.

The especial feature of interest in all Professor Bjerknes's experiments has been the remarkably close analogy which exists between the phenomena exhibited in his mechanical experiments in water and other media, and those of magnetism and of electricity, and it may be of some interest if we here recapitulate some of the more striking of these analogies.

(1) In the first place the vibrating or pulsating bodies, by setting the water, or other medium in which they are immersed, into vibration, set up in their immediate neighbourhood a field of mechanical force very closely analogous to the field of magnetic force with which magnetised bodies are surrounded. The lines of vibration have precisely the same directions and form the same figures, while, at the same time, the decrease of the intensity of vibration by an increase of distance, obeys precisely the same law as does that of magnetic intensity at increasing distances from a magnetic body.

(2) When two or more vibrating bodies are immersed in a fluid they set up around them fields of vibration and act and re-act upon one another in a manner closely analogous to the action and reaction of magnets upon one another, producing the phenomena of attraction and repulsion. In this respect, however, the analogy appears to be inverse, repulsion being produced, where, from the magnetic analogy, one would expect to find attraction, and *vice versâ*.

(3) If a neutral body, that is to say a body having no vibration of its own, be immersed in the fluid and within the field of vibration, phenomena are produced exactly analogous to the magnetic and diamagnetic phenomena produced by the action of a magnet upon soft iron or bismuth, its apparently magnetic or diamagnetic properties being determined by the specific gravity of the neutral body as compared to that of the medium in which it is immersed. If the neutral body be lighter than the medium, it exhibits the magnetic induction of iron with respect to polarity, but is nevertheless repelled; while if it be heavier than the medium its direction is similar to that of diamagnetic bodies such as bismuth, but on the other hand exhibits the phenomena of attraction.

In this way Professor Bjerknes has been able to reproduce analogues of all the phenomena of magnetism and diamagnetism, those phenomena which may be classed as effects of induction, being directly reproduced, while those which may be classed as effects of mechanical action and resulting in change of place, are analogous inversely. This fact has been so much misunderstood both in this country and on the Continent that it will be well, before describing the experiments, to enter more fully into an explanation of these most interesting and instructive phenomena.

For the sake of clearness we will speak of magnetic induction as that property of a magnet by which it is surrounded by a field of force, and by which pieces of iron, within that field, are converted into magnets and pieces of bismuth into diamagnets, and we will speak of magnetic action as that property of a magnet by which it attracts or repels another magnet, or by which it attracts or repels a piece of iron or bismuth magnetised by magnetic induction.

The corresponding hydrodynamic phenomena may be regarded in a similar manner; thus, when a vibrating or pulsating body immersed in a liquid surrounds itself with a field of vibrations or communicates vibrations to other immersed bodies within that vibratory field, the phenomena so produced may be looked upon as phenomena of hydrodynamic induction, while, on the other hand, when a vibrating or pulsating body attracts or repels another pulsating or vibratory body (whether such vibrations be produced by outside mechanical agency or by hydrodynamical induction), then the phenomena so produced are those of hydrodynamical action, and it is in this way that we shall treat the phenomena throughout this article, using the words *induction* and *direct action* in these somewhat restricted meanings.

In the hydrodynamical experiments of Professor Bjerknes all the phenomena of magnetic induction can be reproduced directly and perfectly, but the phenomena of magnetic action are not so exactly reproduced, that is to say, they are subject to a sort of inversion. Thus when two bodies are pulsating together and in the same phase (*i.e.*, both expanding and both contracting at the same time) they mutually attract each other, but if they are pulsating in opposite phases repulsion is the result. From this one experiment taken by itself we might be led to infer that bodies pulsating in similar phases are the hydrodynamic analogues of magnets having their opposite poles presented to one another, and that bodies pulsating in opposite phases are analogous to a presentation of similar magnetic poles, but it will be seen at once that this cannot be the case if three magnetic poles or three pulsating bodies be considered instead of only two. It is clear, on the one hand, that three similar magnet poles will all repel one another, while, on the other, of three pulsating bodies, two of them must always attract one another, while a third would be repelled; and, moreover, two similarly pulsating bodies set up around them the same lines of force as two similar magnetic poles, and two oppositely pulsating bodies produce lines of force identically the same as those set up by two magnets of opposite polarity. Thus it will be seen that there is a break in the analogy between the hydrodynamical and the magnetic phenomena (if a uniform inversion of the effects can be called a break, for it is, as far as Professor Bjerknes's experiments go, without an exception), and if by any means this inversion could be re-inverted all the phenomena of magnetism and diamagnetism could be exactly reproduced by hydrodynamical analogues; there would thus be grounds for forming a theory of magnetism on the basis

* See Engineering, vol. xxxiii., pages 23, 147, and 191.
† *Ibid.*, pages 455, 480, 508, and 558.
‡ *Ibid.*, page 639.

of mechanical phenomena, and a very important link in the chain of the correlation of the physical forces would be supplied.

While the experiments of Professor Bjerknes upon pulsating and rectilinearly vibrating bodies and their influence upon one another illustrate by very close analogies the phenomena of magnetism, those upon circularly vibrating bodies and their mutual influences bear a remarkable analogy to electrical phenomena; and it is a significant fact that exactly as in the case of magnetic illustration, the analogies are direct as regards the phenomena of induction and inverse in their illustration of direct electrical action.

If we examine the figure produced by the field of force surrounding a conductor through which a current of electricity is being transmitted (see Fig. 1)*

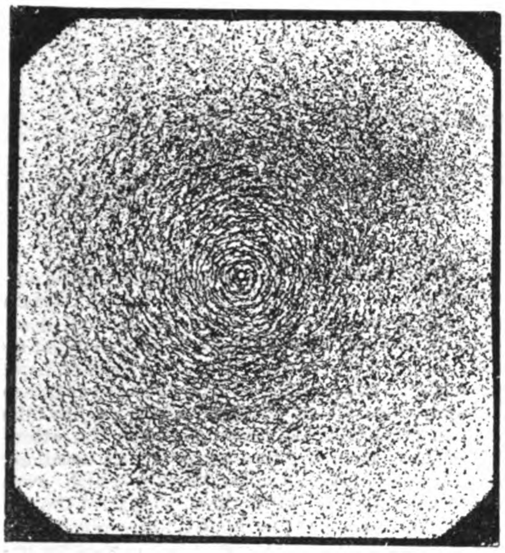
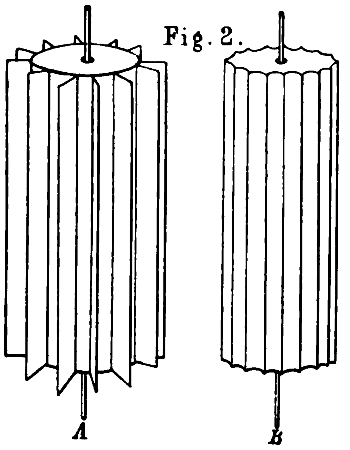


FIG. 1.

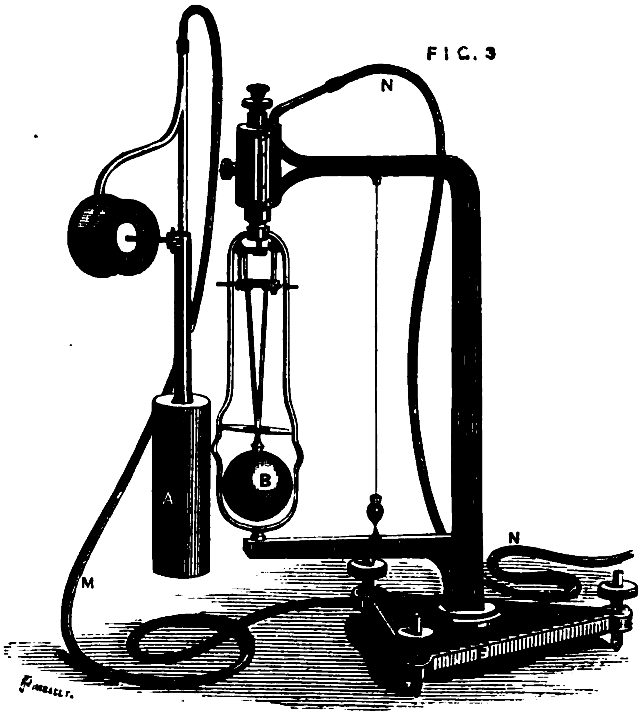
we see that iron filings within that field arrange themselves in more or less concentric circles around the conductor conveying the current. From this fact Professor Bjerknes and his son, reasoning that to produce a similar field of energy around a vibrating body, the vibrations of that body must partake of a circular or rotatory character, constructed apparatus for producing the hydrodynamic analogue of electric currents, in which a conductor transmitting a current of electricity is represented by a cylinder to which oscillations in circles around its axis are given by suitable mechanical means, so as to cause the enveloping medium to follow its motion and make similar rotative vibrations. In some of the earlier experiments in this direction cylinders carrying radial vanes (A, Fig. 2) or fluted

Fig. 2.



longitudinally around their surfaces (B, Fig. 2) were employed with the object of giving the vibrating cylinder a greater hold of the liquid in which they were immersed, but it was found that these vanes or flutings had but little or no effect upon water or liquids of similar viscosity, and Professor Bjerknes was led to adopt highly viscous fluids such as glycerine or maize syrup, both of which substances are well adapted for the experiments, being at the same time both highly viscous and perfectly transparent and colourless. In seeking for the purpose of this research a fluid medium which shall possess analogous properties to the luminiferous ether, or whatever may be the medium whose vibrations render manifest certain physical phenomenon, it might be considered at first sight that substances so dense as glycerine and syrup could have but little in common with the ether, and that an analogy between experiments made within it and phenomena associated with ethereal vibrations would be of a very feeble description, but Professor Bjerknes has shown that the chief requisite in such a medium is that its viscosity should be great, not absolutely, but large only in proportion to its density, and if the density be small the necessary viscosity may be small also. Neither is it necessary for the fluid medium to possess great internal friction, but what is necessary to the experiments is that the medium shall be one which is readily set into vibration by the action of the circularly vibrating cylinder; this property appears to be possessed exclusively by the more viscous fluids, and is, morever, in complete accord with what is known of the luminiferous ether according to the theory of light. The property is rather a kind of elasticity, which ordinary fluids do not possess, but which facilitates the propagation of transverse vibrations.

One form of apparatus for the propagation of rotative oscillations is shown to the left of Fig. 3, and consists of a cylinder A mounted on a tubular spindle, and which is set into circular oscillations around its axis by the little vibrating membrane C, which is attached to the axis of the cylinder by a little crank and connecting rod shown in detail in Fig. 4. This membrane is set into vibration by a rapidly pulsating column of air contained in a flexible tube M by which the apparatus is connected to the pulsation pump which was employed by Professor Bjerknes in his earlier experiments, and



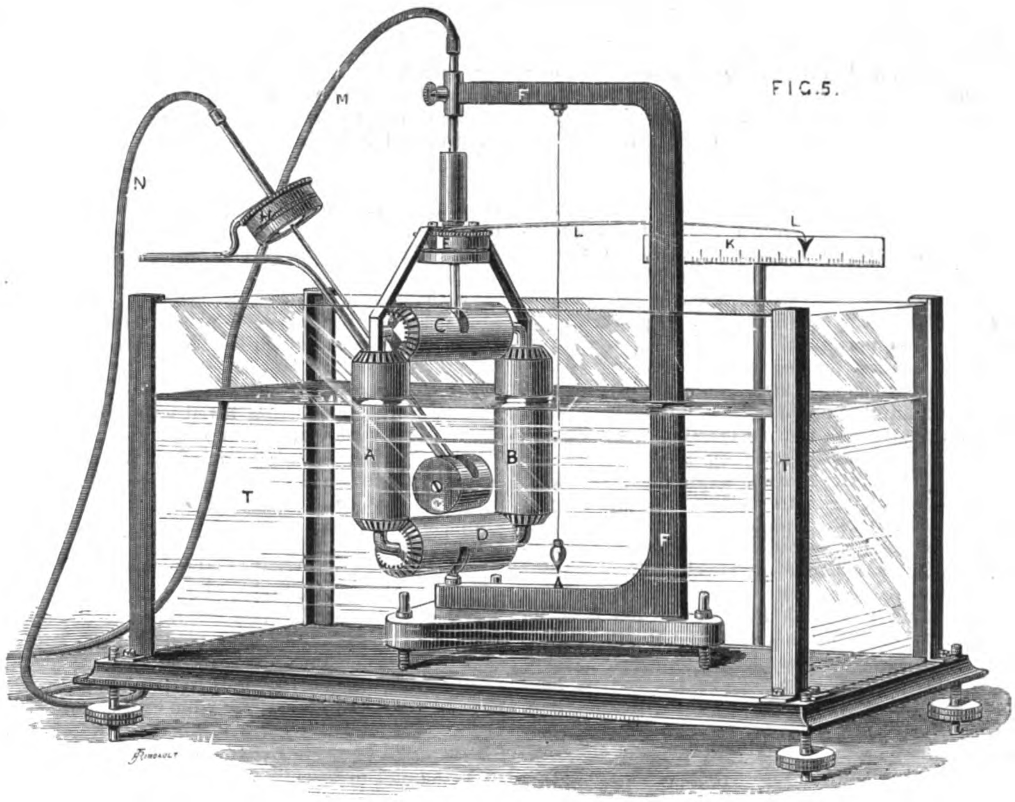
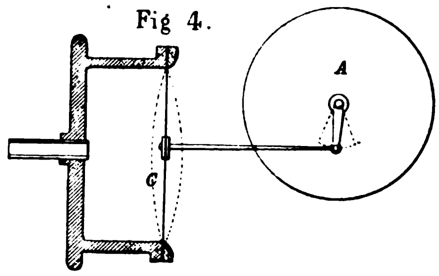


Fig 4.



which we figured and described at the time.* In Fig. 5 a somewhat similar apparatus for producing

* See ENGINEERING, vol. xxvi., page 391.

* See ENGINEERING, vol. xxxiii., p. 23.

horizontal vibrations is shown and marked N H C, the only difference between them being one of mechanical detail necessitated by the change in the position of the axis of vibration from the vertical to the horizontal.

If circularly vibrating cylinders, such as we have described, be immersed in a viscous fluid and set into action, the following phenomena may be observed: 1. The effect upon the fluid itself, setting up therein a field of vibration, and corresponding by analogy with the production of a field of force around a wire conveying an electric current. 2. The effect upon other circularly vibrating bodies within that field of force corresponding to the action and reaction of electric currents upon one another. 3. The effect on pulsating and oscillating bodies similarly immersed, illustrating the mutual effects upon one another of magnets and electric currents. The first of these effects is one of induction, and, from what has been said in an earlier part of this article, it will be understood that the analogy between the hydrodynamic and the electric phenomena is direct and complete. The effects classified under the second and third heads, being phenomena of direct action (in the restricted use of the word), are uniformly analogous to the magnetic and electric phenomena which they illustrate.

(To be continued.)

THE AUTOBIOGRAPHY OF A WHITEHEAD TORPEDO.—No. VIII.

After returning once more on board the ship, life went on very smoothly. I was, as I have said, duly taken to pieces and cleaned, my defects made good, and to all intents and purposes I was as sound as ever. Now I come to think of it, though, I am afraid this statement is not quite true, for though the rust had been duly cleaned off and I looked as bright as ever, it had eaten into me, and I did not work quite so freely as I used to. However, I had plenty of go in me yet, and made two or three successful runs.

Meanwhile there had been rumours of trouble stealing about, and at last these came to a head, and we found ourselves actually at war with France.

Now I don't want to make this a political story at all; a Whitehead torpedo should have no politics; all he has to do is to go straight and die manfully doing his duty. But at the same time I could not help hearing what was said by those about me, and from what I heard there seems little doubt that the country was, at the time I speak of, in a bad way. To be brief, the accusations made against the Government were, that for the sake of economy the number and power of the ships had been permitted to fall far below what it should be. It was not for want of warning either, for the public press had for months been filled with articles and letters pointing this out, and showing by figures that could not be disputed that France was slowly but surely creeping up to us in the strength of her navy. One admiral of the fleet was particularly persistent in this respect, and you would think that the opinion of a man like that, who had worked his way up to the top of his profession, should have had some effect; and perhaps it may have had some, but, at all events, here we were at actual war with France, and our fleet, on which everything depended, was not superior to hers. Some said it was actually inferior, but our people did not generally believe that. The next point was, that our guns were all behindhand. Nobody even attempted to deny this. The only excuse offered by the authorities was that they had been waiting to copy from other nations.

Our fellows were awfully indignant about this, the more so that it was a well-known fact that the system of wire building for guns, offering as it did very many advantages, and which had been at last very nearly adopted, had been persistently urged on the Government for the last twenty years. It showed such petty official jealousy they thought. The inventor was an engineer, and not a gunmaker. Hence the gunmakers refused to listen to him, until they were at last actually obliged to, when, as we know, it was too late.

However, here we were arrayed against France, and the thing was to make the best of it. We, the proper Channel Squadron, were ordered to remain out in the Mediterranean, our places, as usual under the circumstances, being supplied by the reserve ships, and ships especially commissioned. We did not join the Mediterranean squadron, however, but two of their ships were sent to join our flag, thus making the squadron up to eight ships. The reason for this I only imperfectly understood, but it had something to do with the arrangements of the French fleet, part of which were at Toulon preparing for sea, while the remainder were somewhere over on the North African coast, threatening Malta or Gibraltar. It was the former portion of the enemy that we were told off to look after, the other part of the Mediterranean Squadron watching the remainder.

Our duty was to keep a good look-out on the movements of the enemy, running in as close as we could by day and retiring to a respectable distance at night. We had six second-class torpedo boats attached to the fleet, and these were always kept in the water (except on the approach of bad weather) and with the steam pinnaces of the fleet, did it was acknowledged amongst all civilised nations, that the duty of a torpedo boat was to deliver her blow, and then escape if she could, and that if the officer in charge knew that his boat was running out of danger, he would have his mind free to think of the discharge of the torpedo alone. If only the officer's courage were called in question, he could show that, by going as close as he liked to the enemy before turning, and he hoped to show them if the opportunity occurred, that this courage was not wanting.

This idea of Hand's had been broached before war was declared, and I had been fired from the old steam pinnace several times very successfully. Now, as you may imagine, he was very anxious to try it in real earnest. Accordingly he had spent much of his time in observing the position of the French

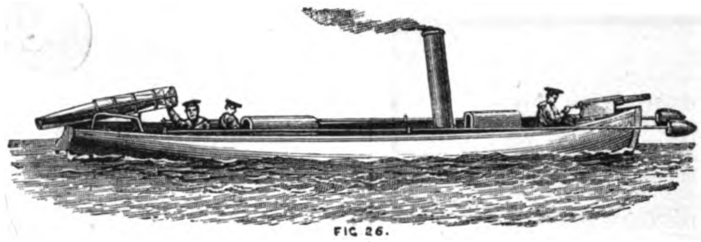


Fig. 26.

duty as guard-boats, forming a cordon of about two miles inside the squadron, so as to give timely notice of any attempted torpedo attacks on the part of the enemy. Besides this the ships always had their torpedo nets out at night, and one watch was almost always on deck specially detailed to man the guns (machine guns especially) should the enemy attempt to attack us with torpedoes. They on their part had swift cruisers always on the watch and an opposing force of torpedo boats guarding the harbour.

Matters went on like this for three weeks or more, many feints at night attack being made on both sides, but neither party making a real attack.

Having been used as an exercising torpedo, I was very much afraid that now we had come to real fighting I should be sent below, and my place taken by one of the torpedoes which had not been used. But to my delight it was determined that I should have my proper gun-cotton charge in, and be used should occasion occur. The reason for this rather unusual arrangement was that I had been running uncommonly well lately, and Hand (who still had charge of the torpedo work as well as the gunnery) considered it was better to have one which they knew than one which had not been practically tried. Two other torpedoes were placed in the second-class torpedo boat, which had, together with a new and powerful steam pinnace been sent out to us. The latter, however, though capable of steaming sixteen knots, and being fitted with most of the latest improvements, had no Whitehead fittings. To remedy this, Hand proposed that when necessary one of the carriages belonging to the ship (there were three on board) should be hoisted into the pinnace without its slide and placed pointing over the stern (see Fig. 26).

This method up to that time had never been adopted in the service (indeed I don't think even now it is recognised as a service fitting), and was one of Hand's original ideas. His plan was to run up astern or down ahead of the enemy, until getting pretty close, then swerve to the right or left, and fire his torpedo going away from the enemy. He was convinced that by this method a more effective attack could be made than by the ordinary method of firing ahead, because:

1. The boat could be more readily got into position.
2. She need not stop to deliver her fire.
3. There was more chance of the boat escaping.
4. There would be less flurry in the minds of those on board when they appreciated that each moment was taking them further from the danger instead of running them into it.

Considerable objections were raised to this last proposition of Hand's, his opponents saying that anybody worth his salt would not be flurried by running into danger, and that it was a cowardly thing to strike your enemy and then run away.

To this Hand replied, that however cool and fearless a man might be, he must appreciate the fact that the boat and the lives of several of his fellow-creatures were in his hands; that it was his duty to do as much damage to the enemy as possible with a minimum amount possible to himself; that fleet whenever we got near enough to do so, an the outcome of it was, that he proposed to Captain Tarr to make a night attack on the French fleet. A dash of all our torpedo boats would have had no effect, as it would simply have meant a hand-to hand fight with the numerous guard-boats at the entrance of the harbour. What Hand proposed was, to take the main portion of the boats, to divert the attention of the French guard-boats by an assumed attack on one of the smaller vessels, which were used in combination with them to patrol the entrance. By this means he hoped to be able to get the mass of the guard-boats away to the western entrance, while he, with two boats, the second-class torpedo boat and the new pinnace, would creep in along the eastern shore and attack two of the vessels lying furthest out in the roads. Captain Tarr thought the matter over, and fancying there might be some chance of success, laid the proposal before the admiral. After some debate the latter agreed to it, but objected to Hand going away in charge, for should anything happen to him, there was the gunnery and torpedo lieutenant gone at once. This was a great blow to Hand, who of course was longing for an opportunity to distinguish himself, and thought it very hard lines that he should not have the chance of coming to the front in his own particular line. The admiral, however, was firm, but promised him that should the attack be successful, his claim for promotion should be fully recognised. With this Hand was fain to be content, and putting his own feelings on one side busied himself with preparations for the attack.

There would be no moon on the third night from the time when this was settled, and it was decided that the attack should take place then. A lieutenant was told off for the second-class boat, while the sub-lieutenant (Willis) belonging to the steam pinnace, and who had always been in her when the trials were carried out with the torpedo over the stern, was allowed to remain in command of her. Captain Tarr was very undecided for a long time about this latter arrangement, as he thought so young an officer very likely to be flurried. Still Willis had seen the thing done many a time when practising, and finally it was decided that he should go. I rather fancied that I might be sent as I had generally been used for exercising in this way, but another carriage was taken, and the torpedo that happened to be in it at the time was selected. Just as well, too, or else I should never have been able to write these my adventures. However, I can tell you pretty well what occurred; indeed I can throw more light on the matter than most people, because I happened to hear a conversation between two of the men afterwards, which never came to the ears of those in authority—more is the pity! The pinnace and torpedo boat left the ship at about 11 P.M., the squadron being at that time twelve miles off the harbour with a pretty fresh breeze blowing from the north-east. It had been arranged that the guard-boats, which as a rule kept in two lines inside of us, should, at half-past eleven, edge further down to the westward, and make a feint of attacking one of the corvettes in that direction. Certain gunboats were to be fired

THE HYDRODYNAMIC RESEARCHES OF PROFESSOR BJERKNES.

By CONRAD W. COOKE.

(*Continued from page 306.*)

WE shall now refer to the three classes of phenomena in detail, and in the order in which we have classified them :

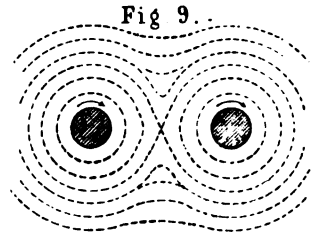
1. The effect of the vibrating cylinder upon the fluid in which it is immersed may be investigated by the apparatus which we figured and described in connection with Professor Bjerknes's earlier experiments,* and which consisted of a hollow metal cylinder with hemispherical ends supported upon a vertical fine elastic steel wire, rising from a firm stand, and surmounted by a camel's hair pencil, which, projecting out of the fluid in which the apparatus is immersed, can be made to record the

By employing in the place of glycerine a fluid, such as maize syrup, of far greater viscosity, a diagram may be obtained, illustrating not only a largely extended field of force around the vertical vibrating cylinder, but the figure so produced is identical with that obtained by iron filings scattered over a glass plate and around a vertical wire, through which an electric current is passing (Fig. 1, see page 305 *ante*). And in the same medium, by employing the horizontal vibrating cylinder shown in Fig. 5, in conjunction with the secondary apparatus, a figure is obtained, which is identical with that produced by iron filings on a glass plate, below which, and parallel to its plane, is fixed a wire through which a current of electricity is being transmitted ; see Fig. 6.

If two cylinders each circularly vibrating about their vertical axes, and of the form shown to the left of Fig. 3, be introduced into a viscous medium, parallel to the plane of the plate, and through which electric currents are being transmitted in opposite directions, it will be seen that the two figures are identical.

If now the two cylinders be similarly placed

Fig. 9.



within the viscous medium, and they be circularly vibrated, but in the same phases, that is to say,

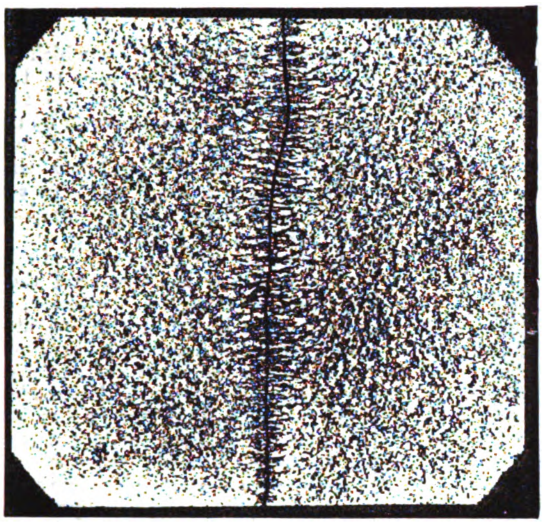


FIG. 6.

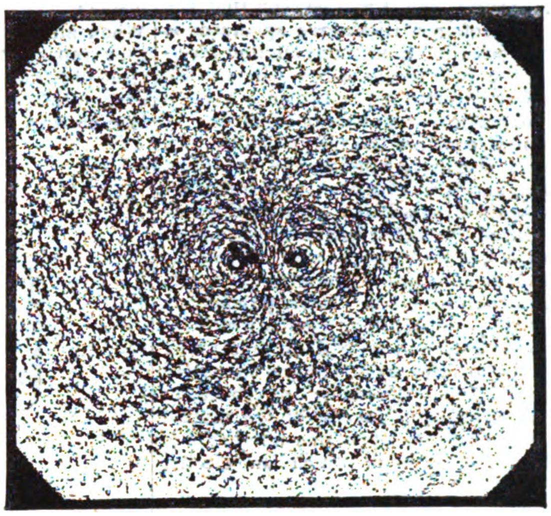


FIG. 8.

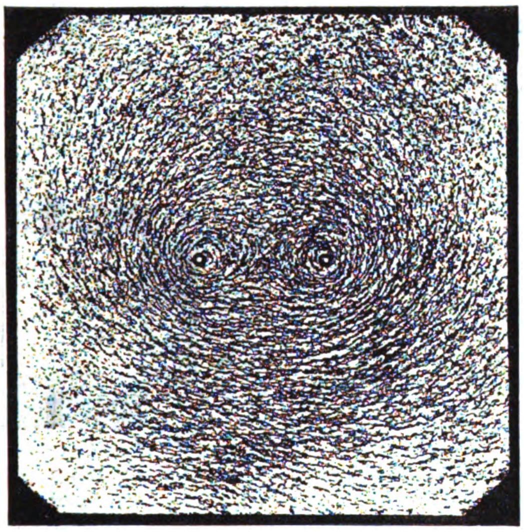


FIG. 10.

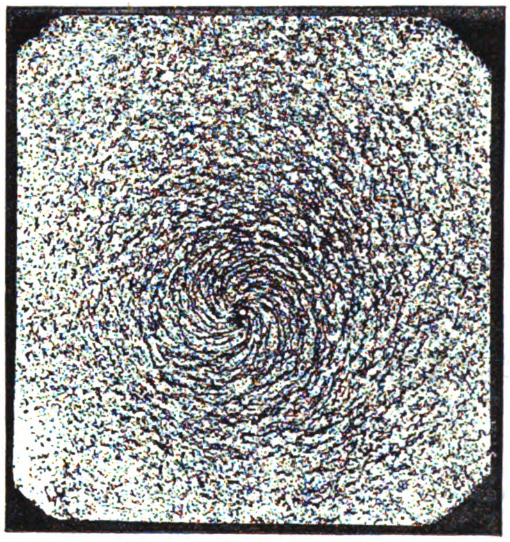
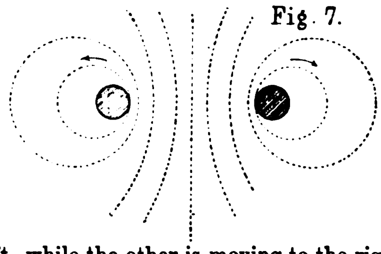


FIG. 12.

direction and amplitude of the vibrations on the underside of a plate of glass or sheet of paper. When this apparatus is immersed in glycerine, and placed in different positions within the field of influence of a vibrating cylinder (such as that shown in Fig. 3), a diagram can be produced which is a graphic record of the directions and extent of the vibrations within that field of influence, but it will be found that in the case of glycerine the field of influence extends but a short distance from the vibrating cylinder, and that the motion communicated to the fluid by the vibrating cylinder, which at the surface of contact is very nearly equal to that of the cylinder itself, very rapidly falls off as the distance from the cylinder increases, and that, moreover, the phase of vibration is more and more retarded until at a few millimetres' distance from the cylinder the direction of movement is reversed ; showing that the ratio of the coefficient of viscosity to the density of the fluid is not large enough to insure the most marked results.

such as maize syrup, and within the range of each other's field of vibration, figures may be produced with the recording apparatus which are identical with the filing figures produced upon a horizontal plate around two vertical wires conveying electric currents. If the two cylinders are moving in opposite phases, that is to say, if the one be rotating to

Fig. 7.



the left, while the other is moving to the right, the figure shown in Fig. 7 is produced, and if this figure be compared with Fig. 8, which is a reproduction of the filing figure produced on a horizontal plate of glass around two wires, whose direction is

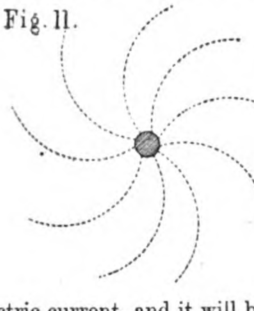
both moving to the right or both moving to the left at the same time, then the recording apparatus will trace out a diagram similar to Fig. 9, and on comparing this figure with the filing figure, shown in Fig. 10, it will be seen to be identical in form with the arrangement of magnetic particles around a field of force produced by two parallel electric currents, moving in similar directions, but perpendicular to the plane on which the magnetic particles are scattered.

One of the most interesting of this series of Professor Bjerknes's experiments is the reproduction in a viscous medium of a field of vibration represented by a diagram which is identical with that obtained by iron filings around a magnet through which an electric current is being transmitted. Professor Bjerknes, reasoning that while a body pulsating within a viscous medium sets up in that medium *radial* lines of force, and a circularly vibrating body produces a field of *concentric* circles of force, combined the two and produced the diagram, Fig. 11, in which a spiral figure is drawn which is a sort of compromise between the radial lines of force

* See ENGINEERING, vol. xxxiii., page 192.

and the concentric circles produced by a circularly vibrating body. Fig. 12 is the figure produced around the pole of a magnet through which an electric current is being transmitted, by iron filings scattered on a plate, the plane of which is perpendicular to the axis of the magnet, and to the direction

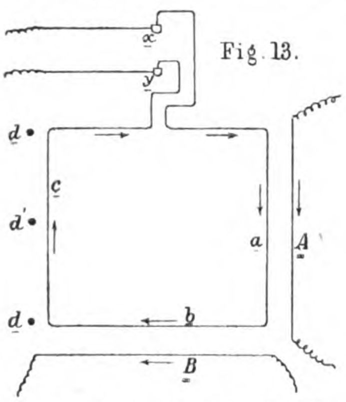
Fig. 11.



of the electric current, and it will be seen that the figure drawn by Professor Bjerknes's apparatus is identical in form with it; thus giving another striking example of the very close analogy which exists between the effect of vibrating bodies in a viscous medium, and magnetic and electric phenomena.

2. We will now consider the mutual effect produced by bodies circularly vibrating in the same viscous medium, and it will be seen that this class of phenomena bears a remarkably close analogy to the effects produced by electric currents transmitted through conductors, of which one or more are capable of moving under the influence of whatever dynamical forces may be called into action. These phenomena were investigated by Ampère in a research which has long become classical, and it will, in this place, be necessary only to refer to one figure connected with that research as explanatory of Professor Bjerknes's hydro-dynamic analogue of the mutual action of electric currents upon one another. If a wire A (Fig. 13), through which an electric

Fig. 13.



current is being transmitted in the direction of the arrow, be presented to the vertical side a of the light wire frame $a\,b\,c$, which is pivotted in the two mercury cups x and y, so that the current in A and in a are parallel, and in the same direction, attraction will take place, and the frame $a\,b\,c$ will follow the wire A if the latter be displaced. If, on the other hand, the wire A be placed near to the opposite side of the frame c, so that the two currents while parallel are in opposite directions, repulsion will ensue. If now a wire conveying an electric current be placed below the frame as at B, attraction will take place when the currents in the wires B and b are in the same direction, and the frame $a\,b\,c$ will place itself in such a position that b becomes parallel to B, but if the currents in the two wires be opposite in direction, repulsion will take place, and the frame will rotate until its plane becomes perpendicular to B. Once more, if the wire conveying the current be presented to one side c of the movable frame, but in a plane perpendicular to the plane of the frame as at d, then a deflection of the frame will take place, and if the wire d be moved lower down, the deflection will become less and less, until a point d^{I} is reached, which is opposite the middle of the length of C; at this neutral point no deflection will take place, and if the wire be still further lowered, it will deflect the frame in the opposite direction, and this deflection will increase as the wire is lowered, until it reaches the point d^{II}, where the deflection will have reached its maximum, being equal to what it was when the wire was at d, and in an opposite direction.

All the above phenomena Professor Bjerknes has been able to reproduce hydrodynamically with remarkable accuracy, by means of the very beautiful apparatus shown in Fig. 5, (see page 305 *ante*), and illustrated in the diagram Fig. 13, so far as its essential parts are concerned. This apparatus consists of a light frame delicately poised between vertical axes on a rigid stand F F, and carrying four cylinders A, B, C, and D, two of which, A and B, are vertical, while the other pair, C and D, are horizontal. On reference to Fig. 5 it will be seen that their axes form together a square, symmetrically disposed about the vertical axis of the frame. The ends of these cylinders are geared together by bevel wheels, and they are set into circular vibrations around their respective axes by a little vibrating membrane stretched over the air chamber E, which is connected by the flexible tube M to the pulsating pump. The mechanical arrangement is precisely similar to that illustrated in Fig. 4 (page 305 *ante*), there being a small connecting-rod attached to the centre of the membrane in E, and taking hold of a crank-pin inside the slot shown in the cylinder C (Fig. 5). When all these cylinders are set into oscillation, they represent a closed electrical circuit such as that illustrated in Fig. 13, and the eight arrows around the figure (Fig. 14) indicate the direction of that current.

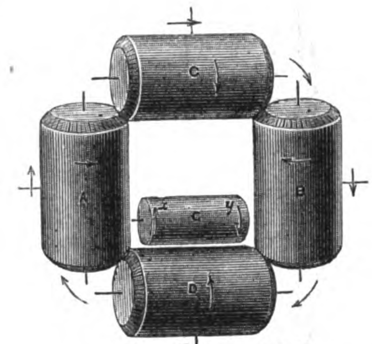


FIG. 14

If now the vertical oscillating cylinder (shown at A, Fig. 3, page 305) be placed close and parallel to the vertical cylinder A or B (Figs. 5 and 14), repulsion will take place when the two cylinders are rotating in the same phase—that is to say, when they are both moving to the right or to the left at the same time—but when the cylinders are oscillating in opposite phases, attraction will take place. These phenomena are illustrated in Fig. 15, the upper part

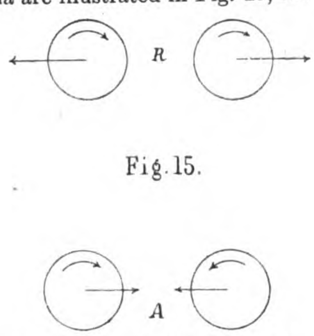


Fig. 15.

of the figure marked R illustrating the repulsion between two cylinders vibrating in similar phases, and the lower part of the figure marked A shows the attraction effect of two cylinders vibrating in the opposite phases. The curved arrows indicate the direction of rotation at any given moment, and the straight arrows show the direction in which the cylinders tend to move through the medium. It will be observed that these phenomena are closely analogous to the action of electric currents upon one another, as illustrated in the diagram Fig. 13, although the phenomena of attraction and repulsion are inversed.

If now we take the horizontal vibrating cylinder G, Fig. 5, and place it close to the lower horizontal cylinder D, as is shown in Fig. 5, and again in the diagram, Fig. 14, the whole system of vibrating cylinders A B C and D, will turn until the axis of the cylinder D lies in the same plane as that of the cylinder G, and is moving in the opposite phase; and this will be its position of stable equilibrium; but if the frame carrying the cylinders be turned through an angle of 180 deg., the two cylinders will again become parallel; this time, however, their phases of oscillation will be similar, and the apparatus will be in its position of unstable equilibrium, as may be shown by moving it slightly to the right or the left, when it will immediately turn until the cylinders again become parallel and are vibrating in opposite phases. In the position shown in the diagram Fig. 14, the balance is in stable equilibrium, when the cylinders are oscillating in the phase indicated by the arrows D and y, and is in unstable equilibrium when oscillating in the phases indicated by the arrows D and x. If the cylinder G be placed above D in such a position that its axis lies in a plane perpendicular to that of the axis of D (as shown in Fig. 16), that

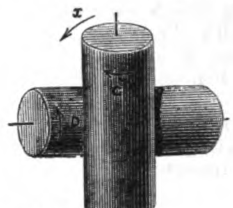


Fig. 16.

is to say, in that position which is farthest from that in which the two axes of the cylinders lie in the same plane, then if the two cylinders are oscillating in the phases shown by the arrows G and D (Fig. 16), the axis of G will turn in the direction shown by the arrow x until parallelism between the cylinders is reached; and this corresponds very exactly with Ampère's experiment with two electric currents similarly disposed.

In the last-mentioned series of experiments, Professor Bjerknes has produced the hydrodynamic analogues of attraction, repulsion, and rotation, by which, what is called "action at a distance" is ordinarily made manifest in electro-dynamics, and in all cases has he demonstrated this by the use of circularly vibrating cylinders. He has, however, gone a step farther, for he has been able to reproduce phenomena analogous to the action of other electric currents upon one another, such as we have already described in connection with Fig. 13; as, for example, the effect upon the current in the upright wire C (Fig. 13) of a current passing through a wire whose plane is perpendicular to that of C, when in the positions indicated in the positions d and d'' as well as in positions intermediate between them. Fig. 17 shows the arrangement of the apparatus for producing the analogues of these phenomena. A, B, C, and D are

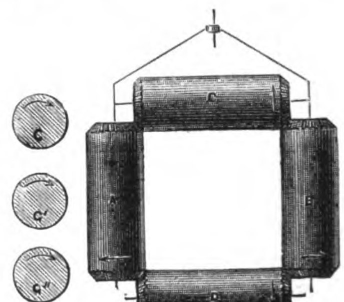


FIG. 17

the four cylinders shown in Fig. 5, and which together are free to turn around a vertical axis; G is the horizontally vibrating cylinder, and if it be placed near to but at the upper end of A, the whole being submerged in viscous fluid, the latter will swing round either forward or backward according to the mutual phases of A and G; if the phases are those indicated by the arrows in the figure, then A will move forward in a direction perpendicular to the plane of the paper; on lowering the position of G this deflective action will become smaller and smaller until it reaches a point G^{I} opposite the middle of the length of A, where it will disappear altogether, and on still further lowering the cylinder G, the deflective action becomes stronger and stronger, but this time in the opposite direction, until the point G^{II} is reached, at which it again reaches a maximum; and on comparing these hydrodynamical phenomena with the electrical phenomena described in connection with Fig. 13, it will be seen that they are inverse to one another.

(To be continued.)

INSTITUTION OF NAVAL ARCHITECTS.

WE concluded our last week's notice of the annual meeting of this Institution with the discussion on Mr. Thornycroft's paper on a light draught pro-

THE HYDRODYNAMIC RESEARCHES OF PROFESSOR BJERKNES.

By CONRAD W. COOKE.

(*Continued from page* 358.)

3. HAVING considered (1) the effect of circularly vibrating cylinders upon a viscous fluid in which they are immersed, and (2) the effect of one vibrating cylinder upon others vibrating in the same medium, we now have to examine (3) the effect of circularly vibrating cylinders upon pulsating and oscillating bodies similarly immersed; and here again we shall find that a remarkable analogy exists between hydrodynamic phenomena of this class and phenomena resulting from the mutual influence of electric currents upon magnets, and of magnets upon electric currents.

From our articles upon Professor Bjerknes's earlier experiments,* it will be remembered that the hydrodynamic analogue of a magnet is a rectilinearly oscillating body, a vibrating sphere for instance, such as is shown at B, Fig. 3,† and when mounted, as shown in that illustration (so as to be capable of turning around a vertical axis) the apparatus becomes the hydrodynamic analogue of a compass needle, or of the needle of a simple galvanometer. With reference to this figure, we need hardly remind our readers that both the cylinder A and the sphere B are set into vibration by an alternating air current transmitted by an air-pump to the two parts of the apparatus respectively through the flexible tubes M and N. If the circularly oscillating cylinder A be brought close to the vibrating sphere B, both being immersed in the viscous medium, the sphere with its frame will rotate around its vertical axis until its axis of vibration lies in a plane perpendicular to that in which the axes of the two instruments both lie. The motions of their proximate surfaces are then in opposite directions, and the position, which is represented in Fig. 18, is one of stable equilibrium. If from this position the frame of B be turned through 180 deg., it will then be in a position of unstable equilibrium, as will be shown by moving it a little to the right or left, when it will immediately return to the position shown in Fig. 18. In this experiment again the hydrodynamic phenomena are inverse to their electro-magnetic analogues, and it is obvious, from what has already been said, that a very perfect hydrodynamic analogy to a galvanometer might be produced by constructing an apparatus in which a horizontally vibrating body, such as a vibrating sphere, is inclosed within the space formed by four circularly vibrating cylinders such as is shown in Fig. 5 and illustrated in the diagram Fig. 14.

Fig. 19 is a view of an exceedingly interesting apparatus designed by Mr. Vilhelm Bjerknes to illustrate the hydrodynamic phenomenon of the rotation of a pulsating body around a circularly vibrating body, which phenomenon is the hydrodynamic analogue of the rotation of a magnet around an electric current, for as we have seen in all Professor Bjerknes's experiments, a pulsating or rectilinearly vibrating body is the analogue of a magnet, while a circularly oscillating body represents hydrodynamically an electric current.

Referring to Fig. 19, A is a cylinder which is made to oscillate around a vertical axis by means of the small pulsating drum H, in connection with the air pump, by means of a flexible tube, and communicating motion to A by a simple system of levers and rods, of which K and L are visible, while others are below the base of the stand F F. B B are two little flat bags of flexible caoutchouc of lenticular form, and are attached by the tubular arm D to a vertical axis which terminates at its lower extremity in a needle point, resting upon an agate centre exactly in the axis of the cylinder A. The little caoutchouc bags B B, are caused to expand and contract together by being connected with the pulsation pump by the flexible tube M, through the air-trap C. When this apparatus is immersed in glycerine and the pump is set to work, the pulsating bodies B B begin to rotate continuously around the cylinder A; and if the phase of pulsation with respect to the phase of vibration of the cylinder be changed, the rotation will be in the opposite direction.

It is a curious fact that in glycerine or in fluids of smaller viscosity the phenomena illustrated by this apparatus are directly analogous to the corresponding electro-dynamic phenomena, thus forming a remarkable exception to the inverse nature of the analogies illustrated by this research, but it must be remembered that the viscosity of glycerine is not so high as that of several other fluids, and it is probable that this may account for the apparent anomaly, for when a fluid of higher viscosity, such as maize syrup, is employed (thus satisfying more completely the conditions required by theory), the rotation of B is in the normal direction, which is inverse to that of the rotation of a magnet around a current.

Just as in the above apparatus the hydro-dynamic analogies of a magnet rotating around an electric current may be produced and studied, so with the apparatus shown in Fig. 20, which is the converse of that illustrated in Fig. 19, the hydrodynamic analogy of an electric current rotating around a magnet may be produced. In this apparatus the circularly vibrating cylinder is replaced by a pulsating cylinder, or, to speak more correctly, by a fixed cylinder A, having a pulsating zone B around the middle of its length, and instead of the pulsating bodies (B B, Fig. 19), there is a circularly vibrating cylinder C, set into motion by the vibrating drum H, and free to turn around the vertical axis of the pulsating cylinder by mechanical devices similar to those described in connection with Fig. 19, the two essential parts of the apparatus being connected respectively to the pulsation pump by the flexible tubes M and N. When this apparatus is set to work in glycerine or in maize syrup, the cylinder C rotates around B, in a direction inverse to that of its electro-magnetic analogue, so that the apparent irregularity applies only to the case of the pulsating body rotating around the circularly vibrating cylinder. Figs. 21 and 22 are diagrams which will explain respectively the action of the apparatus illustrated in Fig. 19, and that of the instrument last described.

In following the long and very beautiful experimental researches of Professor Bjerknes and his son, two points cannot fail to strike the mind of either the experimental philosopher or the practical mechanician; the first is the extremely ingenious and varied devices by which an alternating (blow and suck) current of air is made to do duty in setting all the various parts of the different instruments into synchronous motion, whether that motion be rectilinear vibration, circular oscillation, pulsatory expansions and contractions, or a combination of several of them together; and the second point is that while such a motive power is theoretically nearly perfect for such delicate experiments, it becomes most severely handicapped in its practical application by the apparently overwhelming mechanical difficulties introduced by making joints and pivots, which, while offering no obstruction to the pulsatory current of air through them, should at the same time introduce no more friction or resistance to minute influences of motion than is offered by the needle-point of a compass card. That such extraordinary success should have attended the exceedingly delicate experiments in which an alternating current of air is employed reflects the highest possible credit on Mr. Vilhelm Bjerknes, who devised the apparatus, and upon Mr. Andersen, the resident mechanician to the University of Christiania, who has carried out Mr. Bjerknes's designs with extraordinary perfection of workmanship and constructive ability.

But notwithstanding the great ingenuity displayed in the design, the remarkable skill exhibited in the construction of the apparatus, and the fact that friction and all other disturbing influences have in these instruments been reduced to the lowest possible amount, it must be obvious to any practical mechanician, who is able to appreciate the extremely delicate nature of the experiments, that retarding and disturbing influences, whether of weight or of friction, must, in the case of air-driven instruments, play great havoc with their sensitiveness, and render it impossible for them to exhibit or even detect many phenomena of the

FIG. 19.

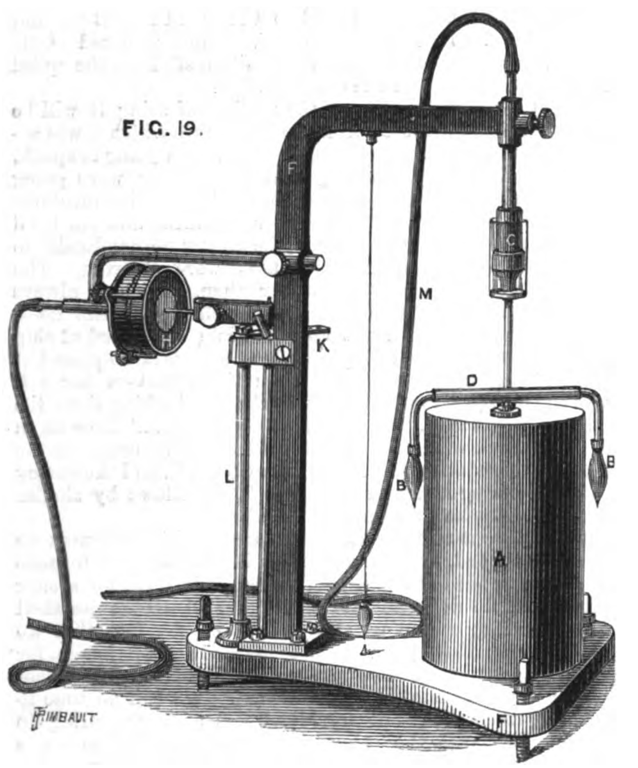


FIG. 20.

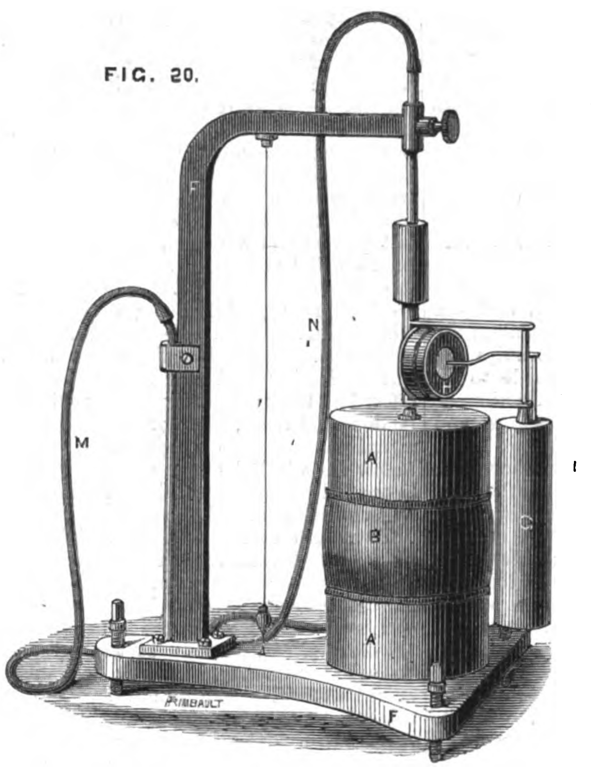


Fig. 18.

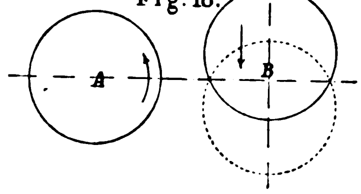


Fig. 21.

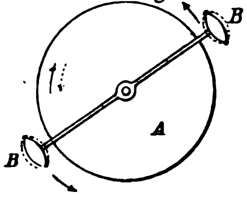
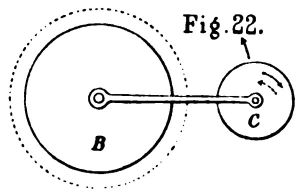


Fig. 22.



* See ENGINEERING, vol. xxxiii., pages 23, 147, and 191.
† See page 305 *ante*.

highest possible importance to the research—for, just as a galvanometer needle, heavy in itself, and involving considerable friction in its method of suspension, is unable to respond to certain currents of electricity transmitted through its coils, indicating an absence of current, when in reality comparatively strong currents are flowing around it, so it is equally clear that in the use of the apparatus which we have been describing, all the phenomena exhibited are reduced in their significance by disturbing and retarding influences, and many phenomena, slightly more delicate but equally important, must be lost altogether to demonstration. Thus Electric Science, as well in her instrumental defects as in her phenomena, finds her hydrodynamic analogue in the researches of Professor Bjerknes and his son.

(*To be continued.*)

THE AUTOBIOGRAPHY OF A WHITEHEAD TORPEDO.—No. XI.

At sunset that night the signal was made from the palace signal station; "Only four corvettes in sight" (being those that had been sent out as pickets).

The coaling proceeded merrily, the officers of those ships which had completed their coaling were allowed to go ashore for an hour or two, and everything seemed very satisfactory. At twelve o'clock rockets were seen from the eastward, followed by two or three guns. Signalmen had been sent up to the palace signal station, so as to communicate with the corvettes in case of need, and now soon the signal was made to them from the eastermost corvette and repeated at once to the admiral, "Enemy in sight close to." Almost immediately after the signal was reported, the corvette ran in and reported that the French were close behind them, coming up from the eastward.

The forts of course were prepared for attack, and now immediately the guns were manned, and preparations were made to resist the attack should the fleet get near enough. The fires of the ships had been banked, but now the signal was made to get up steam full speed again and prepare for action.

Steam was not yet ready in all the ships, and we were awaiting the next signal, when we heard the eastermost forts open fire, and a very short time afterwards a heavy broadside replied. Another and another followed; and then the projectiles began to fall among the shipping. It was certainly the most ridiculous sight any one can imagine; thirty-four English ships like sheep in a fold packed together in Malta harbour, while the whole French squadron steamed past in single column, line ahead at a distance of certainly not more than 800 yards, outside the forts, and firing electric broadsides as they passed. The forts defending the entrance, at the time I speak of, and which can be seen on the chart, were neither so numerous nor so heavily armed as they are now, when we have 100-ton guns in St. Elmo and 38-ton guns in Riscasoli and Tione. The majority of the guns mounted there were the old 10 in. smooth bore coverted guns, with a sprinkling of 8 in. M.L.R. guns, and two 10 in. M.L.R. guns which, if I remember rightly, were at Riscasoli.

The forts inside were armed with 64-pounders and 7 in. M.L.R. guns, and are intended more especially to command the harbour. Hence they were of little use on the present occasion. You can imagine our feelings in the Fearnought, stuck right away inside the Grand Harbour, with half a dozen ships between us and the enemy, so that we could neither get out nor reply to their fire. I had heard some bad language when the fleet got away from Toulon, but the language now was ten times as strong. The abuse that the old admiral got heaped upon his devoted head was something wonderful. "The idea of allowing us to be caught here like rats in a trap, with (like them) nothing to do but squeak; he was an old idiot and only fit to be pole-axed." It never struck any of those who gave vent to these hard sayings, that a suspicion of a thing like this occurring had never for a moment flashed across their own minds until it had actually occured. Ah me! how easy it is to see danger when once you are in it, but how very difficult to foresee what trials or difficulties the next turn of the wheel of fortune may bring upon us.

The French leader having passed along the forts and got well beyond them, made the signal to alter course in succession sixteen points, so arranging his time, that having steamed back well outside his attacking ships, he was ready to follow on again in the wake of the rear ships. Thus a continuous fire was poured into the devoted forts and the shipping beyond them, while fresh assailants were continually coming on. Some two or three of our outermost ships managed to get their broadside to bear, and responded to the fire, but all the other ships were bundled together, and were getting struck right and left, by the enemy's projectiles. It is true that these did not do vital damage, we were too far off for that, but several guns were dismounted, and our upper works knocked about, men killed, and so on; the most galling part of it was that only a few ships could respond to the fire. Meanwhile the reader asks, what was the admiral doing? Surely he did not mean to stop there all night, and let this go on until the French had reduced the forts to a lump of stones and smashed up the fleet.

Oh, no; he had made up his mind at once that he must take the fleet out to meet them, though he fully recognised the great disadvantages under which he must labour, for as our ships were placed, it was impossible to set the fleet out at once in its proper formation, and of course this necessitated making the action simply a disorganised melée, each ship coming into action as best she could and fighting hand to hand regardless of any formation. The enemy were numerically stronger than we were, and of course a hand-to-hand fight like this would give them a great advantage; besides, the first ships that went out would have to contend with fearful odds. All this was fully appreciated, and, while reproaching himself for having thus been caught, he resolved that the attack must be thus made, and that he himself would lead it. He could not move, however, till steam was up, and another twenty minutes, at least, was requisite for this. It was very unfortunate that the ships which were the most backward in this way were the outside ones, but patience is a virtue, and it was necessary to practise that virtue now. Besides, even if some of the ships could have got out, it would have done no good, simply enabling the enemy to mass their whole squadron on the few, and so destroy us piecemeal. Meanwhile the admiral was not idle, but collecting a dozen Maltese boats, he sent off orders to the different ships telling what was to be done. Briefly, these orders were, that when the signal was made to weigh, the ships were to slip, follow the admiral out in the order in which they happened to be anchored, and then engage as the opportunity occurred.

To return to my own ship. The moment that Hand heard that the French fleet were signalled he had caused the torpedoes to be charged and hoisted into our second-class torpedo boat, which had been hoisted out so as to be out of the way of the coaling, and as soon as the firing commenced he asked permission to try his luck with the enemy's fleet. The admiral would have again refused, but the gallant fellow was so eager and enthusiastic that he gave in, and away went Hand in the torpedo boat. He had no preconceived plan, for a wonder, but worked his way out under the high rocks on the left of the Grand Harbour. Having got as far as Point St. Elmo, and seeing the fleet steaming past, he thought this too good an opportunity to be missed, for here was a whole fleet, unprotected by nets, so that they might not be hampered in manœuvring, and steaming steadily past in line. Surely something could be done now with his pet weapon. There was very little chance of concealment, as, though the night was dark enough, the continual flashes from the guns made it quite light, though at the same time the smoke from these same guns helped to increase the obscurity. The breeze was from the north-east and so blew the smoke down from the French fleet on top of the forts, and over the harbour, giving them a decided advantage. Hand might have fired his torpedoes from where he was with comparative safety, and a very fair chance of success, for the enemy were only 800 yards off, and there was a constant stream of them running up and down, so that the odds were much in favour of his hitting something, even if he fired at random. He was not at all fond of leaving things to chance though, and though he well knew that he would be running a risk from the stray fire of both fleets as well as the forts, he determined to run out towards the enemy and trust to the projectiles going over him. I'm not certain whether I told you that I was away in the boat with Hand all this time; you see I was all ready and handy on the main deck; they had charged me with air and whipped me into the boat, so here I was, bound to go at last, and I nerved myself to meet my fate, like a true Whitehead should do; of course it is of no use firing a Whitehead torpedo direct at an object moving through the water, for by the time the torpedo gets to where the object was when it (the torpedo), started, the latter has moved away. Hence the speed of the torpedo and of the object must be taken into consideration when aiming, and for this purpose an instrument called a "torpedo director" is used. The instrument now in use is somewhat as follows:—(see Fig. 37), A B is a director carrying

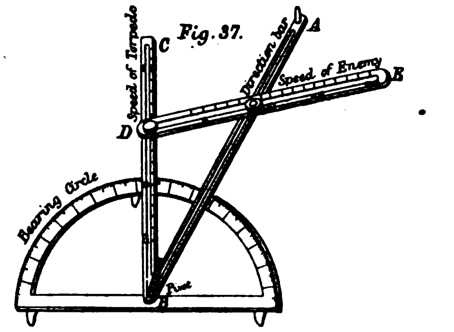


Fig. 37.

sights at A and B. B C is graduated in knots and pivots at B, while B E, which is also graduated in knots, is clamped at D to the speed bar (B C), and at E to the direction bar. The graduated circle serves as a guide for the position of either the speed of torpedo or the direction bar.

An explanation of the method of using it will be best understood from the manner in which it was adjusted on the occasion of which I am going to speak, when Hand judging that the enemy were going 8 knots, while the speed of the torpedo he put down at 20. The torpedo fired right ahead and our head was pointing directly at the enemy perpendicular to the direction in which they were steering. The speed of the torpedo bar then, which is always parallel to the direction in which the torpedo goes, was clamped right ahead, while the speed of ship bar D E was clamped at D at the mark 20 placed at right angles to it, and then the direction bar A B clamped to the 8 mark. Then on looking along the sights B A, when the ship to be fired at came on in a line with them, the torpedo must be fired, for the torpedo leaving in the direction B C, and the enemy coming along parallel to D E, it follows by similar triangles that the two would meet.

So it turned out. On arriving within 300 yards we stopped, and the sights coming on the port torpedo was fired at a French ironclad. We had no sooner fired this torpedo than a storm of Hotchkiss shell falling round us apprised us of the fact that we were discovered. Too late to save the ship though, for thirty seconds afterwards, a loud explosion told that the shot had taken effect. We had no time to watch the result, for Hand was again preparing to discharge the other torpedo, which you know was your humble servant. The ships were one cable apart, therefore in about one quarter of a minute more the sights must come on. Oh, how long that quarter of a minute seemed! Every second appeared a minute to my excited imagination, and I thought the time for action would never come. It became evident too that the next ship, that is the one at which we were going to fire, had also discovered us and had seen the torpedo fired at her next ahead, and preparations being made to give her the same compliment, for a hail of shell now came from her machine guns, threatening us with instantaneous death. Ten, eleven, twelve, thirteen, fourteen, fifteen, then the order "Fire," and I experienced the feeling as of being lifted up by the wind (it was an air gun you know) and thrown into the water, and then I was wending my way under water to destruction.

I was beginning to think that I could not be very far off the enemy, and expecting in a short time to come into collision, when I saw a dark mass on my starboard bow, looming like a huge precipice and rising perpendicularly in the water. "Missed by jingo," I exclaimed to myself, whilst a sort of reprieved feeling crept over me.

I was rather premature, though, in my expression, for the next moment as I glanced past the ram, I found that I had not quite cleared, for I received a violent blow on the screws. This had the effect of bringing the engines to a standstill at once, for as you know the two screws work in opposite directions, and the foremost one being bent by the blow, they immediately locked one another, and so brought up the engines. The result was that in a

THE HYDRODYNAMIC RESEARCHES OF PROFESSOR BJERKNES.

By CONRAD W. COOKE.

(*Continued from page* 414.)

THE two principal difficulties to contend against in the construction of the apparatus were, first, the weights of the various parts, and secondly, the necessity of obtaining vibrations of sufficient amplitude and rapidity with very feeble currents of air, in order not to set the supporting parts into vibration as well, for it is clear that as the weight of the moving parts of the apparatus is reduced, so is the tendency to irregular tremor increased under the influence of pulsatory currents of air of sufficient strength to produce the necessary intensity of vibration.

To meet these difficulties it occurred to Mr. Andersen to apply the principle of the well-known thread-and-button toy, so familiar to every schoolboy, for producing rotary oscillations of great amplitude and velocity. If a disc of cardboard A (Fig. 23), pierced with two holes near its centre and symmetrically disposed thereto, be threaded with an endless loop of thread or twine B twisted on itself as shown in the figure, it may be maintained for an indefinite time in extremely rapid rotary oscillations of very large amplitude, by simply increasing and diminishing alternately the tension of the twisted loop, synchronously with the period of oscillations of the disc. By this means the disc may be caused to make very many vibrations per minute, and of an amplitude which must be measured by many times 360 deg., and, at the same time, it would be difficult to imagine a mechanical device simpler in construction or lighter in the materials of which it is composed. Fig. 24 is a view of a very interesting form of apparatus in which this principle is applied to vibrating cylinders, and by which Professor Bjerknes has been able to reproduce in air some of the phenomena which we have already described in connection with Figs. 5 and 14, but which hitherto could only be performed in glycerine or maize syrup. In this place we would draw our reader's attention to the fact (which we have already pointed out in an earlier article*) that theory does not require a fluid medium of great absolute viscosity, but rather one whose viscosity bears a large ratio to its density, possessing what may be called a great specific viscosity. It is for this reason that the experiments, which we have been describing in the present series of articles, have not been successful when water has been the fluid medium employed, although fluid friction in water is much smaller than that in glycerine or syrup, in which the experiments have been most successful.

* See ENGINEERING, p. 305 *ante*.

In air the friction is still less, while, at the same time, the specific viscosity is much greater than that of water, though smaller perhaps than that of glycerine, and it was this fact that led Professor Bjerknes to undertake a series of experiments with circularly oscillating cylinders in atmospheric air, and with this object the apparatus illustrated in Fig. 24 was constructed.

The arrangement shown in the figure is designed to demonstrate the phenomena of attraction and repulsion between circularly oscillating cylinders whose axes are parallel. It consists of a circular table of brass supported on three legs KKK, fitted with levelling screws, and surmounted by a glass shade G G for protecting the more delicate parts of the apparatus from dust as well as from currents of air. At the centre of the plate is the "balance," which consists of a very light steel frame S S S supporting a pair of vertical cardboard cylinders C C[1], which are kept in circular vibration by the pulsation of a membrane stretched across a drum H, and connected with the pulsation pump by the flexible tube M. The frame S S S is delicately poised upon a vertical axis between two needle points, the upper one being carried by the rigid support F, and the lower within the neck of the drum H. Fig. 25 shows in detail the very ingenious method by which the cylinders are maintained in oscillation by the alternating current of air from an air pump. Referring to this figure, C C is a cylinder made of a tube of stiff paper, its rigidity and cylindrical form being maintained by the three discs x, y, and E, of which x and y form the ends of the cylinder, and E a central plate or diaphragm; through E are drilled two holes symmetrically disposed with respect to its centre, and there is a central hole in x and y. The whole cylinder is supported by being threaded upon an axis consisting of two short lengths of wire passing through x and y, which are drawn together between the fixed arm Q and the vibrating lever P by a twisted loop of fine wire passing through the two holes in the centre disc E. The fixed support Q is a part of the general frame S S S, but the lever P P is pivotted at W to S S, and its bent end rests near the centre of a caoutchouc drumhead stretched over the bell-mouth H, which is connected (as shown in Fig. 24) to the pulsation pump by the flexible tube M. Under the influence of the alternating current of air, the drumhead vibrates, carrying with it the ends of the levers P and P[1], causing an alternate tightening and slacking of the twisted wires, and setting the cylinders into circular vibrations of great rapidity, and of very large amplitude, after the manner of the "thread-and-button" toy shown in Fig. 23. The cylinder D is kept in vibration by a similar device, the only difference being that the lower wire is connected to the centre of the vibrating membrane L, direct instead of through the intervention of a lever as in Fig. 25. The cylinder D can be brought into close proximity to C, and can be made to follow it round by turning the millhead A. The details of this part of the apparatus showing the method by which the alternating air current, brought by the tube N, is conveyed to the drum L in every position of B around its axis, is shown in Fig. 26, which is a vertical section of the parts attached to the centre of the baseplate of the apparatus. The reference letters in Fig. 26 are the same for the same parts as those in Fig. 24. It will be seen that the air current entering at N passes through a hole in the baseplate into a circular groove *a a* cut in the under surface of the block B and concentric with the vertical axis upon which it can be rotated by the millhead A; this latter practically forms part of the block, being rigidly attached to it by the hollow stem shown in the figure, against the shoulder of which it is screwed up with a nut. Thus it will be seen that the relative positions of the cylinder D and cylinders C and C[1] can be adjusted without removing the glass shade G.

When it is required to illustrate the attraction and repulsion between oscillating cylinders whose axes make an angle to one another, the balance carrying the vertical cylinders is removed, and is replaced by the balance shown in Fig. 27, which carries a horizontal cylinder C set into circular vibration by means of the vibrating drum H and a pair of levers shown in the figure, which alternately slacken and tighten a twisted loop of wire, as in the balance shown in Fig. 24.

With this interesting apparatus Professor Bjerknes has been able to reproduce in air all the phenomena which in glycerine or syrup were produced with the apparatus shown in Fig. 5,* and in every case the effects are inverse to their corresponding electro-magnetic analogues.

(*To be continued.*)

* See ENGINEERING, page 305 *ante*.

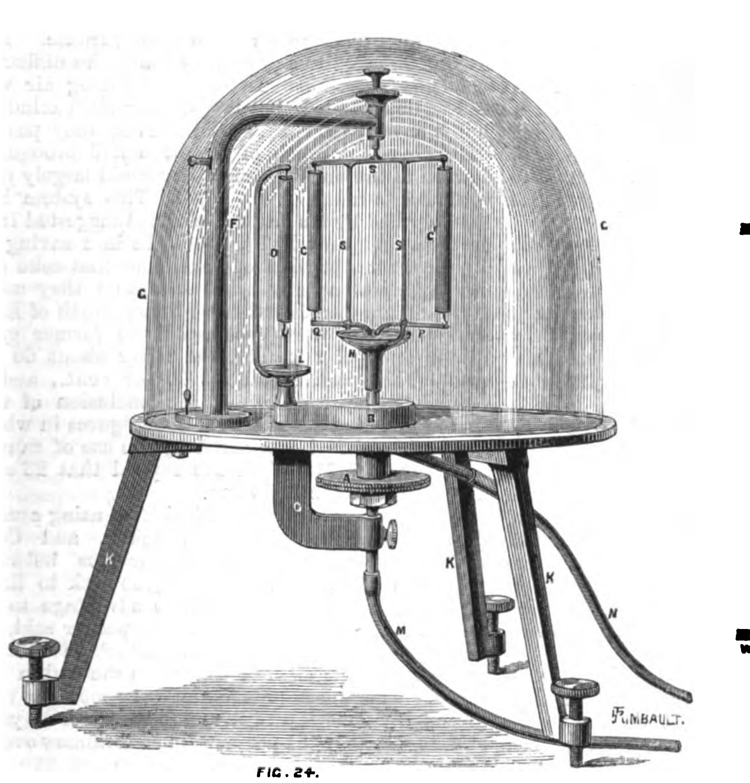
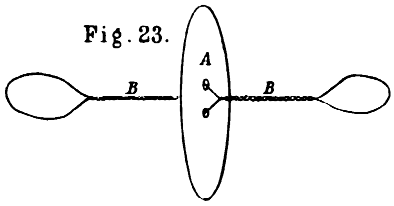


FIG. 24.

Fig. 23.



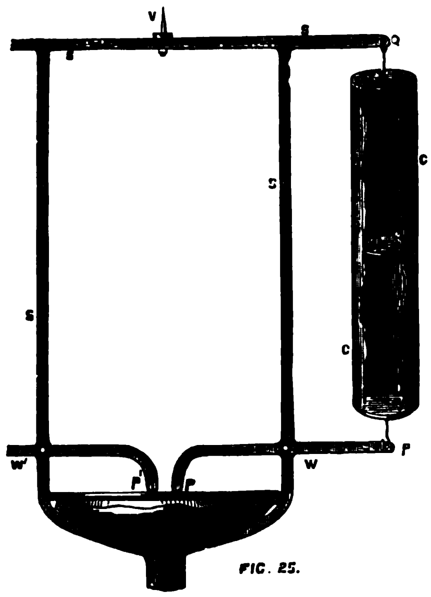
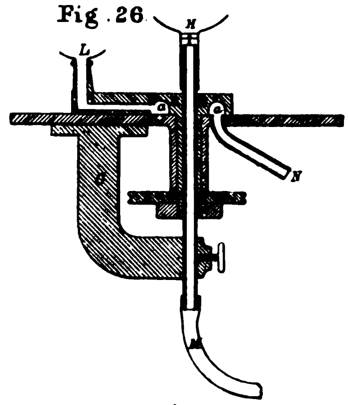


FIG. 25.

Fig. 26



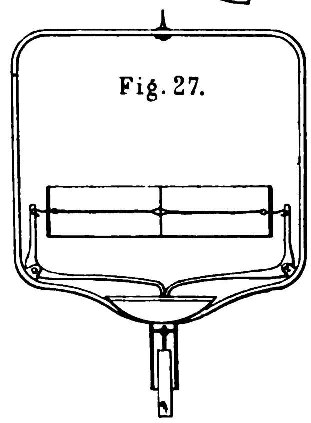


Fig. 27.

THE IRON AND STEEL INSTITUTE.

As we briefly announced last week, the Iron and Steel Institute held its annual London meeting on the 6th inst. and the two following days.

The President's address first occupied the attention of the meeting. This we commenced to print in full last week, and continue it in the present number on page 563. At the conclusion of the reading Sir H. Bessemer moved a vote of thanks for the address just heard, which he characterised as one of the finest the members of the Institution had ever had the good fortune to listen to. The meeting then adjourned until the afternoon.

On assembling again the first business was to