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COMPLETE SPECIFICATION.

[Communicated from abroad by Nikola Tesla, of 46, East Houston Street, Borough of Manhattan, New York, United States of America, Electrician.]

Improvements in Electrical Circuit Controllers.

I, Henry Harris Lake, of the Firm of Haseltine, Lake & Co., Patent Agents, 45, Southampton Buildings, in the County of Middlesex, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

I have heretofore invented and patented methods and apparatus for the generation, conversion and utilization of electrical currents of very high frequency based upon the principle of charging a condenser, and discharging the same, generally through the primary of a transformer, the secondary of which constituted the source of working currents, and under such conditions as to yield a vibrating or rapidly intermittent current.

In some of the forms of apparatus which I have heretofore devised for carrying out the methods referred to, I have employed a mechanism for making and breaking an electric circuit or branch thereof for the purpose of charging and discharging the condenser, and the present application is based upon a novel and improved type of a circuit controller or device for this purpose. The principles of construction and operation of the apparatus designed in accordance with this invention will be understood from the following statement of the nature of its requirements and mode of use.

In every device which makes and breaks an electric circuit with any considerable degree of abruptness, a waste of energy occurs during the periods of make or break, or both, due to the passage of the current through an arc formed between the receding or approaching terminals or contacts, or, in general, through a path of high resistance. The tendency of the current to persist after the actual disjunction or to precede the conjunction of the terminals exists in varying degrees in different forms of apparatus, according to the special conditions present. For example, in the case of an ordinary induction coil, the tendency to the formation of an arc at the break is, as a rule, the greater, while in certain forms of apparatus for utilizing the discharge of a condenser, such as heretofore referred to, this tendency is greatest at the instant immediately preceding the conjunction of the contacts of the circuit controller which effects the discharge of the condenser.

The loss of energy occasioned by the causes mentioned may be very considerable, and is generally such as to greatly restrict the use of the circuit controller and render impossible a practical and economical conversion of any considerable amounts of electrical energy by its means, particularly in cases in which a high frequency of the makes and breaks is required.

Extended experiment and investigation, conducted with the aim of discovering a means for avoiding the loss incident to the use of ordinary forms of circuit controllers, have led me to recognize certain laws governing this waste of energy and which show it to be dependent, chiefly, on the velocity with which the terminals

approach and recede from one another and also more or less on the form of the current wave. Briefly stated, from both theoretical considerations and practical experiment, it appears that the loss of energy in any device for making and breaking a circuit, other conditions being the same, is inversely proportional rather to the square than to the first power of the speed or relative velocity of the terminals in approaching and receding from one another, in any instance in which the current wave is not so steep as to materially depart from one which may be represented as a sine function of the time.

But such a case seldom obtains in practice; on the contrary, the current curve resulting from a make and break is generally very steep, and particularly so when, as in my system, the circuit controller effects the charging and discharging of a condenser, and consequently the loss of energy is still more rapidly reduced by an increased velocity of approach and separation of the terminals. The demonstration of these facts and the recognition of the impossibility of attaining the desired results by using ordinary forms of circuit controllers, have led me to invent the novel apparatus for making and breaking a circuit, which in several modified forms is made the subject of the present application.

Various devices for making and breaking an electric current have heretofore been used or proposed in which the separable contact points or terminals were contained in an exhausted vessel or surrounded by an inert atmosphere, but there are certain theoretical conditions necessary for complete success, which I have recognized and which have not been attained by the means heretofore employed. These may be summed up as follows:

(1) The medium by which the contact points are surrounded should have as high an insulating quality as possible, so that the terminals may be approached to an extremely short distance before the current leaps across the intervening space.

(2) The closing up or repair of the injured dialectric, or in other words, the restoration of the insulating power, should be instantaneous, in order to reduce to a minimum the time during which the waste principally occurs.

(3) The medium should be chemically inert so as to diminish as much as possible the deterioration of the electrodes and to prevent chemical processes which might result in the development of heat, or in general, in loss of energy.

(4) The giving way of the medium under the application of electrical pressure should not be of a yielding nature, but should be very sudden, and in the nature of a crack, similar to that of a solid, such as a piece of glass, when squeezed in a vice;

(5) And most important, the medium ought to be such that the arc, when formed, is restricted to the smallest possible linear dimensions and is not allowed to spread or expand.

As a step in the direction of these theoretical requirements I have heretofore employed in some of my circuit controlling devices a fluid of high insulating qualities, such as liquid hydro-carbon, and caused the same to be forced, preferably, with great speed, between the approaching and receding contact points of the circuit controller. By the use of such liquid insulation a very marked advantage was secured, but while some of the above requirements were attained in this manner, certain defects still existed, notably that due to the fact that the inslating liquid, in common with a vacuous space, though in a lesser degree, permits the arc to expand in length and thickness, and to thus pass through all degrees of resistance, thereby causing a greater or less waste of energy.

To overcome this defect and to still more nearly attain the theoretical conditions required for most efficient working of the circuit controlling devices, I have been finally led to use a gaseous insulating medium subjected to great pressure.

The application of great pressure to the medium in which the make and break are made, secures a number of special advantages. One of these may be obviously inferred from well-established experimental facts, which demonstrate that the

striking distance of an arc is, approximately, inversely proportional to the pressure of the gaseous medium in which it occurs. But in view of the fact that in most cases occurring in practice the striking distance is very small, since the differences of potential between the electrodes are usually not more than a few hundred volts, the economical advantages resulting from the reduction of the striking distance, particularly on the approach of the terminals, are not of very great practical consequence. By far the more important gain I have found to result from a novel effect which I have observed to follow from the action of such a medium when under pressure, upon the arc, namely, that the cross-section of the latter is reduced approximately in an inverse ratio to the pressure. As under conditions, in other respects the same, the waste of energy in an arc is proportional to the cross-section of the latter, a very important gain in economy generally results. A feature of great practical value lies also in the fact that the insulating power of the compressed medium is not materially impaired even by considerable increase in temperature, and, furthermore, that variations of pressure between wide limits, if the apparatus is properly constructed, do not interfere notably with the operation of the circuit controller. In many other respects, however, a gas under great compression, nearly fulfils the ideal requirements above mentioned, as in the sudden breaking down and quick restoration of the insulating power, and also in chemical inertness which, by proper selection of the gas, is easily secured.

In applying this feature of my invention the medium under pressure may be produced or maintained in any proper manner, the improvement not being limited in this particular to any special means for the purpose. I prefer, however, to secure the desired result by confining the circuit controller, or at least so much of the same as shall include the terminals, in a closed chamber or receptacle with rigid walls, with the interior of which communicates a small reservoir containing a liquified gas.

Referring now to the accompanying drawings for a more detailed description of the apparatus,

Fig. 1 is a diagram illustrating the general arrangement of the circuit controller and the special manner in which it is designed to be used.

Fig. 2 is a top plan view of the circuit controller.

Fig. 3 is a view partly in section and partly in elevation of the complete apparatus indicated diagrammatically in Fig. 1.

The remaining figures are central sectional views of modified forms of the apparatus, with the exception of Fig. 10, which is a sectional plan view of the upper portion of the form of apparatus shown in Fig. 9.

The general scheme of the system for use with which the improved circuit controller is more especially designed, will be understood by reference to Fig. 1. In said figure X, X represent the terminals of a source of current, A^1 is a self induction or choking coil included in one branch of the circuit and permanently connected to one side of a condenser A^{11}. The opposite terminal of this condenser is connected to the other terminal of the source through the primary A^3 of a transformer, the secondary A^4 of which supplies the working circuit containing any suitable translating devices, as A^5.

The circuit controller A which is represented conventionally, operates to make and break a bridge from one terminal of the source to a point between the choking coil A^1 and the condenser A^{11}, from which it will result that when the circuit is completed through the controller, the choking coil A^1 is short circuited and stores energy, which is discharged into the condenser when the controller circuit is broken, to be in turn discharged from the condenser through the primary A^3, when the said condenser and primary are short circuited by the subsequent completion of the controller circuit.

Figs. 2 and 3 illustrate a typical form of the circuit controller. The parts marked A, B, compose a closed receptacle of cylindrical form having a dome or

extension of smaller diameter. The receptacle is secured to the end of a spindle a which is mounted vertically in bearings of any character suitable for the purpose.

Rapid rotation is imparted to the receptacle in any suitable manner, as by means of a field magnet a^1 secured to the base or frame, and an annular armature a^{11} secured to the receptacle A. The coils of the armature are connected with the plates c of a commutator secured to the receptacle A and made in cylindrical form so as to surround the socket in which the spindle a is stepped.

A body of magnetic material c^1 which serves as an armature is mounted on anti-friction bearings on an extension of the spindle a so that the receptacle and the body c^1 may have freely independent movements of rotation.

Surrounding the dome B in which the armature is contained is a core with pole pieces c^{11}, which are magnetized by coils b wound on the core. The said core is stationary, being supported by arms b^1, Fig. 2, independently of the receptacle, so that when the receptacle is rotated and the core energized, the attractive force exerted by the poles c^{11} upon the armature c^1 within the receptacle A holds the said armature against rotation. To prevent loss from currents set up in the shell of the dome B, the latter should be made of German silver or other similar precaution taken.

An arm b^{11} is secured to the armature c^1 within the receptacle A and carries at its end a short tube d bent as shown in Fig. 2, so that one end is tangential to the receptacle wall, and the other directed towards the center of the same.

Secured to the top plate of the receptacle A are a series of conducting plates d^1. The part of the top plate d^{11} from which said conducting plates depend, is insulated from the receptacle proper by insulating packing rings, but is electrically connected with the dome B, and in order to maintain electrical connection from an external circuit to the conductors d^1 a mercury cup e is set in the top of the dome, into which cup extends a stationary terminal plug e^1.

A small quantity of a conducting fluid, such as mercury, is put into the receptacle A and when the latter is rotated, the mercury, by centrifugal action, is forced out towards the periphery and rises up along the inner wall of the receptacle. When it reaches the level of the open mouthed tube d, a portion is taken up by the latter which is stationary, and forced by its momentum through the tube and discharged against the conductors d^1 as the latter pass in rapid succession by the orifice of said tube.

In this way the circuit between the receptacle and the conductors d^1 is completed during the periods in which the stream or jet of mercury impinges upon any of the said conductors and broken whenever the stream is discharged through the spaces between them.

The feature of my invention which consists in maintaining an atmosphere of inert gas under pressure in the receptacle containing the circuit controller is applicable to all of the forms of circuit controller herein described. A special arrangement for the purpose, however, is shown in Fig. 4, which exhibits also a modified arrangement of the circuit controlling mechanism designed to overcome the objection which in some cases might lie to such forms as those of Figs. 2 and 3 from the amount of work which the conducting fluid is required to perform at very high speeds.

Referring to Fig. 4, the receptacle A has a head B secured by a gas-tight insulating joint. A spindle C is screwed or otherwise secured centrally in the head B and on this is mounted on antifriction bearings a sleeve D to which rotary motion may be imparted in any suitable manner, as by securing to said sleeve D a laminated magnetic core a^1 and placing around the portion of the head B which contains it a core a^{11} provided with coils and constituting the primary element of a motor capable of producing a rotary field of force which will produce a rapid rotation of the secondary element or core a^1.

To the depending end of the sleeve D is secured a conducting disk D^1 with downwardly extending teeth or projections d^1.

To the sleeve or to the disk D^1 is also attached, but insulated therefrom, a

shaft D^{11} having a spiral blade E^1 and extending down into a well or cylindrical recess in the bottom of the receptacle.

One or more ducts or passages E lead from the bottom of this well to points near the path of the conducting teeth of the disk D^1 so that by the rotation of the screw E^1 the conducting fluid will be forced up through the duct or ducts from which it issues in a jet or jets against the rotating conductor.

To facilitate this operation, the well is surrounded by a flange E^{11} containing passages e^{11} which permit the conducting fluid to flow from the receptacle into the well, and having bevelled sides which serve as a shield to deflect the fluid expelled from the ducts through the spaces in the conductor to the bottom of the receptacle.

Any suitable reservoir M is placed in communication with the interior of the main receptacle and partially filled with a liquified gas which maintains a practically inert atmosphere under pressure in the receptacle. Preferably, though mainly as a matter of convenience, the reservoir M is a metal cup with a hollow central stem F^1, the opening for the passage of gas being controlled by a screw-valve in the top of the cup. The cup is screwed onto the end of the spindle C, through which is a passage F^{11} leading into the interior of the receptacle.

To insure a good electrical connection between the sleeve D and the spindle C, I provide in the former a small chamber *f* which contains mercury, and into which the end of the spindle C extends.

Fig. 5 illustrates a modification of the circuit controller which involves two prominent features useful in devices of this character. One, that it provides for maintaining, in a rotating receptacle, a stationary jet or jets which, by impinging on a rigid conductor, maintain the latter in rotation, thereby securing the requisite rapidly intermittent contact between the two; the other, that it utilizes the rotation of such rigid conductor as a means for opposing or preventing the movement of its own supports in the direction of rotation of the receptacle, thereby securing, among other things, an approximately constant relative movement between the parts, a feature which, in devices of this kind, is often very desirable.

In said Fig. 5 the receptacle A is provided with trunnions which have bearings in standards f^{11}, f^{11}, and which permit the rotation of the receptacle about a horizontal axis.

In the particular form of device under consideration the receptacle is divided into two parts insulated by a washer G and held together by insulated bolts G^1 with nuts G^{11}.

A body I is supported by trunnions *g* having bearings in the ends of the receptacle and concentric with the axis of rotation of the same. The weight of the body I, being eccentric to this axis, tends to oppose its turning about the axis when the receptacle is rotated.

Upon the body or support I, but insulated therefrom, is secured a vertical standard g^1 in which there is a freely rotatable spindle f^1 carrying a disk g^{11} with radial arms inclined to the plane of the disk so as to form vanes d^1.

Arms i, i^1 are also secured to the body I and are formed with, or carry at their ends, ducts or tubes *d* with one end directed towards and opening upon the vanes d^1, and the other end close to the inner wall of the receptacle and opening in the direction opposite to that of its rotation.

A suitable quantity of mercury is placed in the receptacle before the latter is sealed or closed.

The operation of the device is as follows : The receptacle is started in rotation, and, as it acquires a high velocity, the mercury or other conducting fluid is caused, by centrifugal action, to distribute itself in a layer over the inner peripheral surface.

As the tubes or ducts *d* do not take part in the rotation of the fluid, being held at the start by the weighted body I, they take up the mercury as soon as it is

carried to the points where the ducts open, and discharge it upon the vanes of the disk g^{11}.

By this means the disk is set in rapid rotation, establishing the contact between the two sides of the receptacle which constitute the two terminals of the circuit controller whenever the two streams or jets of fluid are simultaneously in contact with the vanes, but breaking the contact whenever the jets discharge through the spaces between the vanes.

The chief object of employing two insulated jets rather than one is to secure a higher velocity of approach and separation, and in this respect the device may be still further improved by providing any number of such insulated compartments and jets and a corresponding number of rotating rigid conductors.

The disk g^{11}, having acquired a very rapid rotation, operates by gyrostatic action to prevent any tendency of the body I to rotate or oscillate, as such movement would change the plane of rotation of the disk. The movement of the parts, therefore, and the operation of the device as a whole is very steady and uniform and a material practical advantage is thereby secured. The speed of the disk will be chiefly dependent on the velocity of the streams and pitch of the blades, and it is, of course, necessary, in order to produce a constant speed of rotation of the disk, that the velocity of the streams be constant. This is accomplished by rotating the receptacle with a constant speed, but when this is impracticable and the uniformity of motion of the disk very desirable, I resort to special means to secure this result, as by providing overflowing reservoirs i^{11}, i^{11}, as indicated by dotted lines, from which the fluid issues upon the vanes with constant velocity, though the speed of the receptacle may vary between wide limits.

It will be understood that the jets which effect the electrical contact, need not necessarily be utilized to drive the disk, but that for this latter purpose additional jets may be provided and applied to an insulated portion of the disk or to a body connected therewith, in which case such jets may be made to impinge instead of upon the peripheral portions, on parts situated nearer to the axis of rotation, thus causing a more rapid movement of the disk. The jets may also be produced in many other ways.

To still further increase the rate of relative movement of the terminals, each may be rotated with respect to the other. This may be effected in various ways, of which the device shown in Fig. 6 is an example. In said figure H designates a casting of cylindrical form within which is a standard or socket in which is mounted a vertical spindle *a* carrying the circuit controlling mechanism.

The said mechanism is contained in a receptacle A, the top or cover of which is composed of an annular plate and a cap or dome B, the latter being of insulating material or of a metal of comparatively high specific resistance, such as German silver. Any suitable means may be employed to effect the rotation of the receptacle, the particular device shown for this purpose being an electro-magnetic motor, one element a^1 of which is secured to the spindle *a* or receptacle A, and the other a^{11} to the box or case H. Within the receptacle A, and secured to the top of the same, but insulated therefrom, is a circular conductor with downwardly extending projections or teeth d^1. This conductor is maintained in electrical connection with a plate H^1 outside of the receptacle by means of screws or bolts H^{11} passing through insulated gaskets in the top of the receptacle A.

Within the latter is a standard or socket *h*, in which is mounted a spindle h^1 concentric with the axis of the receptacle.

Any suitable means may be provided for rotating the spindle independently of the receptacle A, but for this purpose I again employ an electro-magnetic motor, one element h^{11} of which is secured to the spindle h^1 within the receptacle A, and the other *j* is secured to the box H and surrounds the cap or dome B, within which is mounted the armature h^{11}.

Depending from the spindle h^1 or the armature h^{11} is a cylinder, to which are secured arms b^{11}, b^{11} extending radially therefrom and supporting short tubes or

ducts d between the peripheral walls of the receptacle A and the series of teeth or projections d^1.

The tubes d have openings at one end in close proximity to the inner wall of the receptacle A and turned in a direction opposite to that in which the latter is designed to rotate, and at the other end orifices which are adapted to direct a stream or jet of fluid against the projections d^1.

To operate the apparatus the receptacle A, into which a suitable quantity of mercury is first poured, and the spindle h^1 are both set in rotation by their respective motors and in opposite directions. By the rotation of receptacle A the conducting fluid is carried by centrifugal force up the sides or walls of the same and is taken up by the tubes or ducts d and discharged against the rotating conductors d^1. If, therefore, one terminal of the circuit be connected with any part of the receptacle A, or the metal portions of the instrument in electrical connection therewith, and the other terminal be connected to the plate H^1, the circuit between these terminals will be completed whenever a jet from one of the ducts d is discharged against one of the projections d^1, and interrupted when the jets are discharged through the spaces between such projections.

Instead of using a solid or rigid conductor for one of the terminals or contacts and a conducting fluid for the other, I may use a conducting fluid for both, under conditions which permit of a rapidly intermittent contact between them, as will be seen by reference to Fig. 7.

The receptacle, as shown in this figure, is composed of two parts insulated from each other and supported by trunnions so as to rotate about a horizontal axis. The abutting ends of the two parts are formed with inwardly extending flanges J^1 which divide the peripheral portion of its interior into two compartments J^{11} and K^{11}.

Into one of these compartments, as J^{11}, extends a spindle K, having its bearing in one end of the receptacle A, and the trunnion secured to or extending therefrom. Into the other compartment K^{11} extends a spindle K^1 similarly journalled in the opposite end of the receptacle A and its trunnion.

Each spindle carries or is formed with a weighted arm I, which remaining in a vertical position holds its spindle stationary when the receptacle is revolved.

To the weighted arm or spindle K is secured a standard L carrying a tube d with one open end in close proximity to the inner peripheral wall of the compartment J^{11} and the other directed towards the axis, but inclined towards the opposite compartment.

To the weighted arm or spindle K^1 is similarly secured to standard L^1 which is hollow and constitutes a portion of a duct or passage which extends through a part of the spindle and opens through a nozzle l^{11} into a circular chamber l in the wall of the receptacle. From this chamber run passages l^1 to nozzles m in position to discharge jets or streams of liquid in such directions as to intersect, when the nozzles are rotated, a stream issuing from the end of tube d.

In each portion or compartment of the receptacle is placed a quantity of mercury, and the ends of the tubes are provided with openings which take up the mercury when, on the rotation of the receptacle, it is carried by centrifugal force against the peripheral wall. The mercury when taken up by the tube d issues in a stream or jet from the inner end of said tube and is projected into the compartment K^{11}. The mercury taken up by the tube L^1 runs into the circular chamber l from which it is forced through the passages l^1 to the nozzles m from which it issues in jets or streams directed into the compartment J^{11}. As the nozzles m revolve the streams which issue from them will therefore be carried across the path of the stream which issues from the tube d and which is stationary, and the circuit between the two compartments will be completed by the streams whenever they intersect, and interrupted at all other times.

The continuity of the jets or streams is not preserved, ordinarily, to any great distance beyond the orifices from which they issue, and hence they do not serve as

conductors to electrically connect the two sides of the receptacle beyond their point of intersection with each other.

It will be understood that so far as the broad feature of maintaining the terminal jets is concerned, widely different means may be employed for the purpose and that the spindles mounted in free bearings concentrically with the axis of rotation of the receptacle and held against rotation by the weighted arms constitute but one specific way of accomplishing this result. This particular plan, however, has certain advantages and may be applied to circuit controllers of this class generally whenever it is necessary to maintain a stationary or nearly stationary body within a rotating receptacle.

It is further evident, from the nature of the case that it is not essential that the jet or jets in one compartment or portion of the instrument should be stationary and the others rotating, but only that there should be such relative movement between them as to cause the two sets to come into rapidly intermittent contact in the operation of the device.

The number of jets, whether stationary or rotating, is purely arbitrary, but since the conducting fluid is directed from one compartment into the other, the aggregate amount normally discharged from the compartments should be approximately equal. However, since there always exists a tendency to project a greater quantity of the fluid from that compartment which contains the greater into that which contains the lesser amount no difficulty will be found in this respect in maintaining the proper conditions for the satisfactory operation of the instrument.

A practical advantage, especially important when a great number of breaks per unit of time is desired, is secured by making the number of jets in one compartment even and in the other odd, and placing each jet symmetrically with respect to the center of rotation. Preferably the difference between the number of jets should be one. By such means, the distances between the jets of each set are made as great as possible and hurtful short-circuits are avoided.

For the sake of illustration, let the number of jets or nozzles *d* in one compartment be nine, and the number of those marked *m* in the other compartment ten, then by one revolution of the receptacle there will be ninety makes and breaks.

To attain the same result with only one jet as *d* it would be necessary to employ ninety jets *m* in the other compartment, and this would be objectionable, not only because of the close proximity of the jets, but also of the great quantity of fluid required to maintain them.

In the use of the instrument as a circuit controller it is merely necessary to connect the two insulated parts of the receptacle to the two parts of the circuit respectively.

In instruments of this character in which both terminals are formed by a liquid element, there is no wear or deterioration of the terminals and the contact between them is more perfect. The durability and efficiency of the devices are thus very greatly increased.

I may also secure the same result by a modified form of circuit controller, in which the closure of the circuit is effected through two parts of conducting fluid, but in this case instead of breaking the circuit by the movement of these two parts or terminals, as in the device of Fig. 7, I separate them periodically by the interposition of an insulator which is preferably solid and refractory.

For example, I provide a plate or disk with teeth or projections of glass, lava or the like, which are caused by the rotation of the disk to pass through the jet or fluid conductor and thus effect a make and break of the circuit.

By means of such a device the breaks always occur between fluid terminals, and hence deterioration and consequent impairment of the qualities of the apparatus is avoided.

In Fig. 8, which shows this form of controller, the receptacle which contains the terminals is mounted on a spindle *a* in a suitable socket or support so as to rotate freely.

The means shown for rotating the receptacle are the same as in Fig. 3, although any other might be employed.

In the spindle *a*, and concentric with its axis, is a spindle M supported on ball-bearings or otherwise arranged to have a free movement of rotation relatively to the spindle *a* so as to be as little as possible influenced by the rotation of the latter.

Any convenient means is provided to oppose or prevent the rotation of the spindle M during the rotation of the receptacle. In the particular arrangement here shown for this purpose a weight or weighted arm I is secured to the spindle M, and eccentrically to the axis of the latter, and, as the bearing for the spindle *a* holds the same at an angle to the vertical, this weight acts by gravity to hold the spindle M stationary.

Secured to the top or cover of the receptacle A, by a stud m^1 which passes through an insulating bushing in said cover and is held by a nut m^{11}, is a circular disk M^1 of conducting material, preferably iron or steel, having its edge turned downwardly and then inwardly to provide a peripheral through on the underside of the disk.

To the under side of the disk M^1 is secured a second disk M^{11} having downwardly inclined peripheral projections *n*, *n*, of insulating and preferably refractory material in a circle concentric with the disk M^1.

A tube or duct *d* is mounted on the spindle M or the weight I, and is so arranged that the orifice at one end is directed outwardly towards the trough of the disk M^1 while the other lies close to the inner peripheral wall of the receptacle so that if a quantity of mercury or other conducting fluid be placed in the receptacle and the latter rotated, the tube or duct *d*, being held stationary, will take up the fluid which is carried by centrifugal action up the side of the receptacle and deliver it in a stream or jet against the trough or flange of the disk M^1 or against the inner surfaces of the projections *n* of disk M^{11}, as the case may be.

Obviously, since the two disks M^1 and M^{11} rotate with respect to the jet or stream of fluid issuing from the duct *d*, the electrical connection between the receptacle and the disk M^1 through the fluid will be completed by the jet when the latter passes to the disk M^1 between the projections *n*, and will be interrupted whenever the jet is interrupted by the said projections.

The rapidity and the relative duration of the makes and breaks is determined by the speed of rotation of the receptacle and the number and width of the intercepting projections *n*.

By forming that portion of the disk M^1 with which the jet makes contact, as a trough, which will retain, when in rotation, a portion of the fluid directed against it, a very useful feature is secured. The fluid, under the action of centrifugal force accumulates in and is distributed along the trough and forms a layer over the surface upon which the jet impinges. By this means a very perfect contact is always secured, and all deterioration of the terminal surfaces avoided.

It is not necessary that the conducting fluid which forms one of the terminals, should be in the form of a jet issuing from the orifice of a tube or duct. The same results may be secured by the use of a body or stream of the fluid maintained in rapid movement in other ways, and in Figs. 9 and 10 I have illustrated a means for accomplishing this.

The receptacle A is mounted and rotated in the case in the same manner as in Fig. 8, and a spindle M carrying an eccentric weight I is also employed.

Attached to the spindle M or weight I is an insulated bracket O carrying a standard or socket O^1 in which is mounted, on antifriction bearings, a spindle O^{11}. Secured to this latter is a plate with radial arms *o* from which depend vanes or blades o^1, with projections o^{11} extending radially therefrom. A shield or screen P encloses the vanes except on the side adjacent to the inner periphery of the receptacle A.

A small quantity of a conducting fluid is placed in the receptacle, and in order

to secure a good electrical connection between the vanes o^{I} and a terminal on the outside of the receptacle, a small mercury cup p in metallic contact with the vanes through the bracket O and socket O^1 is secured to the weight I. A metal stud set in an insulated bolt m^1 projects into the cup p through a packed opening in its cover. One terminal of the circuit controlling mechanism will thus be any part of the metal receptacle, and the other the insulated bolt m^1.

To operate the apparatus, the receptacle is set in rotation, and as its speed increases the mercury or other conducting fluid which it contains is carried, by centrifugal force, up the sides of the inner wall over which it spreads in a layer. When this layer rises sufficiently to encounter the projections o^{11} on the blades or vanes o^1, the latter are set in rapid rotation, and the electrical connection between the terminals of the apparatus is thereby made and broken, it may be, with very great rapidity.

The projections o^{11} are preferably placed at different heights on the vanes o^1 so as to secure greater certainty of good contact with the mercury film when in rapid rotation.

In all of the several modified forms of my improved apparatus above described, the receptacle which contains or encloses the parts or elements of the circuit controller proper, is rotated; but this is not essential, since, by proper modification of the apparatus the necessary relative movement may be secured between the terminals when contained in a stationary receptacle.

This is illustrated in Fig. 11, in which a stationary receptacle A is shown as composed of top and bottom plates of metal and a cylindrical portion of insulating material, such as porcelain. Within the receptacle, and preferably integral with the side walls, are two annular troughs W, W^1, which contain a conducting fluid, such as mercury. Terminals R, R^1, passing through the bottom of the receptacle through insulating and packed sleeves, afford a means of connecting the mercury in the two troughs with the conductors of the circuit.

Surrounding that portion of the device in which the troughs W, W^1, lie is a core A^{11} wound with coils arranged in any suitable and well-known manner to produce, when energized by currents of different phase, a rotating magnetic field in the space occupied by the two bodies of mercury. To intensify the action, a circular laminated core r is placed within the receptacle.

If by this or any other means, the mercury is set in motion and caused to flow around in the troughs, and if a conductor be mounted in position to be rotated by the mercury, and when so rotated to make intermittent contact therewith, a circuit controller may be obtained of novel and distinctive character, and capable of many useful applications independently of the other features which are embodied in the complete device which is illustrated.

For the present purpose I provide in the center of the receptacle a socket in which is mounted a spindle R^{11} carrying a disk r^1. Depending from said disk are arms r^{11} which afford bearings, for a shaft S supporting two star-shaped wheels S^1, S^{11}, arranged to make contact with the mercury in the two troughs respectively. The shaft S is mounted in insulated bearings, so that when both wheels are in contact with mercury the circuit connecting the terminals R, R^1 will be closed. The disk r^1 carries an annular core T, and coils T^{11} are supported outside of the receptacle and are preferably of the same character as those used for imparting rotation to the mercury, but the direction of rotation should be opposite to that of the mercury.

The rate of rotation of the wheel S^1, S^{11} depends upon the rate of relative movement of the mercury, and hence if the mercury be caused to flow in one direction and the wheels be carried bodily in the opposite direction, the rate of rotation and consequently the frequency of the makes and breaks will be very greatly increased over that which would be obtained if the wheels S^1, S^{11} were supported in a stationary bearing.

In all the forms of circuit controller above described in which the circulation

of the conducting fluid through tubes or ducts is maintained, the force which impels the fluid is derived from the same source as that which rotates the receptacle or maintains the relative movement of the terminals. In other words, instead of employing an independent pump or like device for forcing the fluid trough the ducts, I combine in one, the two mechanisms—the controller and the means for maintaining a circulation of the conducting fluid.

It will be observed that the invention involves many features which are broadly new in instruments of this character, and is not limited to the specific forms of apparatus shown and described, but may be carried out by other and widely differing forms.

Having now particularly described and ascertained the nature of this invention and in what manner the same is to be performed, as communicated to me by my foreign correspondent, I declare that what I claim is:—

1. A circuit controller comprising in combination, a receptacle containing a conducting fluid, means for rapidly rotating the receptacle or the fluid therein, and a terminal or terminals supported within the receptacle and adapted to make and break electrical connection with the fluid.

2. The combination with a receptacle of a conductor or series of spaced conductors, a nozzle or tube for directing a jet or stream of fluid against the same, the nozzle and conductor being capable of movement relatively to each other, and means for maintaining a circulation of conducting fluid, contained in the receptacle, through said nozzle, and dependent for operation upon such relative movement.

3. The combination with a closed receptacle of a conductor or series of spaced conductors, a nozzle or tube for directing a jet or stream of fluid against the same, and means for forcing a conducting fluid contained in the receptacle through the said nozzle, these parts being associated within the receptacle and adapted to be operated by the application of a single actuating power.

4. The combination with a receptacle containing a series of spaced conductors, a duct within the receptacle having one of its ends directed towards the said conductors, means for maintaining a rapid movement of relative rotation between the said end and the conductors and means for maintaining a circulation of a conducting fluid contained in the receptable through the duct against the conductors, the said conductors and jet constituting respectively the terminals or elements of an electric circuit controller.

5. The combination with a receptacle capable of rotation and containing a series of spaced conductors, a duct within the receptacle having an orifice directed towards the said conductors, and an open end in position to take up a conducting fluid from a body of the same contained in the receptacle, when the latter is rotated, and direct it against the conductors, the said conductors and the fluid constituting the terminals or elements of an electric circuit controller.

6. The combination with a receptacle for containing a conducting fluid and a series of spaced conductors therein, of a duct having an orifice directed towards the said conductors and forming a conduit through which the fluid when the receptacle is rotated is forced and thrown upon the conductors.

7. The combination with a receptacle capable of rotation, and a series of conductors mounted therein, of a duct having an orifice directed towards the conductors, a holder for said duct mounted on bearings within the receptacle which permit of a free relative rotation of said receptacle and holder, and means for opposing the rotation of the said holder in the direction of the movement of the fluid while the receptacle is rotated, whereby the conducting fluid within the receptacle will be caused to flow through the duct against the conductors.

8. The combination with a receptacle and a motor for rotating the same, of a magnetic body mounted in the receptacle, a magnet exterior to the receptacle for maintaining the body stationary while the receptacle rotates, a series of conductors

in the receptacle and a duct carried by the said magnetic body and adapted to take up at one end a conducting fluid in the receptacle when the latter rotates and to direct such fluid from its opposite end against the series of conductors.

9. The combination with a receptacle for containing a conducting fluid, a series of spaced conductors within the same, and a motor, the armature of which is connected with the receptacle so as to impart rotation thereto, a magnetic body capable of turning freely within the receptacle about an axis concentric with that of the latter, a duct carried by the said body having one end in position to take up the conducting fluid and the other in position to discharge it against the spaced conductors, and a magnet exterior to the receptacle for holding the magnetic body stationary when the receptacle is rotated.

10. The combination with a closed receptacle in which is maintained an inert insulating gaseous medium under great pressure, of a circuit controller contained within the receptacle, as set forth.

11. The combination with a closed gas tight receptacle of a circuit controller contained within the same, and a vessel containing a liquefied gas, and communicating with the interior of the receptacle, as set forth.

12. The combination with a circuit controlling mechanism, one part or terminal of which is a conducting fluid, such as mercury, of a receptacle enclosing the same and means for maintaining an inert gas under pressure in the receptacle.

13. The combination with a conductor or series of conductors constituting one terminal of a circuit controller, means for maintaining a stream or jet of conducting fluid as the other terminal with which the conductor makes intermittent contact, a closed receptacle containing the terminals, and means for maintaining an inert atmosphere under pressure in the receptacle.

14. A device for making and breaking an electric circuit comprising, in combination, means for maintaining a jet or stream of conducting fluid which constitutes one terminal, a conductor or conductors making intermittent contact with the jet and constituting the other terminal and a receptacle enclosing and excluding oxygen from the said terminals.

15. The combination of a casing, a conductor or series of spaced conductors mounted therein, a motive device for rotating the said conductors, and a pumping device rigidly connected with the conductors for maintaining a stream or streams of conducting fluid directed against the rotating conductors, the said conductors and the fluid constituting respectively the terminals of a circuit controller.

16. The combination of a casing, a conductor or series of spaced conductors mounted therein, a motor for rotating the same, one or more ducts or channels from a receptacle containing a conducting fluid and directed towards the conductors, and a pump operated by the motor for forcing the conducting fluid through the duct or ducts against the conductors, the conductors and the fluid constituting the terminals of an electric circuit controller.

17. The combination with a receptacle containing a conducting fluid, of a conductor mounted within the receptacle, means for rotating the same, a screw rotating with the conductor and extending into a well in which the fluid collects, and a duct or ducts leading from the well to points from which the fluid will be directed against the rotating conductor.

18. The combination with the receptacle, of a spindle secured to its head or cover, a magnetic core mounted on the spindle within the receptacle, means for rotating said core, a conductor rotated by the core, and a pumping device, such as a screw rotated by the core and operating to maintain a jet or jets of conducting fluid, against the conductor, when in rotation.

19. The combination in a circuit controller with a closed receptacle, of a rigid body mounted within the receptacle and through which the circuit is intermittently established, and means for directing a jet or stream of a fluid contained in the receptacle against the said body so as to effect its rotation, as set forth.

20. The combination in a circuit controller of a jet of conducting fluid con-

stituting one terminal, a conductor adapted to be rotated by the force of the jet, and in its rotation to make intermittent contact therewith, and an enclosing receptacle, as set forth.

21. In an electric circuit controller, the combination of a closed receptacle, a conducting body therein adapted to be rotated by the impingement thereon of a jet or stream of conducting fluid, and means for maintaining such a jet and directing it upon the said conductor, as set forth.

22. In a circuit controller, the combination with a rotary receptacle of a body or part mounted within the receptacle and concentrically therewith, a conducting terminal supported by said body and capable of rotation in a plane at an angle to the plane of rotation of the receptacle so as to oppose, by gyrostatic action, the rotation of the support, and means for directing a jet of conducting fluid against the said terminal, as set forth.

23. In a circuit controller, the combination with a rotary receptacle of a support for a conductor mounted thereon concentrically with the receptacle and a gyrostatic disk carried by the support and adapted, when rotating, to oppose its movement in the direction of rotation of the receptacle, as set forth.

24. In a circuit controller, the combination with a rotary receptacle containing a conducting fluid, a support mounted within the receptacle, means for opposing or preventing its movement in the direction of rotation of the receptacle, one or more tubes or ducts carried thereby and adapted to take up the fluid from the rotating receptacle and discharge the same in jets or streams, and a conductor mounted on the support and adapted to be rotated by the impingement thereon of said jet or jets, as set forth.

25. The combination in a circuit controller of a rotary receptacle, one or more tubes or ducts and a support therefor capable of rotation independently of the receptacle, a conductor mounted on said support in a plane at an angle to that of rotation of the receptacle, and adapted to be maintained in rotation by a jet of fluid taken up from the receptacle by and discharged upon it from the said tube or duct, when the receptacle is rotated.

26. The combination with a rotary receptacle of one or more tubes or ducts, a holder or support therefor mounted on bearings within the receptacle, which permit of a free relative rotation of said receptacle and holder, a disk with a bearing on the said holder and having its plane of rotation at an angle to that of the receptacle, the disk being formed or provided with conducting vanes, upon which a jet of conducting fluid, taken up by the tube or duct from the receptacle when in rotation, is directed.

27. A circuit controller comprising in combination means for producing streams or jets of conducting liquid forming the terminals, and means for bringing the jets or streams of the respective terminals into intermittent contact with each other, as set forth.

28. In a circuit controller, the combination with two sets of orifices adapted to discharge jets in different directions, means for maintaining jets of conducting liquid through said orifices, and means for moving said orifices relatively to each other so that the jets from those of one set will intermittently intersect those from the other, as set forth.

29. The combination in a circuit controller of ducts and means for discharging therefrom streams or jets of conducting fluid in electrical contact with the two parts of the circuit respectively, the orifices of said ducts being capable of movement relatively to each other, whereby the streams discharged therefrom will intersect at intervals during their relative movement, and make and break the electric circuit, as set forth.

30. In a circuit controller the combination with one or more stationary nozzles and means for causing a conducting fluid forming one terminal to issue therefrom, of one or more rotating tubes or nozzles, means for causing a conducting liquid forming the other terminal to issue therefrom, the said rotating nozzles being

movable through such a path as to cause the liquid issuing therefrom to intersect that from the stationary nozzles as set forth.

31. The combination with a rotating receptacle divided into two insulated compartments, a spindle in one compartment with its axis concentric with that of the receptacle, means for opposing the rotation of said spindle, and a tube or duct carried by the spindle and adapted to take up a conducting fluid at one end from the inner periphery of the compartment when the receptacle is rotated and direct it from the other end into the other compartment, of a similar spindle in the other compartment and means for opposing its rotation, a tube carried by the spindle and having an opening at one end near the inner periphery of the compartment and discharging into a chamber from which lead one or more passages to nozzles fixed to the rotating receptacle and adapted to discharge across the path of the jet from the stationary nozzle, as set forth.

32. In a circuit controller the combination with a rotating receptacle of a body mounted thereon and formed or provided with a weighted portion eccentric to its axis which opposes its rotation and a tube or duct carried by said body and adapted to take up a conducting fluid from the rotating receptacle, as set forth.

33. In a circuit controller the combination of two sets of terminals symmetrically arranged about an axis of rotation and adapted to be brought successively into contact with each other, the number of terminals in one set being even and in the other odd, as set forth.

34. In a circuit controller the combination of two sets of terminals symmetrically arranged about an axis of rotation and adapted to be brought successively into contact with each other, there being one more terminal in one set than in the other, as set forth.

35. In a circuit controller the combination of two sets of nozzles and means for projecting from the same, jets of conducting fluid which constitute respectively the terminals of the controller, means for moving the nozzles relatively to each other so that the jets of the two sets are brought successively into contact, the nozzles of each set being arranged symmetrically about an axis of rotation, there being one more nozzle in one set than in the other.

36. In an electrical circuit controller, the combination with means for producing a stream or jet of conducting fluid which forms a path for the electric current of a body adapted to be intermittently moved through and to intercept the stream or jet, as set forth.

37. In an electrical circuit controller, the combination with a rigid terminal, of means for directing against such terminal a jet or stream of conducting fluid in electrical connection with the other terminal, and a body adapted to be intermittently moved through and to intercept the jet or stream, as set forth.

38. In an electrical circuit controller, the combination with a rigid terminal, of means for directing against such terminal a jet or stream of conducting fluid in electrical connection with the other terminal, a body having a series of radial projections and means for rotating the same so that the said projections will intermittently intercept the stream or jet, as set forth.

39. In a circuit controller, the combination with a rotary conductor forming one terminal, means for directing against such terminal a jet or stream of conducting fluid in electrical connection with the other terminal, and a body with spaced projections mounted to rotate in a path that intercepts the jet or stream of fluid, as set forth.

40. In a circuit controller, the combination with a conductor forming one terminal, and means for directing intermittently against such terminal a jet or stream of fluid in electrical connection with the other terminal, the part of said conductor upon which the jet or stream impinges being formed or arranged so as to retain, on its surface, a portion of the conducting fluid, as set forth.

41. The combination of the receptacle, a conducting disk secured within it, the insulated disk with peripheral projections and the stationary tube or duct for

directing a stream or jet of conducting fluid towards the conducting disk and across the path of the projections O, as set forth.

42. The combination of the receptacle, the conducting disk with a peripheral trough shaped flange, the insulated disk with peripheral projections O, and the stationary tube or duct for directing a stream or jet of conducting fluid into the trough shaped flange of the conducting disk and across the path of the projections O, as set forth.

43. A circuit controller comprising, in combination, a closed receptacle containing a fluid, means for rotating the receptacle, a support mounted within the receptacle, means for opposing or preventing its movement in the direction of rotation of the receptacle, and a conductor carried by said support and adapted to make and break electric connection with the receptacle through the fluid, as set forth.

44. A circuit controller comprising, in combination, a terminal capable of rotation and formed or provided with radiating contacts, a closed receptacle containing a fluid which constitutes the opposite terminal, means for rotating the receptacle, a support therein for the rotating terminal, and means for opposing or preventing the rotation of the support in the direction of the rotation of the receptacle, as set forth.

45. In a circuit controller, the combination with a receptacle capable of rotation about an axis inclined to the vertical and containing a fluid which constitutes one terminal, a second terminal mounted within the receptacle, on a support capable of free rotation relatively to the receptacle, and a weight eccentric to the axis of rotation of the support for said terminal for opposing or preventing its movement in the direction of the rotation of the said receptacle, as set forth.

46. The combination with a receptacle mounted to revolve about an axis inclined to the vertical, of a spindle within the receptacle and concentric with its axis, a weight eccentric to the spindle, and a terminal carried by the said spindle, and adapted to be rotated by a body of conducting fluid contained in the receptacle when the latter is rotated, as set forth.

47. The combination with a receptacle mounted to rotate about an axis inclined to the vertical, a spindle within the receptacle and concentric with its axis, a weighted arm attached to said spindle, a bracket or arm also secured to said spindle, a rotary terminal with radiating contact arms or vanes mounted on said bracket in position to be rotated by a body of conducting fluid contained in said receptacle when said fluid is displaced by centrifugal action, as set forth.

48. In a circuit controller, the combination with two terminals or sets of terminals, one of which is composed of a conducting fluid, of means for imparting to said terminals movements of rotation in opposite directions, as set forth.

49. The combination in a circuit controller of one or more bodies of conducting fluid and a conductor or conductors constituting, respectively, the terminals of said controller, and means for rotating said terminals in opposite directions, as set forth.

50. The combination in a circuit controller of a receptacle and means for rotating the same, one or more tubes or ducts mounted within the same and capable of rotation independently of the receptacle, means for imparting rotation to said ducts, and a conductor or series of conductors moving with the receptacle, in position to intermittently intercept jets of conducting fluid taken up by the ducts, as set forth.

51. In a circuit controller, the combination with a receptacle containing a conducting fluid, means for imparting a movement of rotation to the fluid, and a conductor adapted to be rotated by the movement of said fluid and to thereby make and break electric connection with the fluid, as set forth.

52. In a circuit controller, the combination with a terminal or series of terminals, contained in a receptacle, and a device operating by centrifugal action for taking

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LAKE'S COMPLETE SPECIFICATION.

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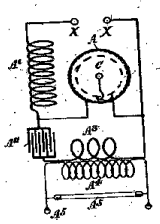


Fig. 1

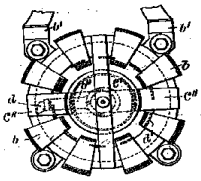
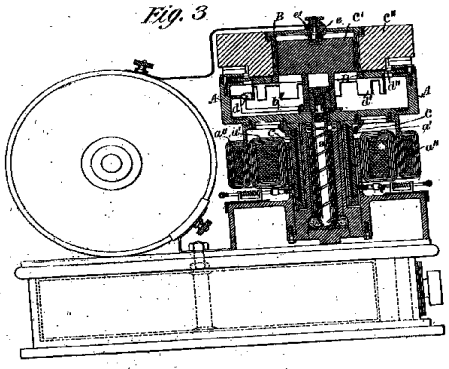


Fig. 2

Fig. 3



[5 SHEETS]
SHEET 2.

Fig. 4

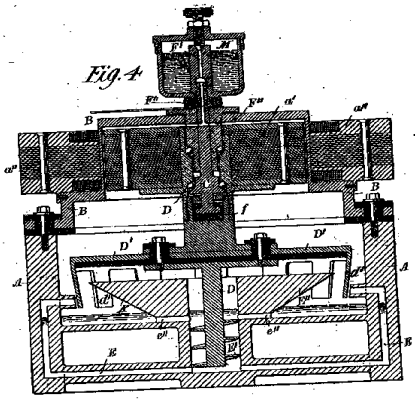
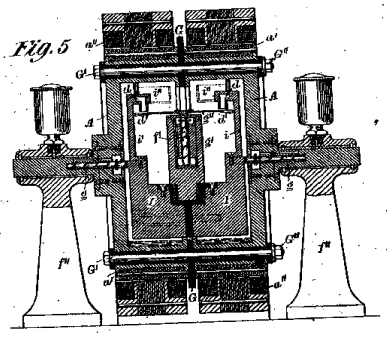


Fig. 5



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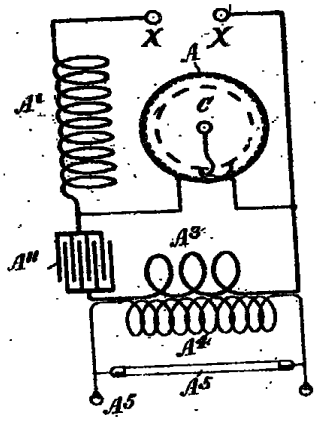


Fig. 1

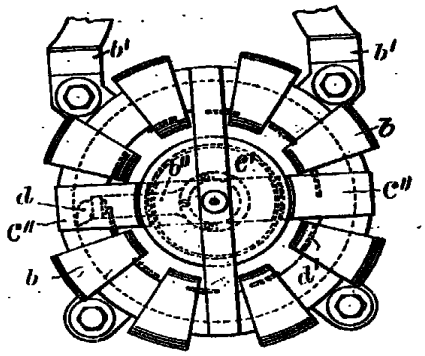
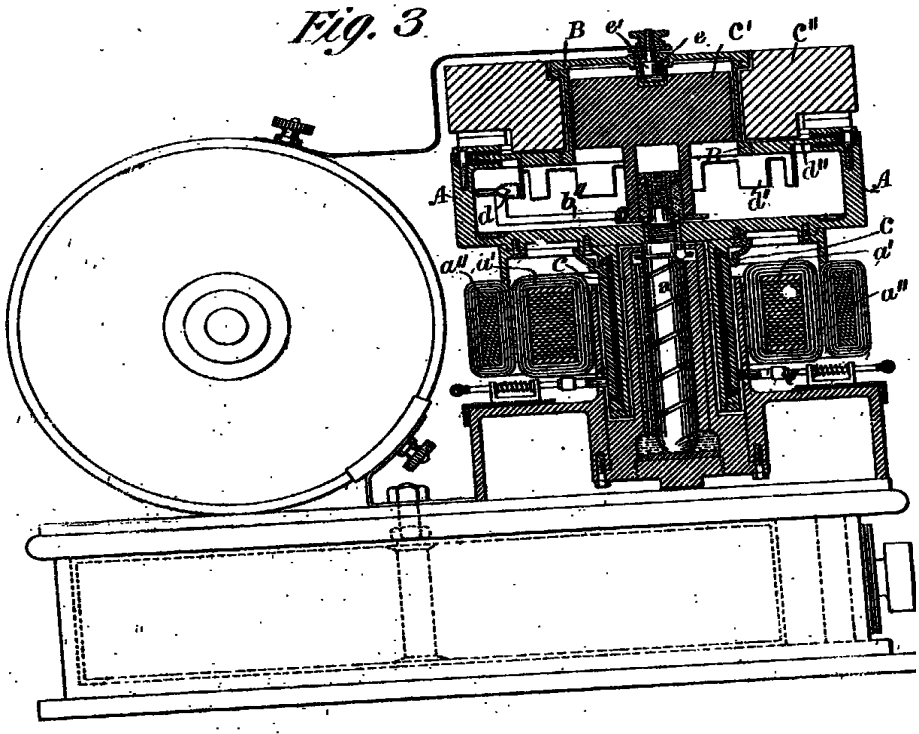


Fig. 2

Fig. 3



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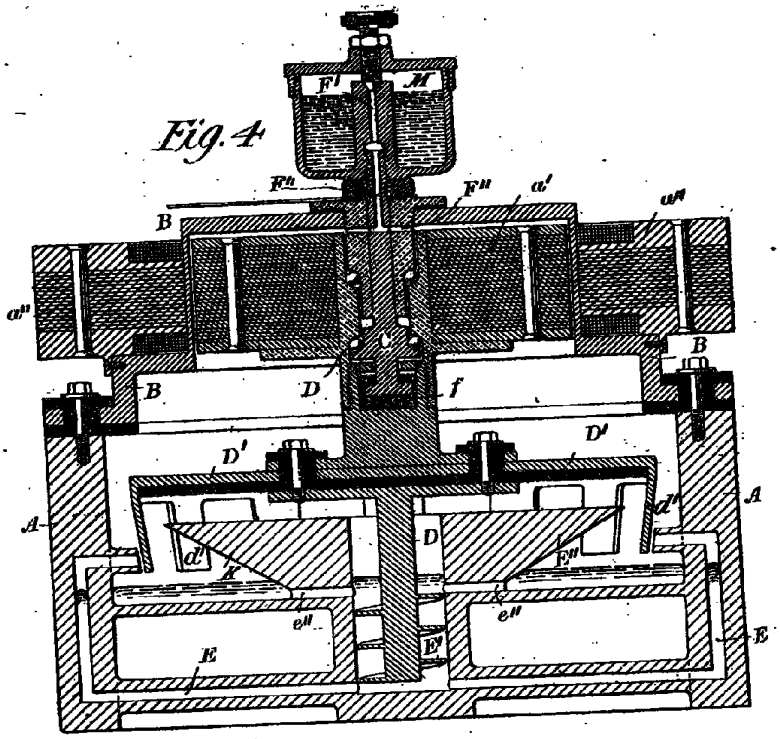
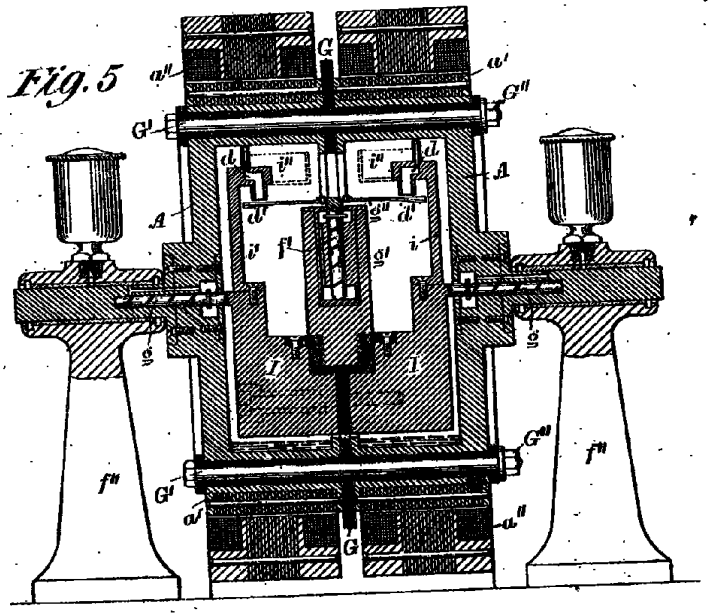


Fig. 5



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SHEET 3. (5 SHEETS)

SHEET 5.

Fig. 6

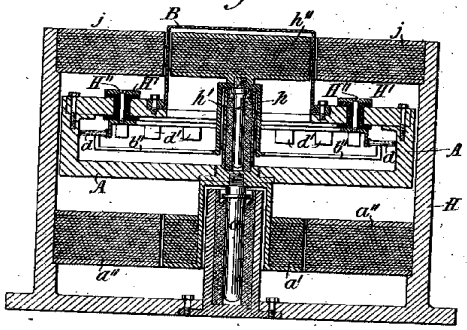

Fig. 7

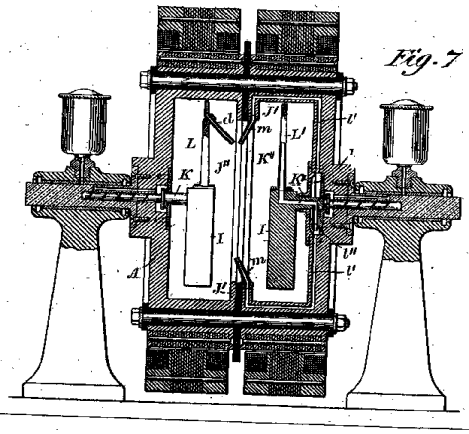

Fig. 8

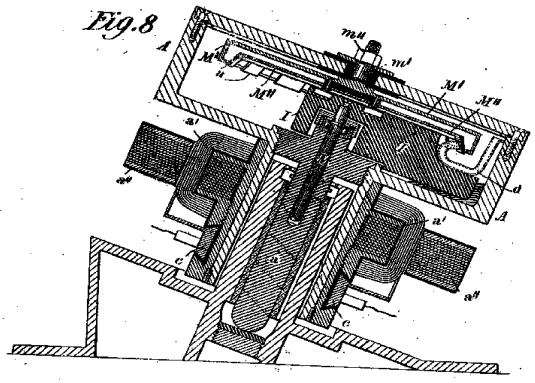

Fig. 11

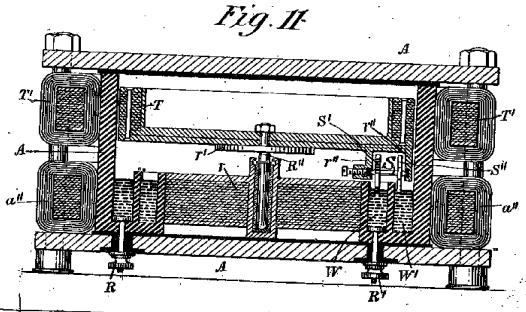

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Fig. 6

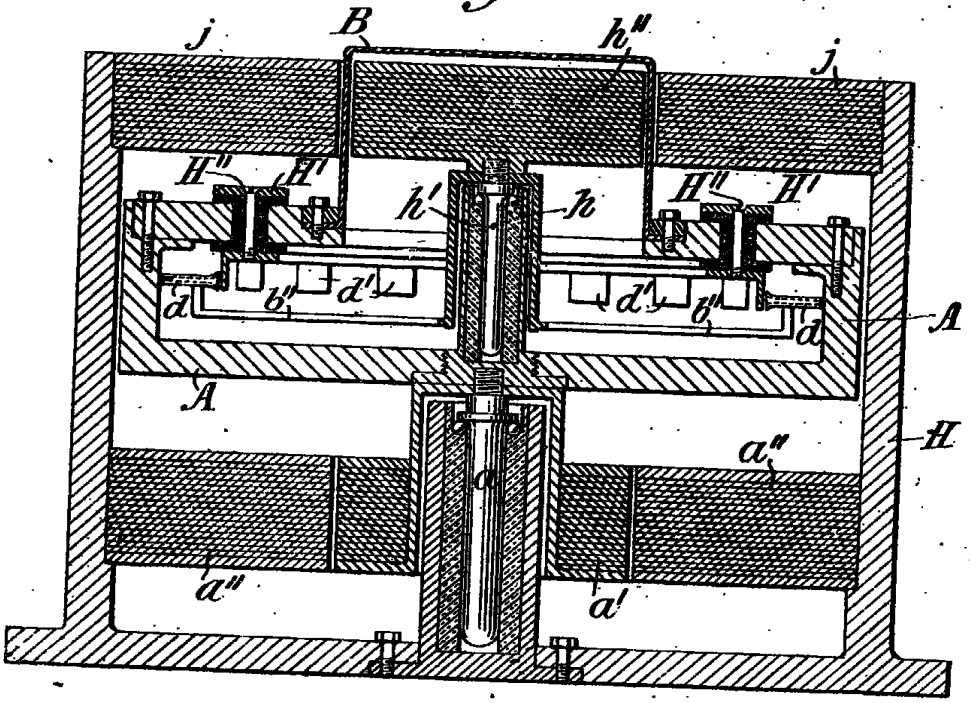

Fig. 7

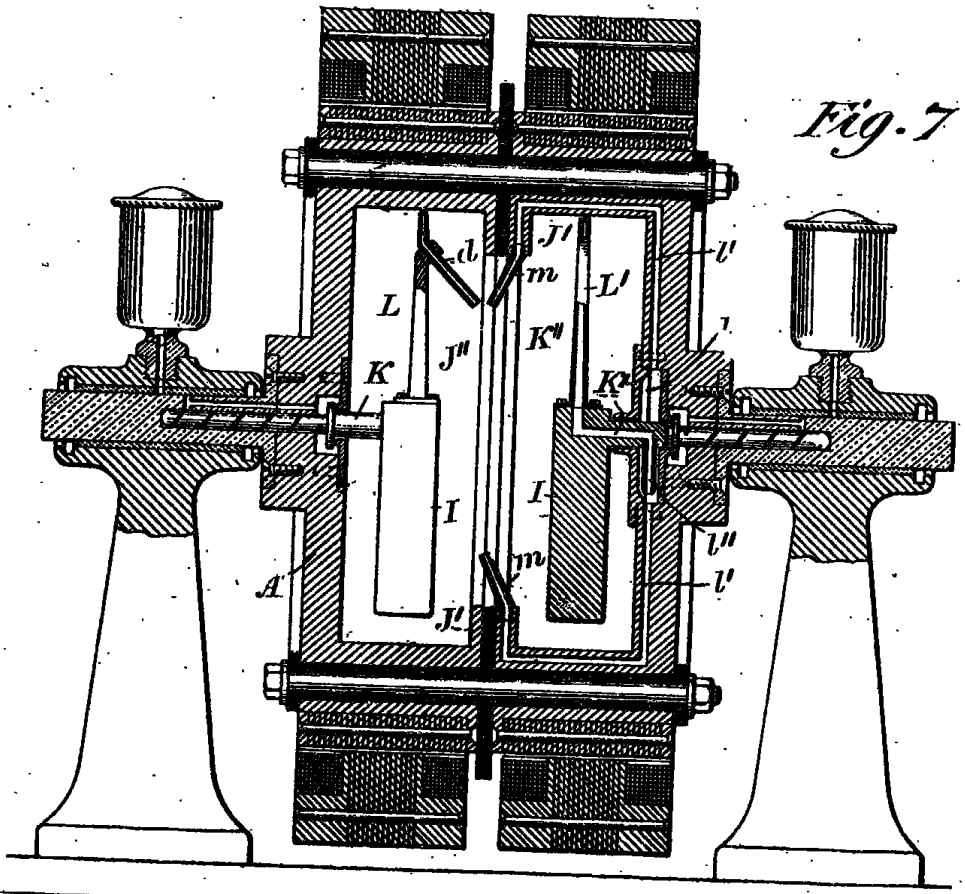

Fig. 8

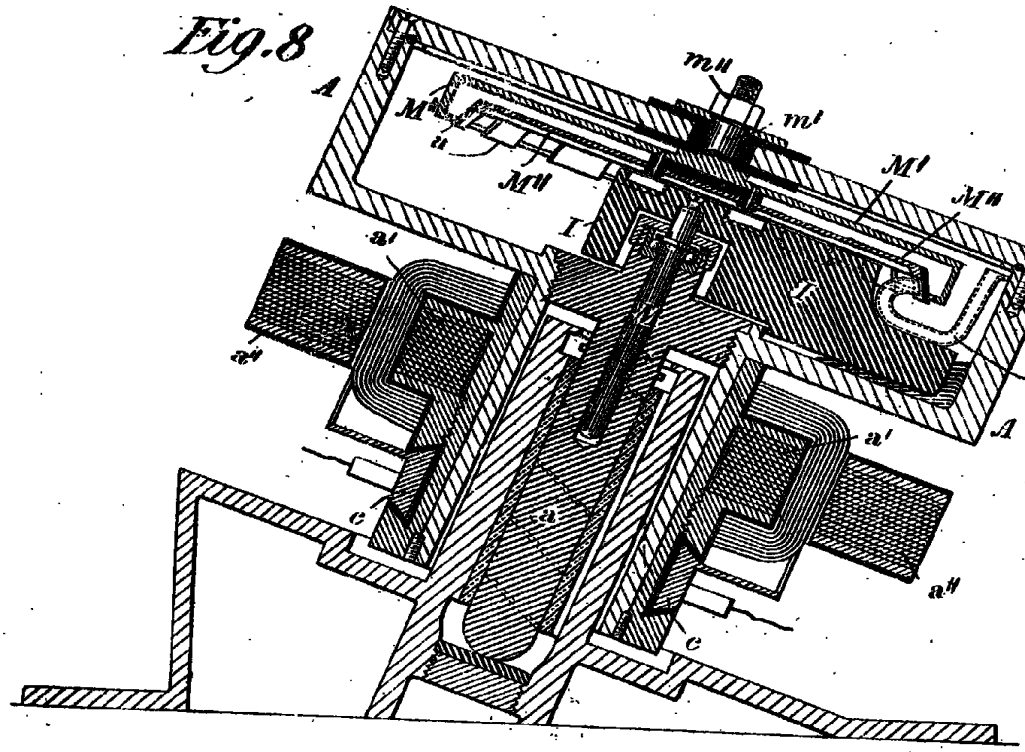

Fig. 11.

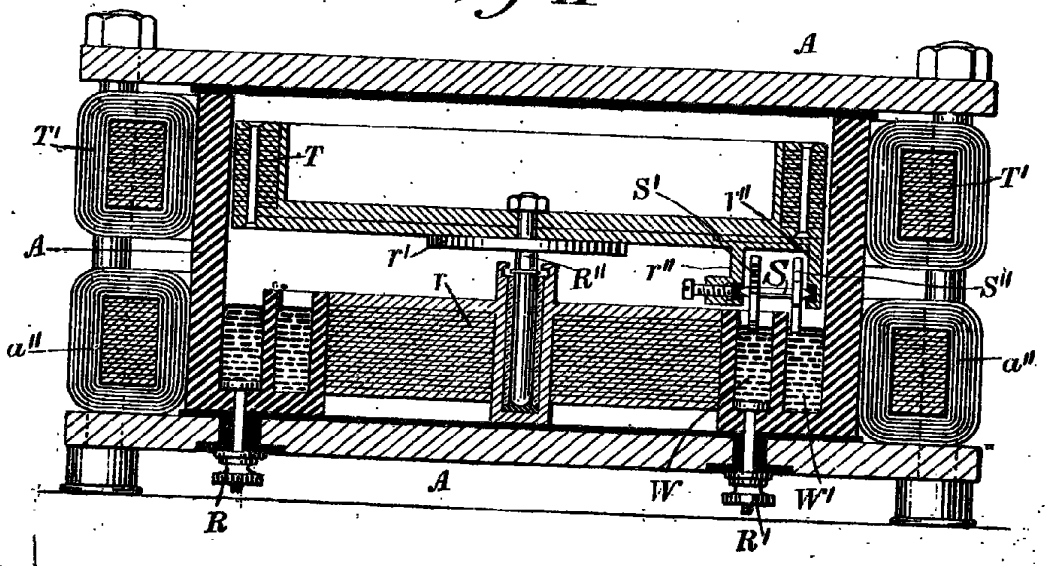

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Fig. 9

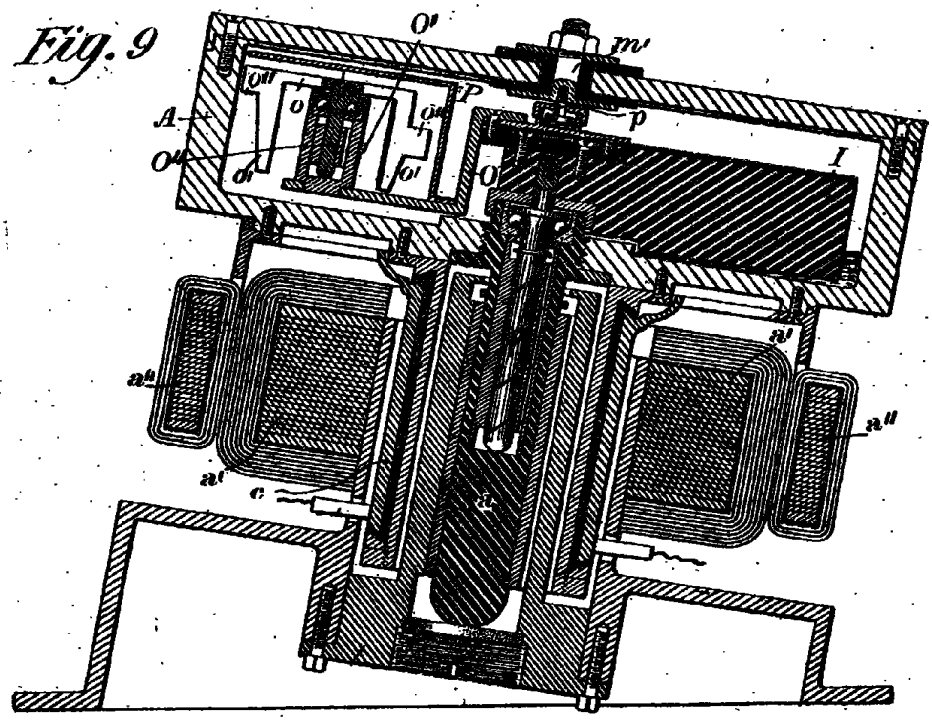
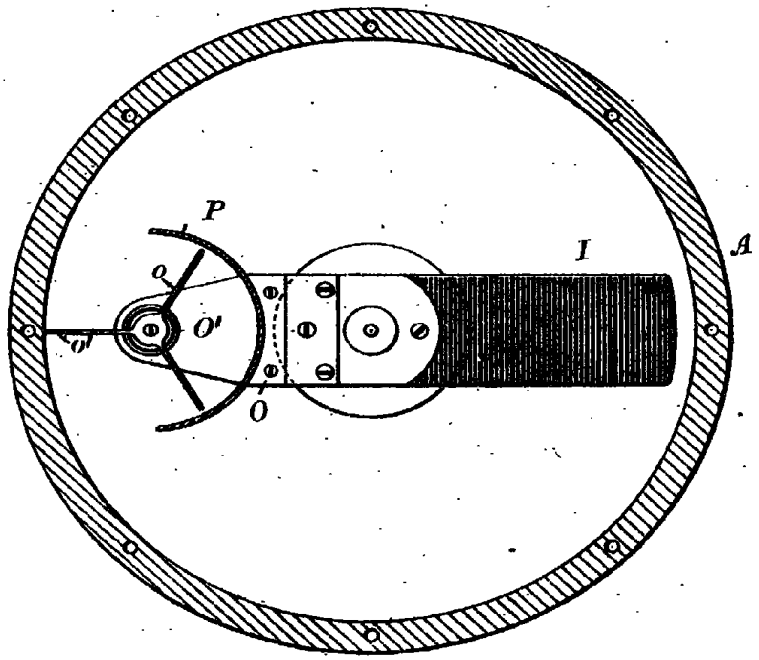


Fig. 10



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