UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

ELECTRICAL TRANSFORMER.

SPECIFICATION forming part of Letters Patent No. 593,138, dated November 2, 1897.

Application filed March 20, 1897. Serial No. 628,453. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electrical Transformers, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

The present application is based upon an apparatus which I have devised and employed for the purpose of developing electrical currents of high potential, which transformers or induction-coils constructed on the principles heretofore followed in the manufacture of such instruments are wholly incapable of producing or practically utilizing, at least without serious liability of the destruction of the apparatus itself and danger to persons approaching or handling it.

The improvement involves a novel form of transformer or induction-coil and a system for the transmission of electrical energy by means of the same in which the energy of the source is raised to a much higher potential for transmission over the line than has ever been practically employed heretofore, and the apparatus is constructed with reference to the production of such a potential and so as to be not only free from the danger of injury from the destruction of insulation, but safe to handle. To this end I construct an induction-coil or transformer in which the primary and secondary coils are wound or arranged in such manner that the convolutions of the conductor of the latter will be farther removed from the primary as the liability of injury from the effects of potential increases, the terminal or point of highest potential being the most remote, and so that between adjacent convolutions there shall be the least possible difference of potential.

The type of coil in which the last-named features are present is the flat spiral, and this form I generally employ, winding the primary on the outside of the secondary and taking off the current from the latter at the center or inner end of the spiral. I may depart from or vary this form, however, in the particulars hereinafter specified.

In constructing my improved transformers I employ a length of secondary which is approximately one-quarter of the wave length of the electrical disturbance in the circuit including the secondary coil, based on the velocity of propagation of electrical disturbances through such circuit, or, in general, of such length that the potential at the terminal of the secondary which is the more remote from the primary shall be at its maximum. In using these coils I connect one end of the secondary, or that in proximity to the primary, to earth, and in order to more effectually provide against injury to persons or to the apparatus I also connect it with the primary.

In the accompanying drawings, Figure 1 is a diagram illustrating the plan of winding and connection which I employ in constructing my improved coils and the manner of using them for the transmission of energy over long distances. Fig. 2 is a side elevation, and Fig. 3 a side elevation and part section, of modified forms of induction-coil made in accordance with my invention.

A designates a core, which may be magnetic when so desired.

B is the secondary coil, wound upon said core in generally spiral form.

C is the primary, which is wound around in proximity to the secondary. One terminal of the latter will be at the center of the spiral coil, and from this the current is taken to line or for other purposes. The other terminal of the secondary is connected to earth and preferably also to the primary.

When two coils are used in a transmission system in which the currents are raised to a high potential and then reconverted to a lower potential, the receiving-transformer will be constructed and connected in the same manner as the first—that is to say, the inner or center end of what corresponds to the secondary of the first will be connected to line and the other end to earth and to the local circuit or that which corresponds to the primary of the first. In such case also the line-wire should be supported in such manner as to avoid loss by the current jumping from line to objects in its vicinity and in contact with earth—as, for example, by means of long insulators, mounted, preferably, on metal poles, so that in case of leakage from the line it will pass harmlessly to earth. In Fig. 1, where such a system is illustrated, a dynamo G is con-

veniently represented as supplying the primary of the sending or "step-up" transformer, and lamps H and motors K are shown as connected with the corresponding circuit of the receiving or "step-down" transformer.

Instead of winding the coils in the form of a flat spiral the secondary may be wound on a support in the shape of a frustum of a cone and the primary wound around its base, as shown in Fig. 2.

In practice for apparatus designed for ordinary usage the coil is preferably constructed on the plan illustrated in Fig. 3. In this figure L L are spools of insulating material upon which the secondary is wound—in the present case, however, in two sections, so as to constitute really two secondaries. The primary C is a spirally-wound flat strip surrounding both secondaries B.

The inner terminals of the secondaries are led out through tubes of insulating material M, while the other or outside terminals are connected with the primary.

The length of the secondary coil B or of each secondary coil when two are used, as in Fig. 3, is, as before stated, approximately one-quarter of the wave length of the electrical disturbance in the secondary circuit, based on the velocity of propagation of the electrical disturbance through the coil itself and the circuit with which it is designed to be used—that is to say, if the rate at which a current traverses the circuit, including the coil, be one hundred and eighty-five thousand miles per second, then a frequency of nine hundred and twenty-five per second would maintain nine hundred and twenty-five stationary waves in a circuit one hundred and eighty-five thousand miles long, and each wave length would be two hundred miles in length. For such a frequency I should use a secondary fifty miles in length, so that at one terminal the potential would be zero and at the other maximum.

Coils of the character herein described have several important advantages. As the potential increases with the number of turns the difference of potential between adjacent turns is comparatively small, and hence a very high potential, impracticable with ordinary coils, may be successfully maintained.

As the secondary is electrically connected with the primary the latter will be at substantially the same potential as the adjacent portions of the secondary, so that there will be no tendency for sparks to jump from one to the other and destroy the insulation. Moreover, as both primary and secondary are grounded and the line-terminal of the coil carried and protected to a point remote from the apparatus the danger of a discharge through the body of a person handling or approaching the apparatus is reduced to a minimum.

I am aware that an induction-coil in the form of a flat spiral is not in itself new, and this I do not claim; but

What I claim as my invention is—

1. A transformer for developing or converting currents of high potential, comprising a primary and secondary coil, one terminal of the secondary being electrically connected with the primary, and with earth when the transformer is in use, as set forth.

2. A transformer for developing or converting currents of high potential, comprising a primary and secondary wound in the form of a flat spiral, the end of the secondary adjacent to the primary being electrically connected therewith and with earth when the transformer is in use, as set forth.

3. A transformer for developing or converting currents of high potential comprising a primary and secondary wound in the form of a spiral, the secondary being inside of, and surrounded by, the convolutions of the primary and having its adjacent terminal electrically connected therewith and with earth when the transformer is in use, as set forth.

4. In a system for the conversion and transmission of electrical energy, the combination of two transformers, one for raising, the other for lowering, the potential of the currents, the said transformers having one terminal of the longer or fine-wire coils connected to line, and the other terminals adjacent to the shorter coils electrically connected therewith and to the earth, as set forth.

NIKOLA TESLA.

Witnesses:
M. LAWSON DYER,
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No. 609,245. Patented Aug. 16, 1898.

N. TESLA.

ELECTRICAL CIRCUIT CONTROLLER.

(Application filed Dec. 2, 1897.)

(No Model.)

Fig. 1

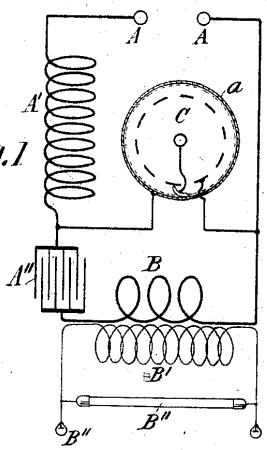


Fig. 2

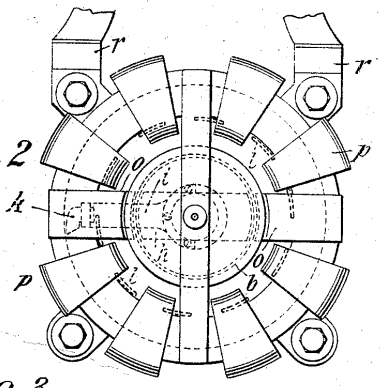
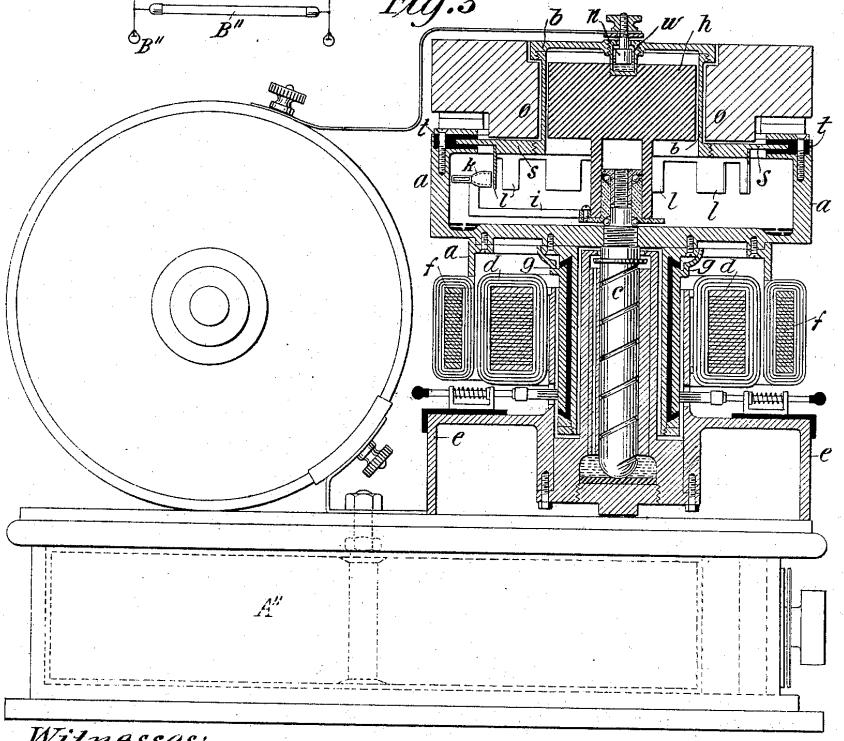


Fig. 3



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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

ELECTRICAL-CIRCUIT CONTROLLER.

SPECIFICATION forming part of Letters Patent No. 609,245, dated August 16, 1898.

Application filed December 2, 1897. Serial No. 660,518. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electrical-Circuit Controllers, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

In every form of electrical apparatus involving a means for making and breaking, more or less abruptly, a circuit 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, more generally, 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 I have invented in which the discharge of a condenser is utilized 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 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 the waste of energy and making it 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 an instance in which the current-curve is not so steep as to materially depart from one which may be represented by 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 increased velocity of approach and separation. The demonstration of these facts and the recognition of the impossibility of attaining the desired results by using ordinary forms of circuit-controllers led me to invent new and essentially different means for making and breaking a circuit in which I have utilized a conducting fluid, such as mercury, as the material for one or both of the terminals and devised novel means for effecting a rapidly-intermittent contact between the fluid and a conductor or series of conductors forming the other terminal.

With a view, however, to securing a more practical and efficient circuit-controller in which not only the relative speed of the terminals but also the frequency of the makes and breaks should be very high I devised the the form of instrument described in an application filed by me June 3, 1897, Serial No. 639,227, in which a receptacle is rotated to impart a rapid movement to a body of conducting fluid contained therein, which is brought in rapidly-intermittent contact with a conductor having peripheral projections extending into the fluid, the movement of the latter being conveniently utilized to rotate the conductor. Such a device, though meeting fully many requirements in practice, is nevertheless subject to certain limitations in the matter of attaining a high relative speed of approach and separation of the terminals, since the path of movement of the conducting projections is not directly away from and toward the fluid, but more or less tangential to the surface of the latter, the velocity of

approach and separation being of course the smaller the greater the diameter of the rotated conductor or terminal.

With the object of securing a greater relative speed of the terminals and a consequently more efficient form of circuit-controller of this type I devised the modified form of apparatus which constitutes the subject of my present application.

In this apparatus one of the members or terminals is a conducting fluid which is caused to issue from an orifice against a series of spaced conductors in rapid succession. For this purpose the series of conductors, or it may be a single conductor, is moved transversely through the stream or jet of fluid, or the jet is moved so as to impinge upon the conductors, or both jet and conductors are moved. This is preferably accomplished by mounting the conductors and the tube or duct from which the fluid issues concentrically and revolving one or both.

The chief feature of novelty which distinguishes the apparatus and in which my improvement resides is the plan adopted for maintaining the stream or jet of conducting fluid. This consists in utilizing the same power that actuates or drives the circuit-controller in effecting the necessary relative movement of its terminals to maintain the proper circulation of the conducting fluid by combining the two mechanisms (the controller and the means for maintaining a circulation of the conducting fluid) in one. This feature is of great practical advantage and may be effected in many ways. A typical arrangement for this purpose is to provide a tube or duct having an orifice at one end directed toward the spaced conductors and its other end in a position to take up a portion of the rapidly-rotating body of conducting fluid, divert it through the duct, and discharge it against the conductors. With this object when a closed receptacle is used a holder for the tube is employed, mounted within the receptacle and concentrically therewith, and this holder, when the receptacle is revolved, is held or influenced by any suitable means, as by magnetic attraction exerted from the outside or otherwise, in such manner as to keep it either in a fixed position or impress upon it a velocity different from that of the rotated fluid.

Such other improvements in details as I have devised and applied to the construction and operation of my improved circuit-controller will be more fully hereinafter described; but from the above general statement of the nature of the device it will be observed that by means of the same the velocity of relative movement of the two parts or elements may be enormously increased and the duration of the arc or discharge between them at the periods of make and break thereby greatly reduced without material increase in the power required to effect it and without impairing the quality of contact or deteriorating the terminals.

In the drawings hereto annexed, Figure 1 is a diagram illustrating the system for which the improvement was more especially designed. Fig. 2 is a top plan view of the circuit-controller. Fig. 3 is a view showing the induction-coil of Fig. 1 with its condenser-case in side elevation and the circuit-controller in vertical central section.

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

The circuit-controller C, 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′ and the condenser A″, from which it will result that when the circuit is completed through the controller the choking-coil A′ 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 B when these two are short-circuited by the subsequent completion of the controller-circuit.

I refer now to Figs. 2 and 3 for an illustration of the more important and typical features of my improved circuit-controller. The parts marked *a* 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 *c*, which is mounted vertically in bearings of any character suitable for the purpose. As it is intended to impart a rapid rotation to the receptacle *a*, I have shown a convenient device for this purpose comprising a field-magnet *d*, secured to the base or frame *e*, and an annular armature *f*, secured to the receptacle *a*. The coils of the armature are connected with the plates *g* of a commutator secured to the receptacle *a* and made in cylindrical form, so as to surround the socket in which the spindle *c* is stepped. A body of magnetic material *h*, which serves as an armature, is mounted on antifriction-bearings on an extension of the spindle *c*, so that the receptacle and the body *h* may have freely independent movements of rotation. Surrounding the dome *b*, in which the armature *h* is contained, is a core with pole-pieces *o*, which are magnetized by coils *p*, wound on the core. The said core is stationary, being

supported by arms r, Fig. 2, independently of the receptacle, so that when the receptacle is rotated and the core energized the attractive force exerted by the poles o upon the armature h 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 i is secured to the armature h within the receptacle a and carries at its end a short tube k, bent, as shown in Fig. 2, so that one open end is tangential to the receptacle-wall and the other directed toward the center of the same. Secured to the top plate of the receptacle a are a series of conducting-plates l. The part of the top plate s from which said conducting-plates l depend is insulated from the receptacle proper by insulating packing-rings t, but is electrically connected with the dome b, and in order to maintain electrical connection from an external circuit to the conductors l a mercury-cup w is set in the top of the dome, into which cup extends a stationary terminal plug n. 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 toward its periphery and rises up along its inner wall. When it reaches the level of the open-mouthed tube k, a portion is taken up by the latter, which is stationary, and forced by its momentum through the tube and discharged against the conductors l as the latter pass in rapid succession by the orifice of said tube. In this way the circuit between the receptacle and the conductors l is completed during the periods in which the stream or jet of mercury impinges upon any of the conductors l and broken whenever the stream is discharged through the spaces between the conductors.

From the nature of the construction and mode of operation of the above-described apparatus it is evident that the relative speed of separation and approach of the two elements or terminals (the jet and the conductors l) may be extremely high, while such increased speed affects in no material respect the quality of contact.

A circuit-controller of the kind described is applicable and useful in many other systems and apparatus than that particularly described herein, and may be greatly modified in construction without departure from the invention.

I am aware that a jet or stream of conducting fluid has heretofore been employed as a means for completing an electric circuit, and I do not claim, broadly, the employment of a conducting fluid in such form as a contact or terminal; but so far as I am aware both the purpose for which I employ such form of contact or terminal and the manner in which I apply it are wholly of my invention, neither having been heretofore proposed.

What I claim is—

1. 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 the said nozzle, and dependent for operation upon such relative movement, as set forth.

2. 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, as set forth.

3. The combination with a receptacle containing a series of spaced conductors, a duct within the receptacle having one of its ends directed toward 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 receptacle through the duct against the conductors, the said conductors and jet constituting respectively the terminals or elements of an electric-circuit controller.

4. The combination with a receptacle capable of rotation and containing a series of spaced conductors, a duct within the receptacle having an orifice directed toward 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.

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

6. The combination with a receptacle capable of rotation, and a series of conductors mounted therein, of a duct having an orifice directed toward 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.

7. 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.

8. 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.

NIKOLA TESLA.

Witnesses:
M. LAWSON DYER,
G. W. MARTLING.

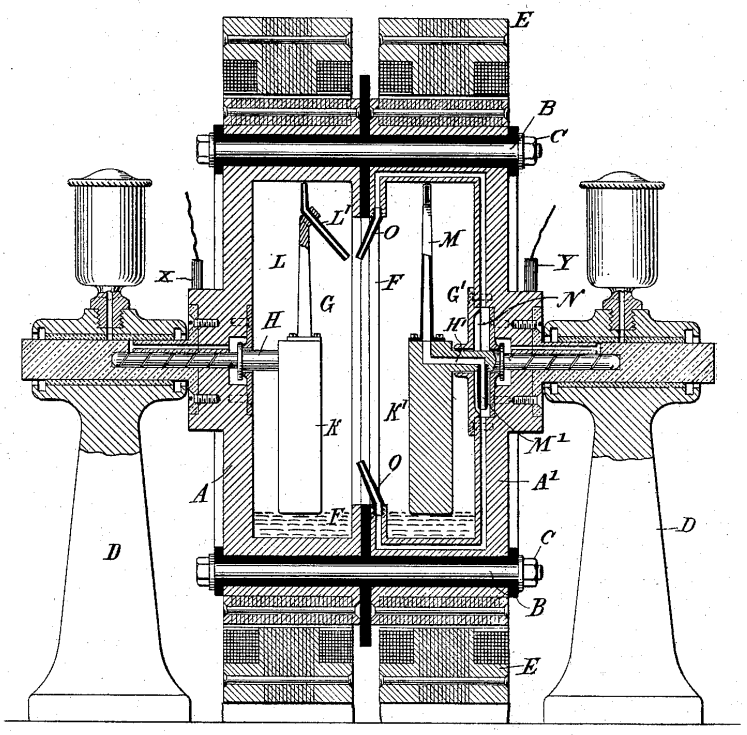
No 609.246. Patented Aug. 16, 1898.

N. TESLA.

ELECTRIC CIRCUIT CONTROLLER.

Application filed Feb. 28, 1898.

(No Model.)



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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

ELECTRIC-CIRCUIT CONTROLLER.

SPECIFICATION forming part of Letters Patent No. 609,246, dated August 16, 1898.

Application filed February 28, 1898. Serial No. 671,897. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing in the borough of Manhattan, in the city, county, and State of New York, have invented certain new and useful Improvements in Electric-Circuit Controllers, of which the following is a specification, reference being had to the drawing accompanying and forming a part of the same.

The invention which forms the subject of my present application is an improvement in a novel class of circuit-controlling appliances heretofore invented by me and more especially designed to be used with my now well-known apparatus for the production of electric currents of high frequency by means of condenser-discharges, but applicable generally as a means for making and breaking an electric circuit.

In the circuit-controllers of the particular class or type to which my present improvement pertains I have utilized a conducting liquid as one of the terminals and have employed as the other terminal a solid conductor and provided various means for bringing the two into rapidly-intermittent contact.

The distinguishing feature of my present improvement lies chiefly in the use of a conducting liquid for both the terminals under conditions which permit of a rapidly-intermittent contact between them, as will be herein set forth.

The accompanying drawing illustrates an apparatus embodying the principle of my said improvement.

The figure is a central vertical section of the circuit-controller.

In the drawing is shown a receptacle composed of two cylindrical metallic portions A A′, secured together by bolts B and nuts C, but insulated from each other. The receptacle is journaled, by means of trunnions formed on or secured to its ends, in standards D D, and any suitable means is employed to impart rotation to it. This is conveniently effected by constructing or organizing the receptacle in such manner that it may serve as the rotating element of an electromagnetic motor in conjunction with a surrounding stationary element E E. The abutting ends of the two parts of the receptacle are formed with inwardly-extending flanges F, which divide the peripheral portions of the receptacle into two compartments G G′. Into one of these compartments, as G, extends a spindle H, having its bearing in the end of the part A and the trunnion secured to or extending therefrom. Into the other compartment G′ extends a spindle H′, similarly journaled in the end of part A′ and its trunnion. Each spindle carries or is formed with a weighted arm K, which, remaining in a vertical position, holds its spindle stationary when the receptacle is revolved.

To the weighted arm of spindle H is secured a standard L, carrying a tube L′, with one open end in close proximity to the inner peripheral wall of the compartment G and the other directed toward the axis, but inclined toward the opposite compartment. To the weighted arm of spindle H′ is similarly secured a standard M, 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 M′ into a circular chamber N in the wall of the part A′. From this chamber run passages N′ to nozzles O, 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 L′.

In each portion or compartment of the receptacle is placed a quantity of a conducting liquid, such as mercury, and the ends of the tubes L′ and M 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 L′ issues in a stream or jet from the inner end of said tube and is projected into the compartment G′. The mercury taken up by the tube M runs into the circular chamber N, from which it is forced through the passages N′ to the nozzles O, from which it issues in jets or streams directed into the compartment G. As the nozzles O revolve with the receptacle the streams which issue from them will therefore be carried across the path of the stream which issues from the tube L′ 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 the greatest possible and hurtful short-circuits are avoided.

For the sake of illustration let the number of jets or nozzles L′ in one compartment be nine and the number of those marked O 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 L′, it would be necessary to employ ninety jets O 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, as by causing brushes X Y, connected with circuit-wires, to bear at any suitable points on the said two parts A A′.

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.

Having now described my invention, what I claim is—

1. 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.

2. 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.

3. 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.

4. 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.

5. 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 re-

ceptacle and adapted to discharge across the path of the jet from the stationary nozzle, as set forth.

6. In a circuit-controller the combination with a rotating receptacle of a body mounted therein 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.

7. 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.

NIKOLA TESLA.

Witnesses:
M. LAWSON DYER,
G. W. MARTLING.

No. 609,247. Patented Aug. 16, 1898.

N. TESLA.

ELECTRIC CIRCUIT CONTROLLER.

(Application filed Mar. 12, 1898.)

(No Model.)

Fig. 1

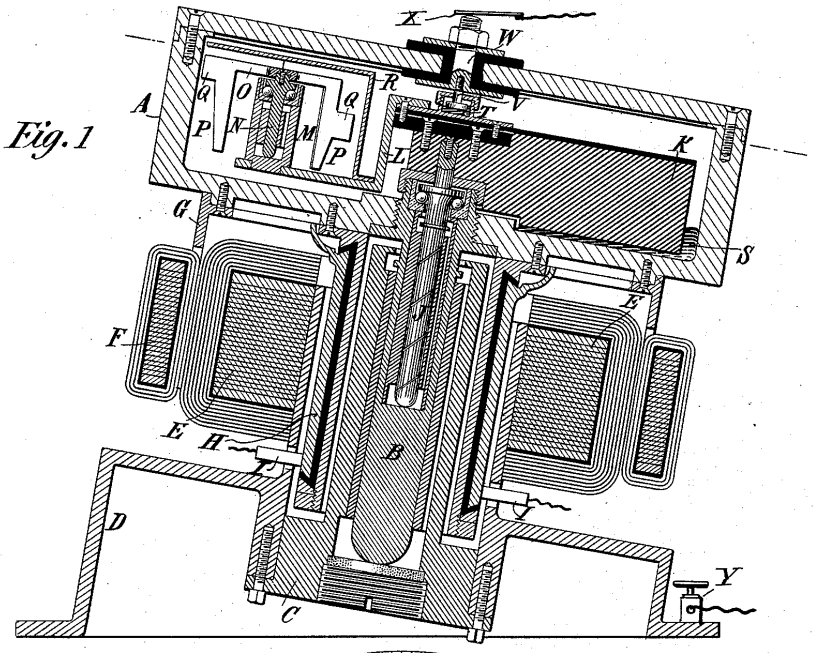
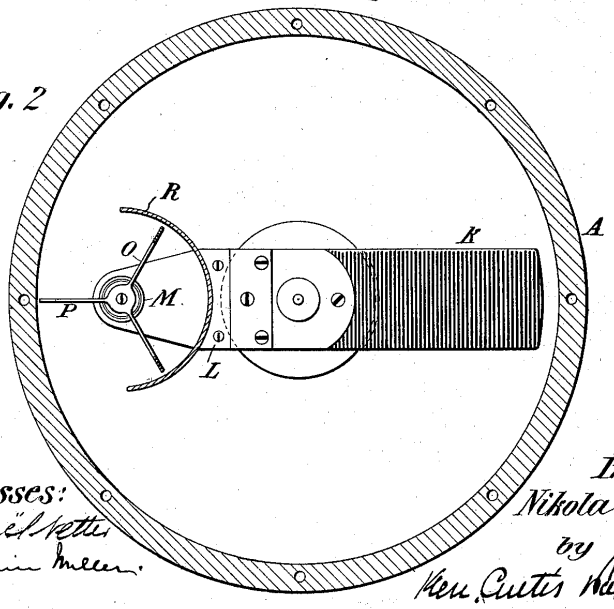


Fig. 2



Witnesses:
Raphael Netter
Benjamin Miller.

Inventor
Nikola Tesla
by
Kerr, Curtis & Page Attys.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

ELECTRIC-CIRCUIT CONTROLLER.

SPECIFICATION forming part of Letters Patent No. 609,247, dated August 16, 1898.

Application filed March 12, 1898. Serial No. 673,558. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, of the borough of Manhattan, in the city, county, and State of New York, have invented certain new and useful Improvements in Circuit-Controllers, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

In an application filed by me on June 3, 1897, Serial No. 639,227, I have shown and described a device for making and breaking an electric circuit comprising a rotary receptacle containing a conducting fluid and a terminal mounted within but independently of the receptacle and caused by the rotation of the latter to make and break electrical contact with the fluid.

The invention on which my present application is based is an improvement in devices of this particular class, and has primarily as its object the production of a circuit-controller in which an independently-mounted terminal operated in a similar manner by a rotating body of conducting fluid may be inclosed within a gas-tight receptacle.

The invention comprises features of construction by which this object is practically secured and certain improvements applicable to this and other analogous devices, as will be more fully hereinafter set forth.

In the accompanying drawings, Figure 1 is vertical central section of the improved circuit-controller, and Fig. 2 a top plan view of the same with the top or cover of the receptacle removed.

The operative portions of the circuit-controlling mechanism are contained in a closed cylindrical receptacle A, of iron or steel, mounted on a spindle B in a suitable socket or support C to permit it to be freely and rapidly rotated. The socket C is secured to or forms a part of a base or stand D.

As a means of producing the proper rotation of the receptacle A, I have shown a field-magnet E, mounted on or secured to the base D, and an armature F, supported by a bracket G from the under side of the receptacle A. The same bracket also carries a series of commutator-segments H, upon which bear brushes I, these parts being arranged to constitute an electromagnetic motor with stationary field and rotating armature. It may be stated that any other suitable means may be employed to rotate the receptacle and the fluid.

In the spindle B and concentric with its axis is a spindle J in bearings specially constructed to reduce friction in order that the spindle J may be as little as possible influenced by the rotation of the main spindle and receptacle carried thereby. A suitable provision is made to oppose or prevent the rotation of the spindle J during the rotation of the receptacle. I have devised for this purpose the following:

The spindle B is held by its bearings at an angle to the vertical, and a weight K is secured eccentrically to the spindle J and tends to hold the said spindle always in one position. The inclination of the axes of rotation necessary for this result may be substantially that shown and should not be materially greater, for the reason that it is especially advantageous to preserve the spindles and bearings as nearly as practicable vertical on account of lesser friction and easier lubrication.

Attached to the spindle J or weight K is an insulated bracket L, carrying a standard or socket M, in which is mounted on antifriction-bearings a spindle N. Secured to this latter is a plate with radial arms O, from which depend vanes or blades P, with projections Q extending radially therefrom. A shield or screen R incloses the vanes, except on the side adjacent to the inner periphery of the receptacle A.

A small quantity of a conducting fluid S is placed in the receptacle, and in order to secure a good electrical connection between the vanes P and a terminal on the outside of the receptacle a small mercury-cup T, in metallic contact with the vanes through the bracket L and socket M, is secured to the weight K. A metal stud V, set in an insulated bolt W, projects into the cup T 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 W. The apparatus may be connected up in circuit by connecting the wires of the circuit to a brush X, bearing on the bolt W, and to a binding-post Y in contact with the base D.

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 Q on the blades or vanes P, the latter are set in rapid rotation, and the electrical connection between the terminal of the apparatus is thereby made and broken, it may be, with very great rapidity.

The projections Q are preferably placed at different heights on the vanes P, so as to secure greater certainty of good contact with the mercury film when in rapid rotation.

As to the forms of the circuit-controller heretofore referred to and upon which my present invention is an improvement the blades or vanes P may be regarded in a broad sense as typical of any device—such, for example, as a stelliform disk—which will be set and maintained in rotation by that of the receptacle. So, also, having regard to the feature of my invention which provides for maintaining such a device in operation in a receptacle which may be hermetically sealed, so as to be capable of containing an inert medium under pressure in which the makes and breaks occur and which medium is practically essential to a long-continued and economical operation of the device, I may employ other and widely-different means for opposing or preventing the rotation of the part carrying such vanes in the direction of the rotation of the receptacle and fluid.

Having now described my invention, what I claim is—

1. 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.

2. 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.

3. 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.

4. 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.

5. 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.

NIKOLA TESLA.

Witnesses:
M. LAWSON DYER,
G. W. MARTLING.

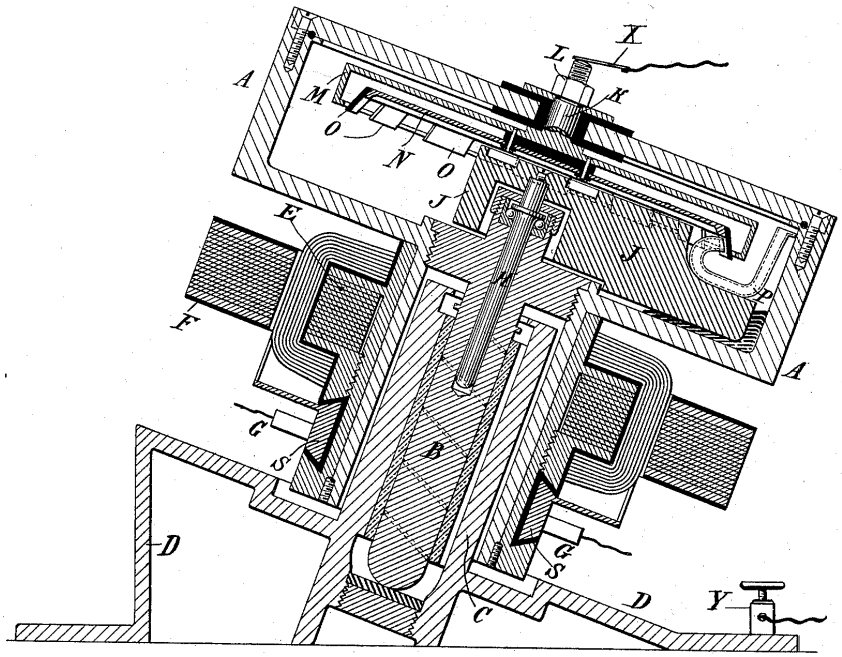
No. 609,248. Patented Aug. 16, 1898.

N. TESLA.

ELECTRIC CIRCUIT CONTROLLER.

(Application filed Mar. 12, 1898.)

(No Model.)



Witnesses:
Raphael Netter
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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

ELECTRIC-CIRCUIT CONTROLLER.

SPECIFICATION forming part of Letters Patent No. 609,248, dated August 16, 1898.

Application filed March 12, 1898. Serial No. 673,559. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, of the borough of Manhattan, in the city, county, and State of New York, have invented certain new and useful Improvements in Circuit-Controllers, of which the following is a specification, reference being had to the drawing accompanying and forming a part of the same.

In previous applications filed by me, notably in Serial No. 660,518, filed December 2, 1897, and others, I have shown and described various forms of electric-circuit controllers in which a conducting fluid is used for one or both of the terminals. These contrivances, while applicable generally as a means of making and breaking an electric circuit with great rapidity, were devised by me more especially for use in my now well-known system of electrical conversion by means of condenser-discharges and for this reason have been designed with especial reference to the peculiar and exceptional conditions which obtain in such systems. My present invention is an improvement in circuit-controllers of this kind, and in order that the object and nature of the improvement may be more readily understood and appreciated I may refer briefly to the more essential characteristics of the devices described before upon which the present improvement is based. As it was primarily essential that these controllers be capable of making and breaking the circuit at a very rapid rate and as such a result could not be secured practically or economically by any of the ordinary devices employing rigid contacts or terminals I was led to invent apparatus in which the circuit connections were established and broken between a rigid terminal and a fluid conductor or between two fluid conductors in the form of jets or streams. In the forms of apparatus employing a rigid or solid conductor as one terminal and a fluid as the other the makes and breaks of course occur always between a solid and a fluid terminal, and although the operative parts of my improved circuit-controllers were usually contained in air or gas tight receptacles and in an inert medium, both for the purpose of improving their action and preventing deterioration of the terminals, there is still a liability to wear of the rigid or solid terminal.

Under certain conditions, as when the circuit-controller is operated from a source of direct current, the deterioration of the solid terminal may be materially reduced by connecting it to the negative pole of the generator. Nevertheless, there will be always a slow wearing away of the metal, which to overcome entirely in a novel manner is the object of my present improvement. To do this, I effect the closure of the circuit through two parts of conducting fluid; but instead of breaking the circuit by the movement of these two parts or terminals, as before, 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—preferably of glass, lava, or the like—which are caused by the rotation of the disk to pass through the fluid conductor, jet, or whatever it may be, 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 are avoided.

A preferred form of my improved circuit-controller is illustrated in the accompanying drawing, which shows a central vertical section of the same.

The two terminals are contained in an air-tight receptacle A, of iron or steel, which is mounted on a spindle B in a suitable socket or support C, so as to rotate freely. The socket C is secured to or forms part of a base or stand D. Any suitable means may be employed for effecting the rotation of the receptacle, and in illustration of a convenient and practicable means for this purpose I have shown an armature E, secured to a cylindrical extension of the receptacle that surrounds the socket C, and a field-magnet F, which is supported independently and is stationary. The armature-coils are connected with the segments S of a commutator on which bear brushes G.

In the spindle B and concentric with its axis is a spindle H, supported on ball-bearings or otherwise arranged to have a free movement of rotation relatively to the spindle B, 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 H

during the rotation of the receptacle. In the particular arrangement here shown for this purpose a weight or weighted arm J is secured to the spindle H and eccentrically to the axis of the latter, and as the bearing for the spindle B holds the same at an angle to the vertical this weight acts by gravity to hold the spindle H stationary.

Secured to the top or cover of the receptacle A by a stud K, which passes through an insulating-bushing in said cover and is held by a nut L, is a circular disk M, of conducting material, preferably iron or steel, having its edge turned downwardly and then inwardly to provide a peripheral trough on the under side of the disk.

To the under side of the disk M is secured a second disk N, having downwardly-inclined peripheral projections O O, of insulating and preferably refractory material, in a circle concentric with the disk M.

A tube or duct P is mounted on the spindle H or the weight J and is so arranged that the orifice at one end is directed outwardly toward the trough of the disk M, 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 P, 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 or against the inner surfaces of the projections O of disk N, as the case may be.

Obviously, since the two disks M and N rotate with respect to the jet or stream of fluid issuing from the duct P, the electrical connection between the receptacle and the disk M through the fluid will be completed by the jet when the latter passes to the disk M between the projections O and will be interrupted whenever the jet is intercepted 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 O.

By forming that portion of the disk M 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.

The principle of interrupting the circuit by intermittently passing an insulator through a fluid conductor may be carried out by many specifically-different forms of apparatus, and in this respect I do not limit myself to the particular form herein shown.

What I claim is—

1. In an electrical-circuit controller, the combination with a conductor forming one of the terminals, of means for maintaining a jet or stream of conducting fluid forming the other terminal, and directing it against said conductor, and a body adapted to be intermittently moved through and to intercept the jet or stream, as set forth.

2. 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.

3. 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.

4. 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.

5. In a circuit-controller, the combination with a rotary 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 rotary conductor upon which the jet or stream impinges being formed so as to retain, by centrifugal force, a portion of the fluid directed against it, as set forth.

6. The combination of the receptacle, the 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 toward the conducting-disk and across the path of the projections O, as set forth.

7. 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.

NIKOLA TESLA.

Witnesses:
M. LAWSON DYER,
G. W. MARTLING.

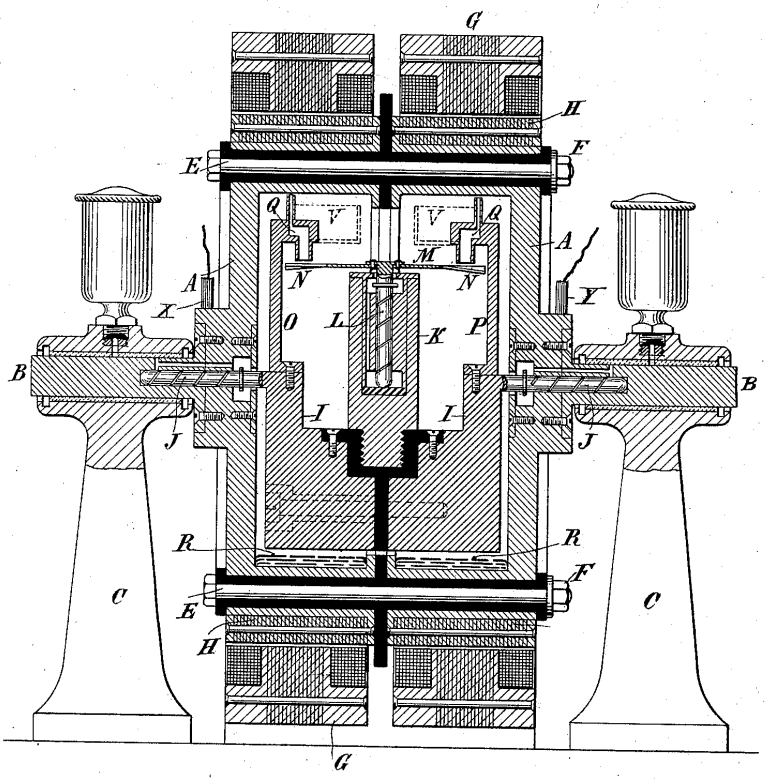
No. 609,249. Patented Aug. 16, 1898.

N. TESLA.

ELECTRIC CIRCUIT CONTROLLER.

(Application filed Mar. 12, 1898.)

(No Model.)



Witnesses:
Raphael Netter
Benjamin Miller.

Nikola Tesla, Inventor
by Kerr Curtis Page Attys

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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

ELECTRIC-CIRCUIT CONTROLLER.

SPECIFICATION forming part of Letters Patent No. 609,249, dated August 16, 1898.

Application filed March 12, 1898. Serial No. 673,560. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, of the borough of Manhattan, in the city, county, and State of New York, have invented certain new and useful Improvements in Electrical-Circuit Controllers, of which the following is a specification, reference being had to the drawing accompanying and forming part of the same.

The present application is based upon improvements in electrical-circuit controllers of the kind heretofore invented by me and described in previous applications, notably in an application filed December 2, 1897, Serial No. 660,518. The chief distinguishing features of these devices are the use of a conducting fluid for one or both of the terminals under conditions which permit of a very rapid succession of makes and breaks and a construction or arrangement which allows the inclosing of the terminals in an air-tight receptacle in which an inert medium may be maintained. My efforts to meet the practical requirements of apparatus of this kind have led me to adopt expedients and to invent mechanisms entirely novel in such devices. For example, in order to effect a rapidly-intermittent contact between two terminals by the use of a jet or jets in a closed receptacle it is obviously necessary to employ special means which will operate to hold one part of the apparatus stationary while the other rotates or to rotate both the essential parts or terminals in opposite directions or, as the case may be, in the same direction at different speeds.

The present invention is embodied in a device for securing the proper relative movement of the two parts or terminals of the circuit-controller and involves two salient features of novelty, 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, and 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 the drawing hereto annexed I have illustrated the preferred form of apparatus which I have devised for carrying out these improvements. The figure is a central vertical cross-section of a circuit-controller.

A designates a receptacle, usually of iron or steel and mounted in any suitable manner, as by trunnions B B, having bearings in standards C C, so as to be capable of rapid rotation about a horizontal axis.

In the particular form of device under consideration the receptacle is divided into two parts insulated by a washer D and held together by insulated bolts E with nuts F. These two parts are electrically connected, respectively, with the two terminals of the apparatus, as hereinafter described, and by means of brushes X Y, bearing at any suitable points on the two parts of the receptacle, the circuit-controller is connected with the wires of a circuit.

Any convenient means may be employed to rotate the receptacle; but a simple way to effect this is to surround the same with a field-magnet G and to make the receptacle itself the armature of an electric motor or else to secure to it armature-cores, as H.

A body I is supported by trunnions J, 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 K, in which there is a freely-rotatable spindle L, carrying a disk M, with radial arms inclined to the plane of the disk, so as to form vanes N. Arms O P are also secured to the body I and are formed with or carry at their ends ducts or tubes Q, with one end directed toward and opening upon the vanes N and the other end close to the inner wall of the receptacle and opening in the direction opposite to that of the rotation of the receptacle.

A suitable quantity of mercury R 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 R is caused by centrifugal action to distribute itself in a layer over the inner peripheral surface of the receptacle. As the tubes or ducts Q 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 M. 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 more than one insulated jet is to secure a higher velocity of approach and separation, and in respect to the number of jets thus employed the device may be obviously modified as desired without departure from the invention. The disk M, having acquired a very rapid rotation, operates to prevent by gyrostatic action 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 are 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 V V, 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 may be stated that the jets can be produced in any other known ways and that they may be utilized in any desired manner to produce rotation of the disk.

Having now described my invention, what I claim is—

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

2. In an electric-circuit controller, the combination of a closed rotary receptacle, a conducting body therein adapted to be rotated independently of the receptacle 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.

3. 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.

4. 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.

5. 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.

6. 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.

7. 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.

NIKOLA TESLA.

Witnesses:
M. LAWSON DYER,
G. W. MARTLING.

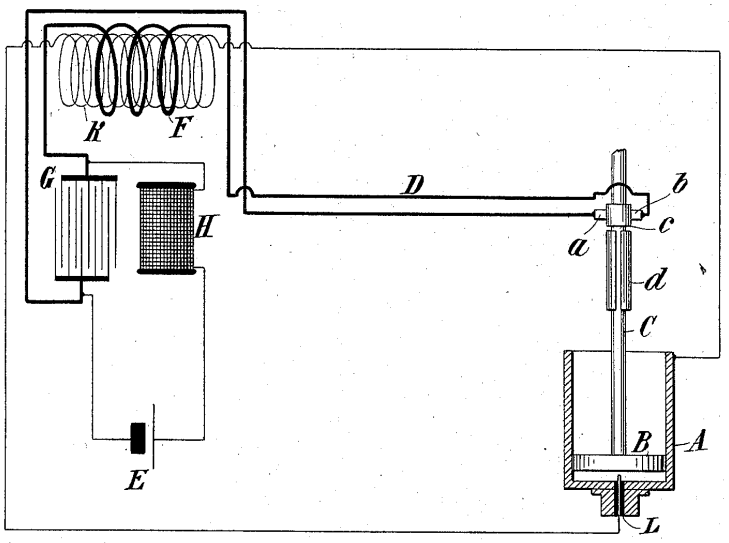
No. 609,250. Patented Aug. 16, 1898.

N. TESLA.

ELECTRICAL IGNITER FOR GAS ENGINES.

(Application filed Feb. 17, 1897. Renewed June 15, 1898.)

(No Model.)



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Nikola Tesla, Inventor
by Kerr, Curtis & Page Attys

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

ELECTRICAL IGNITER FOR GAS-ENGINES.

SPECIFICATION forming part of Letters Patent No. 609,250, dated August 16, 1898.

Application filed February 17, 1897. Renewed June 15, 1898. Serial No. 683,524. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electrical Igniters for Gas-Engines and Analogous Purposes, of which the following is a specification, reference being had to the drawing accompanying and forming a part of the same.

In certain kinds of apparatus it is necessary for the operation of the machine itself or for effecting the object for which it is used to produce an electric spark or any other similar local effect at a given instant of time or at predetermined intervals. For example, in certain gas or explosive engines a flame or spark is necessary for the ignition of an explosive mixture of air and gas under the piston, and the most effective way of igniting the gaseous mixture has been found to be the production in the cylinder at the proper moments of an electric spark. The only practicable device by which this has been accomplished heretofore is an induction-coil comprising a primary and secondary circuit with a buzzer or rapidly-acting automatic circuit-breaker in the primary and a circuit-controller, such as a switch or commutator, located also in the primary or battery circuit and operated by some moving portion of the apparatus to temporarily close such circuit at the proper time, and thereby set in operation the automatic circuit-breaker, which causes between secondary terminals in the cylinder the discharge which is necessary for the proper ignition of the explosive mixture. Instead of thus temporarily closing the primary circuit the automatic circuit-breaker might be permitted to operate continuously, and the secondary, circuit normally broken, might be closed at the proper time to cause the spark to pass at any point. In either case the employment of a quick-acting circuit-breaker is necessary, for unless the induction-coil be of large size and the source of current of considerable power a slow or gradual make and break of the primary of a simple transformer, such as would ordinarily be effected by a switch or commutator, would not effect a discharge of the character necessary for the proper ignition of the gas.

There is, however, no form of vibrating or quick-acting circuit-breaker of which I am aware that can be depended upon to operate with certainty to produce such a spark or which will continue to operate for any length of time without deterioration, and hence not only in the case of engines of the kind described, but in other forms of apparatus which involve the use of a high-tension induction-coil with a quick-acting circuit-breaker, the operation of the machine is contingent upon the proper operation of a comparatively insignificant but essential part.

The object of my invention is to provide a more certain and satisfactory means for use with and control by such machines or apparatus as I have mentioned for producing sparks or discharges of the desired character, and to this end I employ the following arrangement: Any suitable moving portion of the apparatus is caused to mechanically control the charging of a condenser and its discharge through a circuit in inductive relation to a secondary circuit leading to the terminals between which the discharge is to occur, so that at the desired intervals the condenser may be discharged through its circuit and induce in the other circuit a current of high potential which produces the desired spark or discharge.

One practical means of accomplishing this is to employ any proper form of switch or commutator operated directly or through suitable intermediate devices by a moving part of the apparatus and which is caused to complete an electric circuit which has been previously broken or interrupted for an appreciable time when the occurrence of the spark or discharge is necessary. The circuit thus closed includes a condenser, which by this operation of the switch is permitted to discharge, through the primary of a transformer, energy which it had previously received during the interruption of said circuit from a battery or discharge of a self-induction coil in series with the battery in the charging-circuit.

The ends of the secondary circuit of the transformer above mentioned are connected with the points or terminals in the machine between which the spark is to pass, and following the short-circuiting of the condenser by the closing of the switch a strong secondary discharge induced by the discharge of the

condenser through the primary will occur. It is possible by this means not only to produce a strong discharge of high tension, as in the form of a spark well adapted for the ignition of gas or other purposes for which sparks are employed, but to secure such result by apparatus very much less complicated and expensive than that heretofore employed for the purpose and which will be capable of certain and effective operation for an indefinite period of time.

I have illustrated the principle of my improvement and the manner in which the same is or may be carried out in the drawing hereto annexed. The invention is shown as used for effecting the operation of the piston of a gas-engine, the figure being a diagram.

A designates the cylinder of a gas-engine, B the piston, and C the piston-rod. Other parts of the engine are omitted from the illustration as unnecessary to an understanding of the invention.

On the piston-rod C is a commutator or circuit-controller upon which bear the terminals *a b* of an electric circuit D. This commutator comprises a continuous ring *c* and a split ring *d* side by side, so that when the terminals are on the latter the circuit is interrupted, but when on the former it is closed. The to-and-fro movement of the piston, therefore, operates to alternately make and break the circuit, the position of the commutator being such that the make occurs at the moment desired for the ignition of the explosive charge under the piston.

In the circuit D is a battery or other source of current E and the primary F of a transformer. Across the two conductors of the circuit, between the battery and the primary F, is a condenser G, which is charged by the battery when circuit D is interrupted at the commutator and which discharges through the primary when such circuit is closed.

In order that the condenser may receive a charge of high tension, a self-induction coil H is introduced in the circuit between itself and the battery, which coil stores up the energy of the battery when the circuit D is closed at the commutator and discharges it into the condenser when the circuit is broken.

The primary F is combined with a secondary K, the conductors from which lead, respectively, to an insulated terminal L within the cylinder A and to any other conducting-body in the vicinity of such point as to the cylinder itself. In consequence of this arrangement, when the piston reaches the proper point the circuit D is closed, the energy of the condenser is discharged through the primary with a sudden rush, and a strong and effective spark or flash is produced between the point L and the cylinder or piston which ignites the charge of explosive gas.

It will be understood from the preceding description that I do not limit myself to the specific construction or arrangement of the devices employed in carrying out my improvement and that these may be varied within wide limits.

What I claim is—

1. In an apparatus which depends for its operation or effect upon the production of a sudden electric discharge at a given instant, or at predetermined intervals of time, the combination with a moving part of said apparatus of a switch or commutator, a condenser, a charging-circuit for the same, a primary circuit through which the condenser discharges, and a secondary circuit in inductive relation to the said primary circuit and connected with the terminals at the point in the apparatus where the discharge is required, the switch or commutator being operated by the said moving part to effect the discharge of the condenser at the proper intervals, as set forth.

2. In an apparatus which depends for its operation or effect upon the production of a sudden electric discharge at a given instant, or at predetermined intervals of time, the combination with a moving part of said apparatus of a circuit and a circuit-controller adapted to close said circuit at the time when the occurrence of said discharge is desired, a source of current in said circuit, a condenser adapted to be charged by said source while the circuit is interrupted, and a transformer through the primary of which the condenser discharges when the circuit is closed, the secondary of the transformer being connected with the terminals at the point in the apparatus where the discharge is required, as set forth.

3. In an apparatus which depends for its operation or effect upon the production of an electric discharge, at a given instant, or at predetermined intervals of time, the combination with a moving part of said apparatus of a circuit and a circuit-controller adapted to close said circuit at the time when the occurrence of the spark is desired, a source of current in said circuit, a self-induction coil which stores the energy of the source while the circuit is closed, a condenser into which said coil discharges when the circuit is broken, and a transformer through the primary of which the condenser discharges, the secondary of said transformer being connected with separated terminals at the point where the discharge is required.

4. In a gas or explosive engine of the kind described, the combination with a moving part of said engine of a circuit-closer or switch controlling the charging and discharging of a condenser, separated terminals in the cylinder or explosive-chamber, and a transformer through the primary of which the condenser discharges, the secondary being connected with the terminals in the cylinder, as set forth.

NIKOLA TESLA.

Witnesses:
M. LAWSON DYER,
EDWIN B. HOPKINSON.

No. 609,251. Patented Aug. 16, 1898.

N. TESLA.

ELECTRIC CIRCUIT CONTROLLER.

(Application filed June 3, 1897. Renewed June 15, 1898.)

(No Model.) 2 Sheets—Sheet 1.

Fig. 3

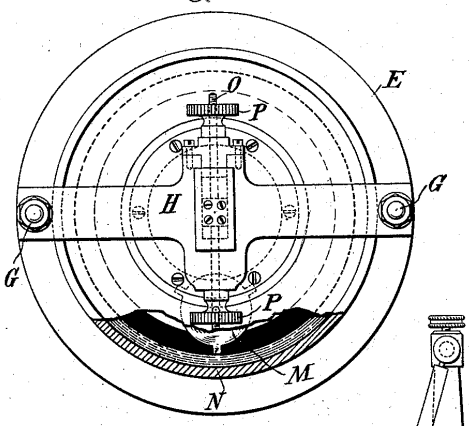


Fig. 2

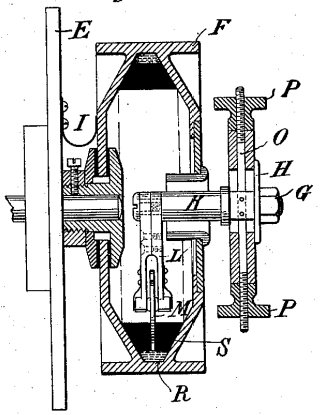
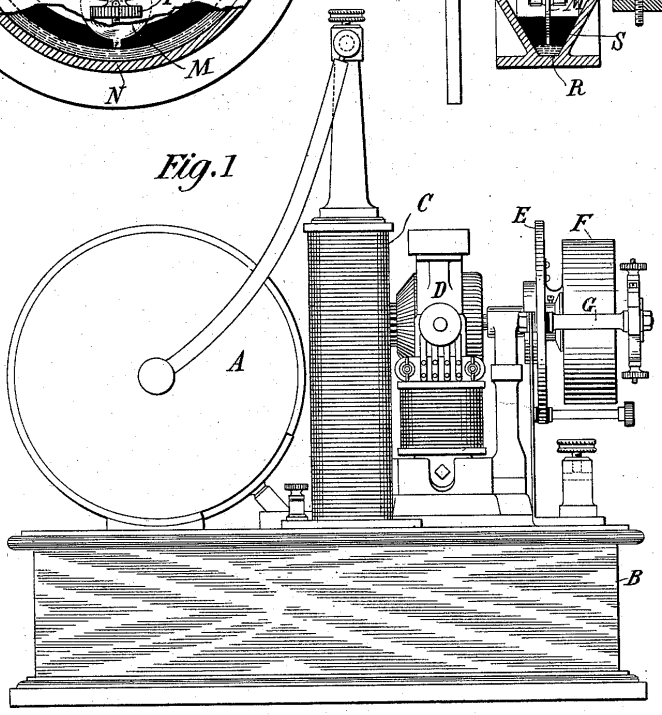


Fig. 1



Witnesses:
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THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

No. 609,251. Patented Aug. 16, 1898.

N. TESLA.

ELECTRIC CIRCUIT CONTROLLER.

(Application filed June 3, 1897. Renewed June 15, 1898.)

(No Model.) 2 Sheets—Sheet 2.

Fig. 4

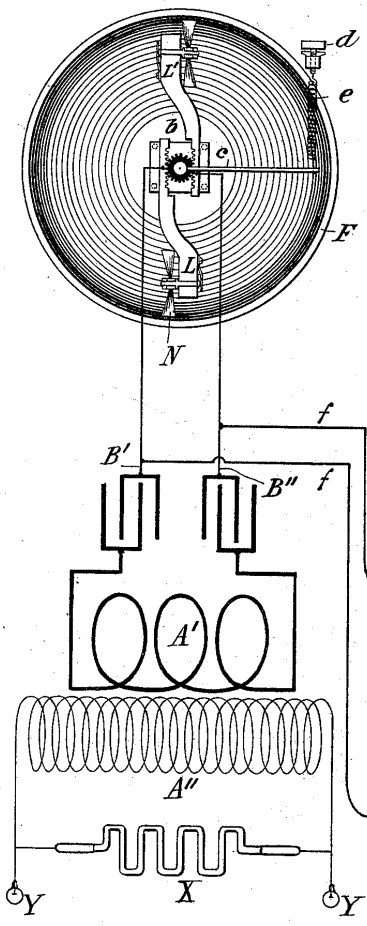
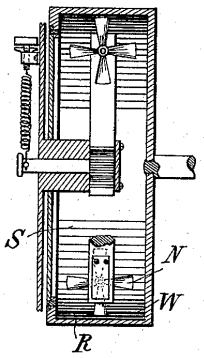


Fig. 5



WITNESSES

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G. B. Lorin.

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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

ELECTRIC-CIRCUIT CONTROLLER.

SPECIFICATION forming part of Letters Patent No. 609,251, dated August 16, 1898.

Application filed June 3, 1897. Renewed June 15, 1898. Serial No. 683,525. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electric-Circuit Controllers, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

In previous patents granted to me I have shown and described methods and apparatus for the conversion and utilization of electrical currents of very high frequency based upon the principle of charging a condenser or a circuit possessing capacity and discharging the same generally through the primary of a transformer, the secondary of which constituted the source of working current 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 this invention 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 my present application is based upon a novel and improved form of device for this purpose, which may be generally styled a "circuit-controller."

In order that the full advantages of my system may be realized and the best practical results secured, the said circuit-controller should be capable of fulfilling certain requirements, the most important among which is the capability of effecting an extremely-rapid interruption and completion of the circuit. It is also of importance that such makes and breaks, and more especially the former, should be positive and abrupt, and from considerations of economy and practicability it is essential that the apparatus should be cheaply constructed, not liable to derangement, and capable of prolonged use without attention or adjustment. With the object of attaining these results, which have never heretofore been fully attained in any form of mechanical circuit-controller of which I am aware, I devised and developed the circuit-controller which forms the subject of my present application and which may in general terms be described as follows:

The device in its typical embodiment comprises as essential elements two terminals—one with peripheral contacts alternating with insulating-spaces, such as is exemplified in a stelliform disk and which is capable of rotation, and the other a rotatable receptacle containing a fluid in which more or less of the first-named terminal is immersed.

In the preferred construction of the apparatus the receptacle contains both a conducting and a non-conducting fluid, the former being the heavier, and I maintain the terminals in such relations that the electrical connection between them is made and broken by the successive immersion of the contact-points into and their withdrawal from the conducting through the non-conducting fluid. These relations are best maintained by such construction of the receptacle that the distribution of the two fluids necessary for the proper operation of the device may be preserved by centrifugal action and the rotation of the other terminal effected by the movement of the fluid or fluids relatively thereto.

To secure the conditions necessary for the accomplishment of the objects of the invention, various mechanical expedients may be resorted to; but the best and most practicable device for the purpose of which I am aware is a hollow wheel or drum mounted so as to be rotated at any desired speed and containing a conducting fluid, such as mercury or an electrolyte, which by the rotation of the drum is thrown by centrifugal force outward to the inner periphery of the same, and a sufficient quantity of a lighter non-conducting or poorly-conductive fluid, such as water or oil, which by the centrifugal action is maintained on the surface of the heavier conducting fluid and tends to prevent the occurrence of arcs between the contact-points and the conducting fluid.

A central opening is formed in one side of the drum, through which enters an arm carrying a disk with peripheral projections or vanes which when the drum is rotated project to a sufficient extent toward or into the conducting fluid to effect the makes and breaks of the circuit.

The motion of the fluid within the drum causes the disk to rotate and its projections or vanes to make and break the circuit with

a rapidity which may be very great. In fact, when the drum is rotated at a high rate of speed the fluid conductor may become in its effect similar to a solid body, upon which the conducting-disk rolls, so that the conducting fluid might be dispensed with, although I find it preferable to use it.

In order to insure the proper immersion of the projections into the fluid to compensate for wear and at the same time to secure a yielding pressure between the fluid and the disk, it is desirable to employ for the disk some form of spring connection or support which will exert a force tending to force it in contact with the fluid.

I have also devised certain details of construction which add to the efficiency and practicability of the apparatus which will be more conveniently described by reference to the accompanying drawings.

Figure 1 is a side elevation of a complete apparatus for producing currents of high frequency and to which my present invention is applied. Fig. 2 is a central vertical section of the improved circuit-controller of Fig. 1; Fig. 3, an end view of the same; Fig. 4, a modified form of the circuit-controller, showing it in connection with the remaining parts of the apparatus illustrated diagrammatically; and Fig. 5, a side view of the same with the receptacle in section.

As the apparatus as a whole is now well known, a brief description of the same will suffice for an understanding of its character.

The various parts or devices are preferably mounted on a base B, which contains the condenser, and comprise a transformer A with primary and secondary coils, one or more self-induction coils C, a small electromagnetic motor D, and the circuit-controller, which is driven by the motor. The circuit connections will be described in connection with Fig. 5.

In general plan of construction and arrangement the apparatus is essentially the same as that described and shown in a patent granted to me September 22, 1896, No. 568,176.

The shaft of the motor D extends through a stationary disk E, and to its end is keyed a hollow wheel or drum F, which rotates with it. Two standards G are secured to the disk E and connected by a cross-bar H, from which extends an arm K into the interior of the drum F through a central opening in its side.

To the end of the arm K is secured an arm L, carrying at its free end a disk M with peripheral teeth or projections N, as shown in Fig. 3. The disk is mounted on any suitable bearings in the arm L, so as to be capable of free rotation.

It is desirable that the disk should admit of adjustment with respect to the inner peripheral surface of the drum, and for this purpose I secure the arm K to a rod O, which passes through supports in the cross-bar H and is adjustable therein by means of threaded nuts P.

The interior of the drum F is formed by preference in substantially the manner shown in Fig. 2—that is to say, it is tapered or contracted toward the periphery so as to form a narrow trough in which the fluid is confined when the drum is rotated.

R designates the conducting fluid, and S the lighter non-conducting fluid, which are used in the drum. If the proper quantities and proportions of these fluids be introduced into the drum and the latter set in rapid rotation, the two fluids will distribute themselves under the action of centrifugal force around the drum in the manner indicated in Fig. 2. The arm K is adjusted so that the teeth or projections on the disk M will just enter the conducting fluid, and by the action of either or both the disk will be rapidly rotated. Its teeth are so arranged that no two are simultaneously in contact with the conducting fluid, but come into the same successively. If, therefore, one part of the circuit be connected to the drum, as by a contact strip or brush T, and the other part to the disk M, or to any part, as the standards G, which are insulated from the frame of the apparatus and in metallic connection with the disk M, the circuit will be made and broken with a rapidity which may obviously be made enormously high. The presence of the non-conducting fluid on the surface of the other operates to prevent the occurrence of sparks as the teeth N leave the latter and also to prevent the current from leaping across the space between the teeth and the conductor as the two approach.

In illustration of the modifications of which the improvement is susceptible I now refer to Figs. 4 and 5, in which also certain novel and useful details of construction applicable generally to the invention are shown.

In the modification shown in Figs. 4 and 5 two rigid arms L and L′, each carrying a disk M, are shown, and this number may be increased, if so desired. The rotating disks in this case are mounted on spindles at right angles to the axis of rotation of the drum F, and the contact points or projections are formed as vanes, with faces inclined to the plane of rotation, so as to be rotated by the movement of the fluid in the manner of turbine wheels.

In order to provide a means for automatically adjusting the disks to compensate for any wear and keep the ends of the vanes or points properly immersed in the fluids, each disk-carrying arm is impelled by a spring or weight in the direction of the periphery of the drum. A convenient way to accomplish this is to form racks on the arms L L′ and to provide a pinion *b* in engagement therewith. From the shaft of the pinion extends an arm *c*, the end of which is connected to an adjustable stop *d* by a spiral spring *e*, the tendency of which is to turn the pinion and force both arms L and L′ toward the periphery of the drum.

In some applications of the invention it is practicable to prevent the occurrence of arcs

still more effectively or even entirely by using in addition to the non-conducting fluid a somewhat heavier fluid W, which is a comparatively poor conductor and which takes up a position between the conducting and non-conducting fluids.

When two or more disks or equivalent devices are used, they may be connected either in series or multiple. In the present illustration they are shown as in series, and as the arms L and L′ are insulated from each other and each connected with a terminal of the source of current the circuit is completed only when a vane of each disk is immersed in the conducting fluid and interrupted at all other times.

The diagram of circuit connections will serve to illustrate the purpose and mode of operation of the device. Let *f f* be the conductors from a source of current, each including a self-induction coil C C′ and connected with the arms L and L′ and with two conductors B′ B″, respectively. Then during the periods when the circuit is completed between the two arms L L′ the coils C C′ store energy, which on the interruption of said circuit rushes into and charges the condensers. These latter during the periods when the circuit is closed between arms L and L′ discharge through the primary A′ and induce by such discharge currents in the secondary A″, which are utilized for any purpose for which they may be suited, as in operating vacuum-tubes X or suitable lamps Y.

It will be understood that the rotating drum may be mounted in a horizontal or other plane and from the nature and objects of the results which are attained by the particular apparatus described the construction of this apparatus may be very greatly varied without departure from my invention.

Without therefore limiting myself to the details of construction and arrangement shown herein in illustration of the manner in which my invention is or may be carried out, what I claim is—

1. A circuit-controller comprising, in combination, a receptacle containing a fluid, means for rotating the receptacle, and a terminal supported independently of the receptacle and adapted to make and break electric connection with the receptacle through the fluid, as set forth.

2. A circuit-controller comprising in combination a receptacle containing a conducting fluid and a non-conducting fluid, means for rotating the receptacle and a terminal adapted to make and break electrical connection with the conducting fluid within or under the non-conducting fluid, as set forth.

3. A circuit-controller comprising in combination a terminal capable of rotation and formed or provided with peripheral contacts, a receptacle comprising the opposite terminal and containing a fluid into which the said contacts extend, and means for rotating the receptacle, as set forth.

4. A circuit-controller, comprising, in combination, a terminal capable of rotation and formed or provided with peripheral projections, a receptacle containing a fluid conductor into which the points or projections of the said conductor extend, and means for rotating the said receptacle, as set forth.

5. A circuit-controller comprising, in combination, a terminal capable of rotation and formed or provided with peripheral projections, a centrifugal drum or wheel containing a fluid conductor into which the points or projections of the said conductor extend, and means for rotating the said drum, as set forth.

6. A circuit-controller comprising, in combination, a terminal capable of rotation and formed or provided with peripheral projections, a centrifugal drum or wheel containing a fluid conductor into which the points of the said terminal extend, and means for adjusting the latter with relation to the surface of the fluid, as set forth.

7. A circuit-controller comprising, in combination, a terminal having peripheral projections and capable of rotation, a centrifugal drum or receptacle containing a conducting and a lighter non-conducting fluid, the said terminal being arranged so that its points or projections extend through the non-conducting into the conducting fluid, when the fluids are distributed in the drum under the action of centrifugal force, as set forth.

8. The combination with a hollow centrifugal drum or wheel containing a conducting fluid, a motor for rotating the same, a support extending through an opening into the drum, and a rotatable terminal having peripheral projections, mounted on said support in position in which its projections extend into the fluid when displaced by centrifugal action, as set forth.

9. The combination with a receptacle containing a fluid and means for rotating the same, a terminal with peripheral projections capable of rotation, and a spring connection or support for said terminal tending to force it toward the periphery of the receptacle, as set forth.

10. The combination with a hollow centrifugal drum or wheel containing a conducting fluid and a lighter non-conducting fluid, means for rotating the said drum, a support extending through an opening into the drum, and a rotatable terminal having peripheral projections, mounted on said support in position in which the projections extend through the non-conducting into the conducting fluid when the fluids are displaced by centrifugal action, as set forth.

11. The combination with a centrifugal drum containing a conducting and a non-conducting fluid, means for rotating the drum, a terminal capable of rotation and having peripheral projections, mounted within the drum on a stationary support, and a spring or its equivalent acting on the said terminal

and tending to force its projections toward the inner periphery of said drum, as set forth.

12. The combination with a receptacle containing a conducting fluid, a lighter fluid of low conductivity and a non-conducting fluid lighter than the others, and means for rotating the receptacle, of a terminal adapted to make and break the circuit by movements between the conducting and non-conducting fluid through the intermediate fluid of low conductivity, as set forth.

NIKOLA TESLA.

Witnesses:
M. LAWSON DYER,
PARKER W. PAGE.

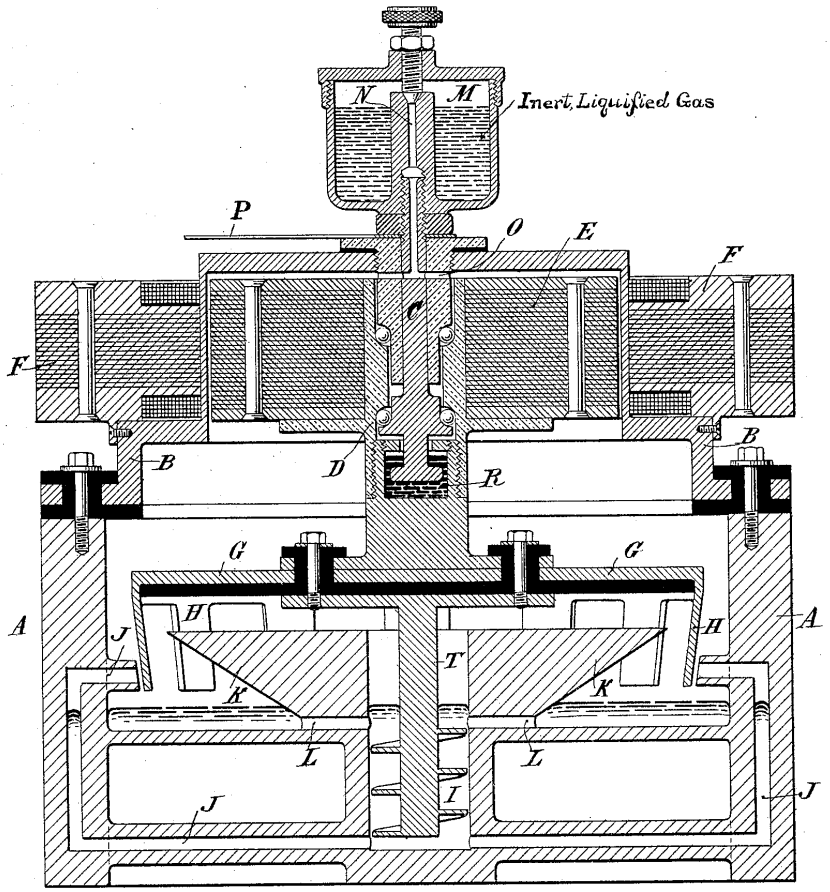
No. 611,719. Patented Oct. 4, 1898.

N. TESLA.

ELECTRICAL CIRCUIT CONTROLLER.

(Application filed Dec. 10, 1897.)

(No Model.)



Witnesses:
Raphaël Netter
Edwin B. Hopkinson.

Nikola Tesla, Inventor
by Kerr, Curtis & Page Att'ys.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

ELECTRICAL-CIRCUIT CONTROLLER.

SPECIFICATION forming part of Letters Patent No. 611,719, dated October 4, 1898.

Application filed December 10, 1897. Serial No. 661,403. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electrical-Circuit Controllers, of which the following is a specification, reference being had to the drawings accompanying and forming part of the same.

In order to secure a more efficient working of circuit-controllers, particularly in their use in connection with my system of electrical-energy conversion by means of condenser discharges, I have devised certain novel forms of such appliances, comprising as essential elements a body of conducting fluid constituting one of the terminals, a conductor or series of conductors forming the other terminal, and means for bringing the two into rapidly-intermittent contact with each other. These devices possess many desirable qualities, particularly that of being eminently adapted for making and breaking at a very rapid rate an electric circuit and thus reducing to a minimum the time of passage of the current through an arc or path of high resistance and diminishing thereby the losses incident to the closure and interruption of the circuit. Continued experimentation with these appliances has led me to make further important improvements by causing the make-and-break to be effected in an inert medium of very high insulating power.

It is a fact, which was fully demonstrated by Poggendorff and utilized by him to improve the operation of induction-coils, that when the contact-points of a circuit-breaker are inclosed in a vessel and the latter exhausted to a high degree the interruption of the current is rendered more sudden, as if a condenser were connected around the break. Furthermore, my own investigations have shown that under such conditions the closure also is more sudden, and this to even a greater degree than the break, which result I attribute to the high insulating quality of the vacuous space, in consequence of which the electrodes may be brought in very close proximity before an arc can be formed between them. Obviously these facts may be utilized in connection with my novel circuit-controllers; but inasmuch as only a very moderate improvement is secured in this manner and as the high vacuum required is quickly destroyed and cannot be maintained, unless by a continuous process of rarefaction and other inconvenient measures, I have found it desirable to employ more effective and practical means to increase the efficiency of the devices in question. The measures I have adopted for this purpose have resulted from my recognition of certain ideal qualifications of the medium wherein to effect a make-and-break. These may be summed up as follows: First, 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; second, the closing up or repair of the injured dielectric, 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; third, 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; fourth, 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 vise, and, fifth, 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 employed in some of my circuit-controlling devices a fluid of high insulating qualities, such as liquid hydrocarbon, 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 insulator a very marked advantage was secured; but while some of the above requirements are attained in this manner certain defects still exist, notably that due to the fact that the insulating liquid, in common with a vacuous space, though in a less degree, permits the arc to expand in length and

thickness, and thus pass through all degrees of resistance and causing a more or less considerable 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 fluid insulating medium subjected to great pressure.

The application of great pressure to the medium in which the make-and-break is made secures a number of specific 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 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 difference of potential between the electrodes is usually not more than a few hundred volts, the economical advantages resulting from the reduction of the striking distance, particularly on approach of the terminals, are not of very great practical consequence. By far the more important gain I have found to result from an 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 its cross-section, 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 do not interfere notably with the operation of the circuit-controller, whereas such conditions are fatal drawbacks when, for instance, Poggendorff's method of insulating the terminals is used. 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 carrying out 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 inclosing the circuit-controller, or at least so much of the same as shall include the terminals, in a chamber or receptacle with which communicates a small reservoir containing a liquefied gas. For purpose of illustration this particular manner of carrying out the invention is described herein.

While the improvement is applicable generally to circuit-controllers, the best results will be secured by the use of devices in which a high relative speed between the terminals is obtainable, and with this special object in view I have devised a novel circuit-controller which, though belonging to the class of which I have shown a typical form in my application for patent filed December 2, 1897, Serial No. 660,518, differs in certain particulars of construction, which will be understood from the following comparison: In the previously-described form of said circuit-controllers a rotary receptacle, carrying within it a series of spaced conductors, is driven at a high speed by a suitable motor. Mounted within and concentrically with the receptacle, but capable of free independent rotation with respect thereto, is a body which during the rotation of the receptacle is retarded or restrained against rotation by the application of a suitable force. This body carries a tube or duct which takes up at one end a fluid conductor contained in the receptacle and rotating with the same and discharges it from the other end against the rotating spaced conductors.

While an apparatus thus constructed is very efficient and performs the work required of it in a highly-satisfactory manner, it is nevertheless subject to certain limitations, arising mainly from the amount of work which the conducting fluid is required to perform and which increases with the speed. With the object of overcoming objections that might lie to this form of circuit-controller in the particular referred to, I devised the form of instrument shown herein. The features which more particularly distinguish this form are the following: I employ a closed stationary receptacle within which is mounted a body that is capable of being rotated in any way—as, for example, by the drag or pull upon it of an external field of force or a magnet rotated bodily. The rotary body imparts rotation to a series of spaced conductors within the receptacle and also operates as a pump to maintain a flow of conducting fluid through one or more stationary ducts and from the same against the rotating conductors.

The details of this apparatus will be described by reference to the accompanying drawing, which is a vertical central section of the circuit-controller complete.

A is a receptacle, of iron, steel, or other proper material, with a head B, secured by a gas-tight insulating-joint. Within this receptacle is contained the circuit-controller, which, in so far as the main feature of my present invention is concerned, may be of any desired construction, but which, for the reason stated above, is of the special character shown. A spindle C is screwed or otherwise secured centrally in the head B, and on this is mounted on antifriction-bearings a body to which rotary motion may be imparted. The construction of the device in this particular and the means for imparting rotation to the said body may be greatly varied; but a convenient means for accomplishing this is to secure to the rotary sleeve D a laminated

magnetic core E and place around the portion of the head B which contains it a core F, 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 E. To the depending end of the sleeve D is secured a conductor G, usually in the form of a disk with downwardly-extending teeth or peripheral projections H. To the sleeve or the disk G is also attached, but insulated therefrom, a shaft T, having a spiral blade and extending down into a well or cylindrical recess in the bottom of the receptacle. One or more ducts or passages J lead from the bottom of this well to points near the path of the conducting-teeth H, so that by the rotation of the screw I a conducting fluid, which runs into the well from the receptacle, 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 K, containing passages L, which permit the conducting fluid to flow from the receptacle into the well, and having beveled 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.

M is any suitable reservoir communicating with the interior of the main receptacle and containing a liquefied gas, such as ammonia, which maintains a practically inert atmosphere under pressure in the receptacle.

Preferably, though mainly as a matter of convenience, the receptacle M is a metal cup with a hollow central stem N, the opening for the passage of gas being controlled by a screw-valve in the top of the cup. The said cup is screwed onto the end of the spindle C, through which is a passage O, leading into the interior of the receptacle A.

The receptacle A and the conducting fluid, which is generally mercury, being normally insulated from the head B and the parts attached and supported thereby, are connected to one part of the circuit to be controlled. The other circuit connection is made by a conductor P to any part of the head, so that when the core E and conductor G are rotated the circuit will be completed between the two insulated parts of the receptacle through the jet or jets of conducting fluid whenever they impinge upon the said conductor.

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

The special advantages of this particular form of circuit-controller heretofore referred to will now more readily appear. The mass and weight of the rotating parts are greatly reduced and a very high speed of rotation obtained with small expenditure of energy. The power required to maintain the jets of conducting fluid is, moreover, very small.

Having now described my invention, what I claim is—

1. The combination with a closed receptacle, of a circuit-controller contained therein and surrounded by an inert insulating medium under pressure.

2. The combination with a closed receptacle, of a circuit-controller contained therein and means for maintaining within said receptacle an inert atmosphere under pressure.

3. The combination with a closed receptacle, of a circuit-controller contained therein, and a vessel containing a liquefied inert gas, and communicating with the interior of the receptacle.

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

5. 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 close receptacle containing the terminals, and means for maintaining an inert atmosphere under pressure in the receptacle.

6. 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 inclosing and excluding oxygen from the said terminals.

7. The combination with a receptacle, of a conductor or series of spaced conductors mounted therein, a motive device for rotating said conductors, one or more nozzles for directing a stream or jet of fluid against the conductor, and a force-pump in direct connection with the conductor for maintaining a circulation of conducting fluid contained in the receptacle through the nozzle or nozzles, the conductor and the fluid constituting respectively the terminals of a circuit-controller.

8. 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 toward the conductors, and a screw 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.

9. 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.

10. 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.

NIKOLA TESLA.

Witnesses:
M. LAWSON DYER,
G. W. MARTLING.

No. 613,735. Patented Nov. 8, 1898.

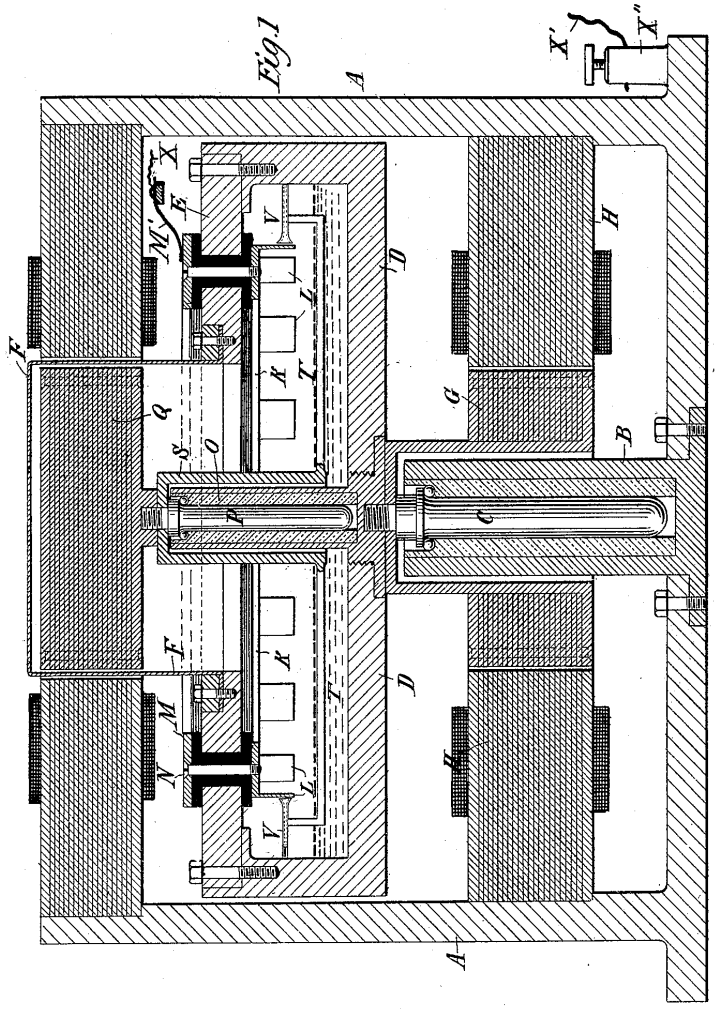
N. TESLA.

ELECTRIC CIRCUIT CONTROLLER.

(Application filed Apr. 19, 1898.)

(No Model.) 2 Sheets—Sheet 1.

Fig. 1



Witnesses:
Raphael Netter
Benjamin Miller.

Nikola Tesla, Inventor
by Kerr, Curtis & Page Attys.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

No. 613,735. Patented Nov. 8, 1898.

N. TESLA.

ELECTRIC CIRCUIT CONTROLLER.

(Application filed Apr. 19, 1898.)

(No Model.) 2 Sheets—Sheet 2.

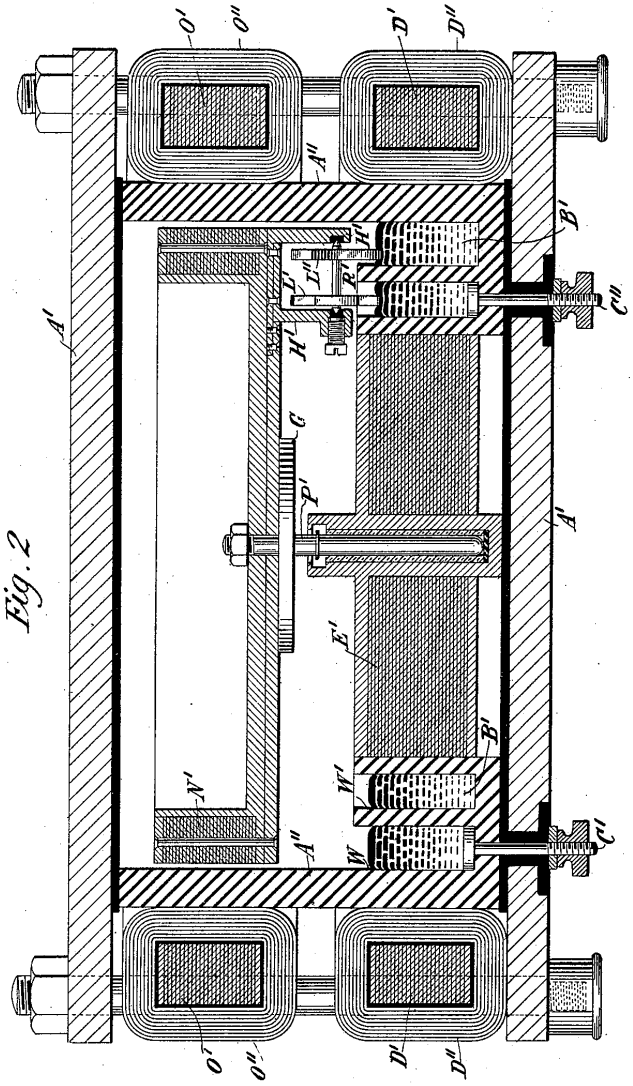


Fig. 2

Witnesses:
Raphael Netter
Benjamin Miller.

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THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

ELECTRIC-CIRCUIT CONTROLLER.

SPECIFICATION forming part of Letters Patent No. 613,735, dated November 8, 1898.

Application filed April 19, 1898. Serial No. 678,127. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electrical-Circuit Controllers, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

In the electrical system or combination of apparatus for the conversion of electrical energy by means of the discharges of a condenser invented and heretofore described by me the means employed for making and breaking the electric circuit, though performing a subordinate function, may from the peculiar conditions which exist become a highly important consideration, not only as regards their practicability and durability, but also the economy in the operation of the system or apparatus. Of such importance is this consideration that for the most efficient and reliable operation of my said system I have found it necessary to devise special appliances for making and breaking the circuit which differ materially in construction and mode of operation from any previously-existing devices of this character of which I am aware. In the forms of such apparatus which I have produced at least one of the terminals is a conducting fluid, while the other is usually a solid conductor or series of conductors, both being preferably inclosed in a gas-tight receptacle and brought by rotary movement into rapidly intermittent contact. I have shown and described typical forms of such circuit-controllers in applications Serial No. 660,518, filed December 2, 1897; Serial No. 639,227, filed June 3, 1897, and Serial No. 671,897, filed February 28, 1898.

The invention, subject of my present application, pertains to apparatus of this class and involves certain improvements in the construction and mode of operation of the same which have primarily for their object to secure a greater relative speed between the two terminals, whereby the periods of make-and-break, during which occurs the chief loss of energy, may be materially shortened and also a higher frequency of current impulses secured. A brief consideration of the forms of circuit-controller of this general kind which I have heretofore shown and described will conduce to a better understanding of the principles followed in the construction of the apparatus upon which my present application is based and of the primary object which I have in view—to increase the relative speed of the two terminals in approaching and receding from each other.

In some forms of the circuit-controllers heretofore described by me I employ a closed receptacle capable of being maintained in rapid rotation. Within this receptacle is mounted a body the rotation of which is retarded or prevented and which carries a tube or duct which takes up a conducting fluid from the receptacle when the latter is rotated and directs the said fluid against a conductor or series of spaced conductors carried by the rotating receptacle. This apparatus, while effective to a high degree and possessing many advantages over previously-existing forms, is nevertheless subject to certain limitations as to efficiency, having regard to the speed at which the receptacle is rotated, for not only may an undue loss of energy result from rotating the receptacle, but also from the unnecessarily-rapid movement of the conducting fluid. With a view to improving the apparatus in these particulars I devised forms in which the receptacle was stationary and the interior terminal conductor rotated, and by this means I reduced the mass and weight of the moving parts. I also employed a device in the nature of a pump, which formed a part of the circuit-controller proper and was operated by the motor used for rotating the conductor, and thus maintained a flow of conducting fluid from ducts in the receptacle against the rotating conductor with no greater speed than required for efficient operation. By such an apparatus it is not only possible to secure a higher relative speed between the two terminals, but to do this with a smaller expenditure of mechanical energy. To still further increase the relative speed of the terminals, I now provide for rotating each of the terminals with respect to the other, so that the rate of mutual contact is very greatly increased.

Obviously various means may be employed for rotating the conductors, or, in general, the two essential parts which by their movement

produce a make and break; but in the annexed drawings I have only shown such forms of the apparatus as best illustrate the present improvement.

Figure 1 is a central vertical section of a circuit-controller comprising a conductor or series of conductors forming one terminal and means for maintaining a jet or jets of conducting fluid constituting the other terminal, which are arranged to be rotated in opposite directions. Fig. 2 is a similar view of a modified form of circuit-controller.

A designates a casting of cylindrical form within which is a standard or socket B, in which is mounted a vertical spindle C, carrying the circuit-controlling mechanism. The said mechanism is contained in a receptacle D, of iron or steel, the top or cover of which is composed of an annular plate E and a cap or dome F, the latter being of insulating material or of a metal of comparatively high specific resistance, such as German silver. The receptacle D as a whole is made air-tight and any suitable means may be employed to effect its rotation, the particular device shown for this purpose being an electromagnetic motor, one element, G, of which is secured to the spindle C or receptacle D and the other, H, to the box or case A. Within the receptacle D and secured to the top of the same, but insulated therefrom, is a circular conductor K, with downwardly-extending projections or teeth L. This conductor is maintained in electrical connection with a plate M outside of the receptacle by means of screws or bolts N, passing through insulated gaskets in the top of the receptacle D. Within the latter is a standard or socket O, in which is mounted a spindle P, concentric with the axis of the receptacle.

Any suitable means may be provided for rotating the spindle P independently of the receptacle D; but for this purpose I again employ an electromagnetic motor, one element, Q, of which is secured to the spindle P within the receptacle D and the other, R, is secured to the box A and surrounds the cap or dome F, within which is mounted the armature Q.

Depending from the spindle P or the armature Q is a cylinder S, to which are secured arms T T, extending radially therefrom and supporting short tubes or ducts V between the peripheral walls of the receptacle D and the series of teeth or projections L.

The tubes V have openings at one end in close proximity to the inner wall of the receptacle D 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 L.

To operate the apparatus, the receptacle D, into which a suitable quantity of conducting fluid, such as mercury, is first poured, and the spindles P are both set in rotation by their respective motors and in opposite directions. By the rotation of receptacle D 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 V and discharged against the rotating conductors L. If, therefore, one terminal of the circuit be connected with any part of the receptacle D or the metal portions of the instrument in electrical connection therewith and the other terminal be connected to the plate M, the circuit between these terminals will be completed whenever a jet from one of the ducts V is discharged against one of the projections L and interrupted when the jets are discharged through the spaces between such projections. I have indicated the necessary circuit connections by wires X and X′, connected, respectively, with a brush M′, bearing upon the circular plate M, and a binding-post X″, set in the frame or casing A.

In Fig. 2 a modified form of apparatus is shown and by means of which similar results are obtained. In this device the top and bottom A′ of the receptacle are metal plates, while the cylindrical portion or sides A″ is of insulating material, such as porcelain. Within the receptacle and preferably integral with the side walls A″ are two annular troughs W W′, which contain a conducting fluid B′, such as mercury. Terminals C′ C″, 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′ lie is a core D′, wound with coils D″, 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 E′ 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 P′, carrying a disk G′. Depending from said disk are arms H′, which afford bearings for a shaft K′, supporting two star-shaped wheels L′ L″, arranged to make contact with the mercury in the two troughs, respectively. The shaft K′ is mounted in insulated bearings, so that when both wheels are in contact with mercury the circuit connecting the terminals C′ C″ will be closed. The disk G′ carries an annular core N′, which is adapted to be maintained in rotation by a core O′ and coils O″, supported outside of the receptacle and 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 wheels L′ L″ 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 L′ L″ were supported in a stationary bearing.

It is obvious that by means of devices of the character described a rapid interruption of the circuit may be effected, while all the practical advantages which may be derived from inclosing the terminals or contacts in a closed receptacle are readily realized to the fullest extent.

Having now described my invention, what I claim is—

1. In a circuit-controller, the combination with rigid and fluid conductors adapted to be brought intermittently into contact with each other, thereby making and breaking the electric circuit, of means for imparting rotary motion to both of said conductors, as set forth.

2. 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.

NIKOLA TESLA.

Witnesses:
M. LAWSON DYER,
G. W. MARTLING.

No. 613,809. Patented Nov. 8, 1898.

N. TESLA.

METHOD OF AND APPARATUS FOR CONTROLLING MECHANISM OF MOVING VESSELS OR VEHICLES.

(No Model.) 5 Sheets—Sheet 1.

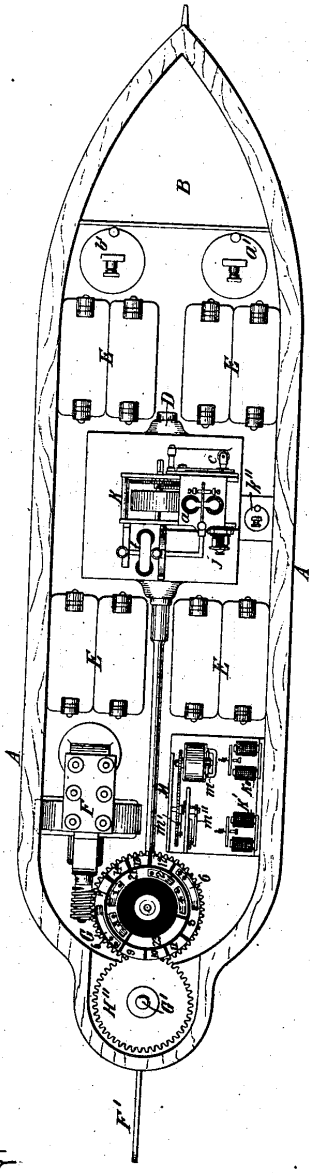

Fig. 1

Witnesses:
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George Scherff.

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Nikola Tesla

No. 613,809. Patented Nov. 8, 1898.

N. TESLA.

METHOD OF AND APPARATUS FOR CONTROLLING MECHANISM OF MOVING VESSELS OR VEHICLES.

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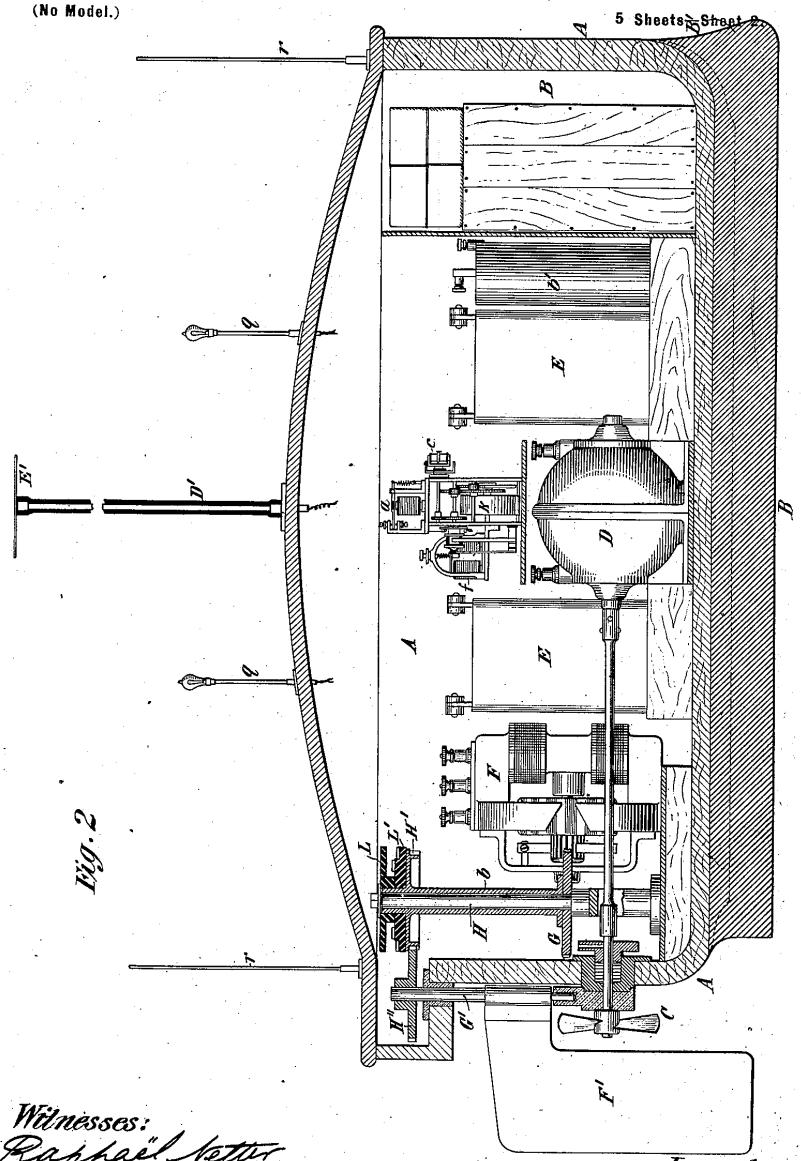

Fig. 2.

Witnesses:
Raphael Netter
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Inventor:
Nikola Tesla

No. 613,809. Patented Nov. 8, 1898.

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METHOD OF AND APPARATUS FOR CONTROLLING MECHANISM OF MOVING VESSELS OR VEHICLES.

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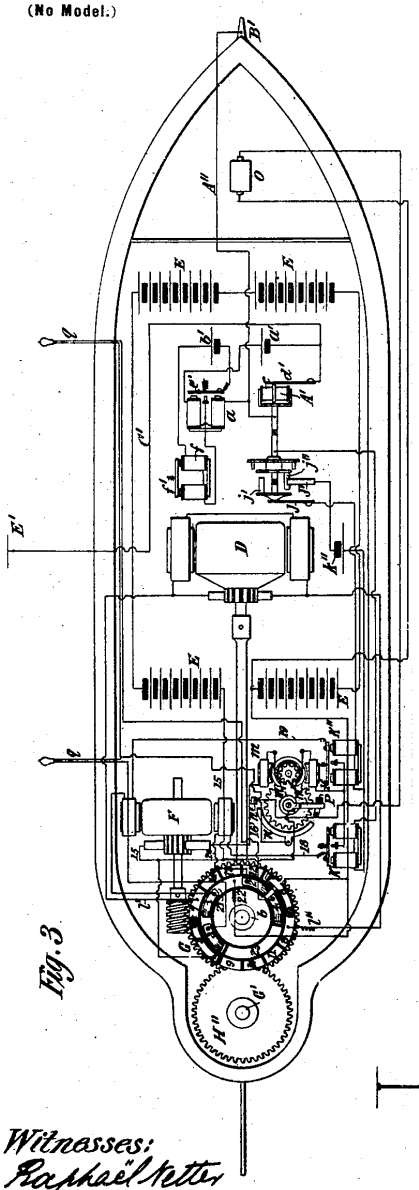

Fig. 3.

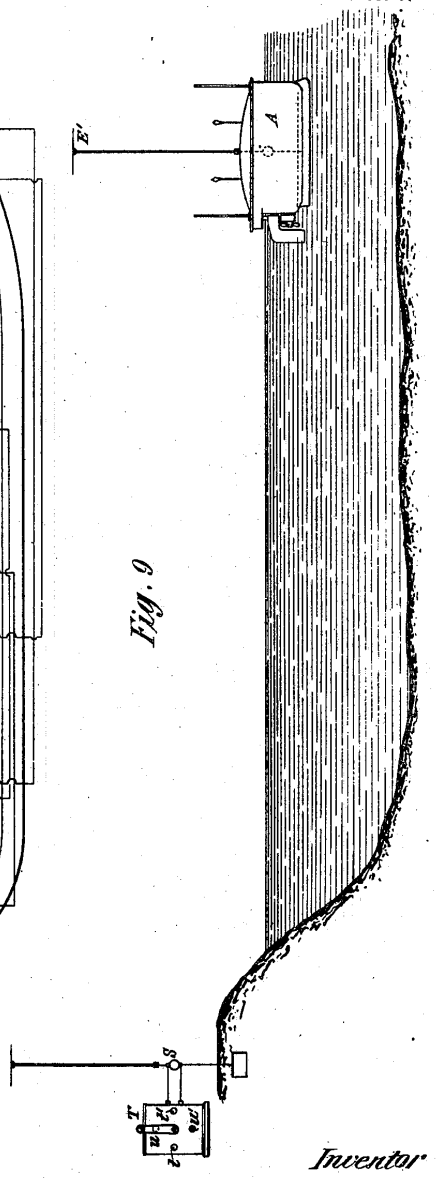

Fig. 9.

Witnesses:
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METHOD OF AND APPARATUS FOR CONTROLLING MECHANISM OF MOVING VESSELS OR VEHICLES.

(No Model.) 5 Sheets—Sheet 4.

Fig. 5

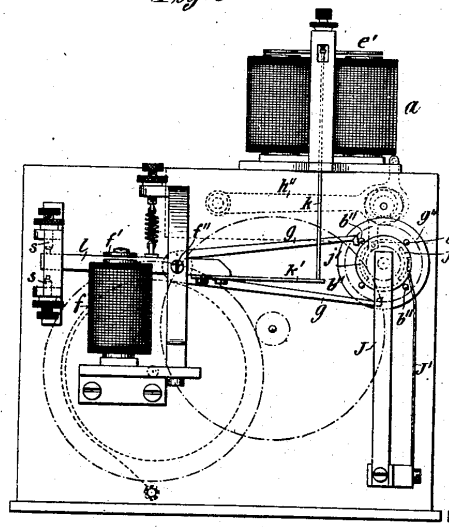


Fig. 6

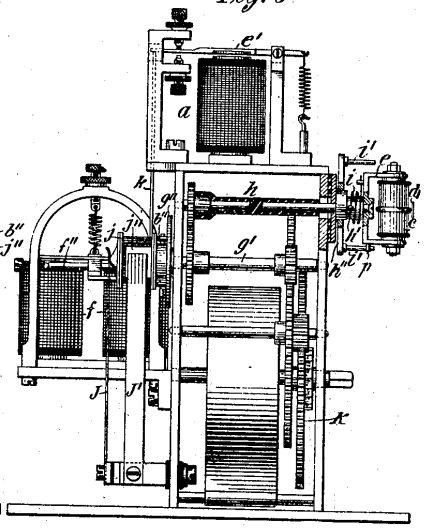


Fig. 4

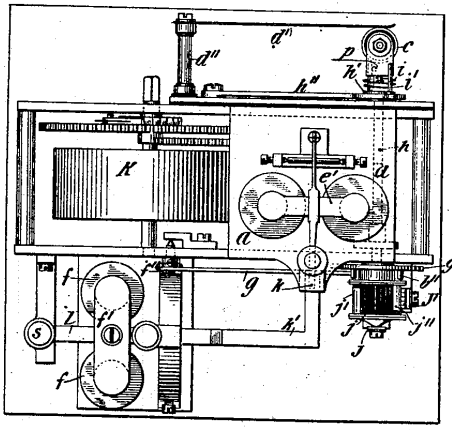


Fig. 8

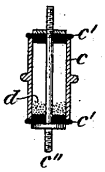
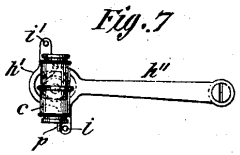


Fig. 7



Witnesses:
Raphael Netter
George Scherff.

Inventor:
Nikola Tesla

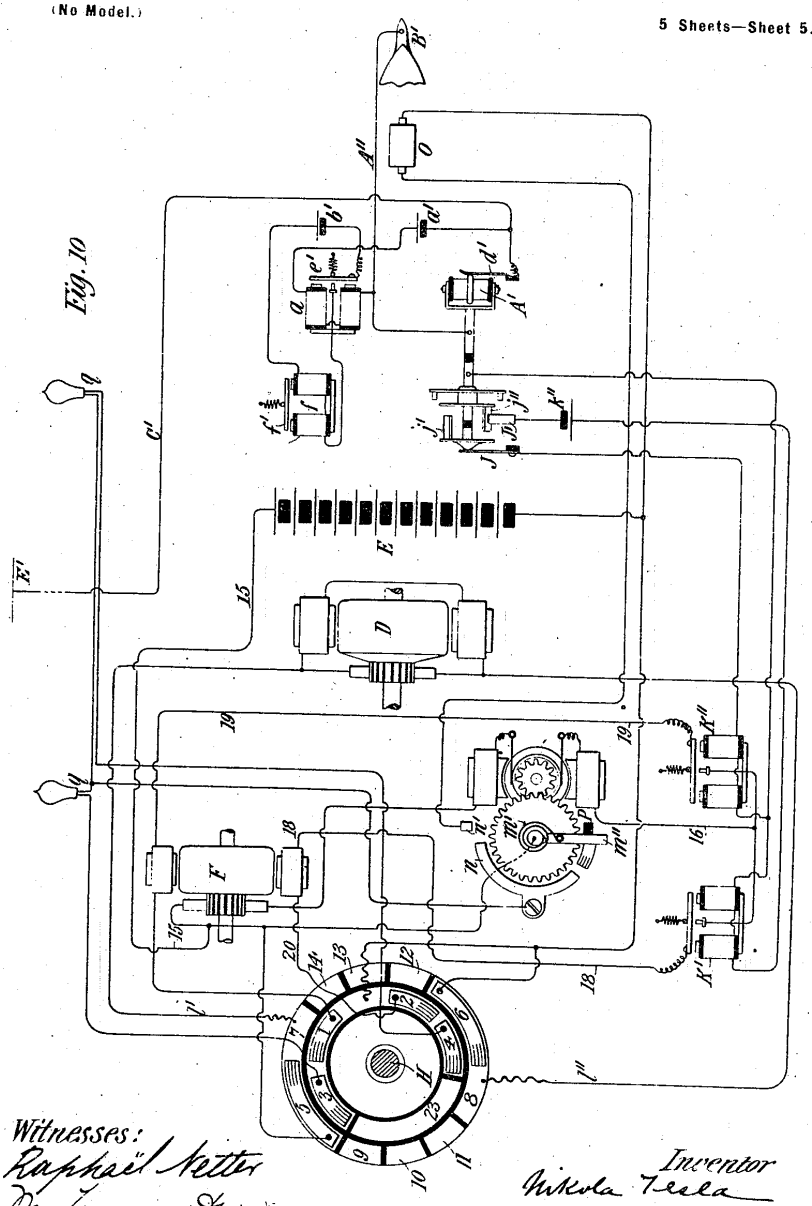
No. 613,809. Patented Nov. 8, 1898.

N. TESLA.

METHOD OF AND APPARATUS FOR CONTROLLING MECHANISM OF MOVING VESSELS OR VEHICLES.

(No Model.) 5 Sheets—Sheet 5.

Fig. 10



Witnesses:
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M. Lawson Dyer.

Inventor
Nikola Tesla
By Kerr, Curtis & Page
attys.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

METHOD OF AND APPARATUS FOR CONTROLLING MECHANISM OF MOVING VESSELS OR VEHICLES.

SPECIFICATION forming part of Letters Patent No. 613,809, dated November 8, 1898.

Application filed July 1, 1898. Serial No. 684,934. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at New York, in the county and State of New York, have invented certain new and useful improvements in methods of and apparatus for controlling from a distance the operation of the propelling-engines, the steering apparatus, and other mechanism carried by moving bodies or floating vessels, of which the following is a specification, reference being had to the drawings accompanying and forming part of the same.

The problem for which the invention forming the subject of my present application affords a complete and practicable solution is that of controlling from a given point the operation of the propelling-engines, the steering apparatus, and other mechanism carried by a moving object, such as a boat or any floating vessel, whereby the movements and course of such body or vessel may be directed and controlled from a distance and any device carried by the same brought into action at any desired time. So far as I am aware the only attempts to solve this problem which have heretofore met with any measure of success have been made in connection with a certain class of vessels the machinery of which was governed by electric currents conveyed to the controlling apparatus through a flexible conductor; but this system is subject to such obvious limitations as are imposed by the length, weight, and strength of the conductor which can be practically used, by the difficulty of maintaining with safety a high speed of the vessel or changing the direction of movement of the same with the desired rapidity, by the necessity for effecting the control from a point which is practically fixed, and by many well-understood drawbacks inseparably connected with such a system. The plan which I have perfected involves none of these objections, for I am enabled by the use of my invention to employ any means of propulsion, to impart to the moving body or vessel the highest possible speed, to control the operation of its machinery and to direct its movements from either a fixed point or from a body moving and changing its direction however rapidly, and to maintain this control over great distances without any artificial connections between the vessel and the apparatus governing its movements and without such restrictions as these must necessarily impose.

In a broad sense, then, my invention differs from all of those systems which provide for the control of the mechanism carried by a moving object and governing its motion in that I require no intermediate wires, cables, or other form of electrical or mechanical connection with the object save the natural media in space. I accomplish, nevertheless, similar results and in a much more practicable manner by producing waves, impulses, or radiations which are received through the earth, water, or atmosphere by suitable apparatus on the moving body and cause the desired actions so long as the body remains within the active region or effective range of such currents, waves, impulses, or radiations.

The many and difficult requirements of the object here contemplated, involving peculiar means for transmitting to a considerable distance an influence capable of causing in a positive and reliable manner these actions, necessitated the designing of devices and apparatus of a novel kind in order to utilize to the best advantage various facts or results, which, either through my own investigations or those of others, have been rendered practically available.

As to that part of my invention which involves the production of suitable waves or variations and the conveying of the same to a remote receiving apparatus capable of being operated or controlled by their influence, it may be carried out in various ways, which are at the present time more or less understood. For example, I may pass through a conducting-path, preferably inclosing a large area, a rapidly-varying current and by electromagnetic induction of the same affect a circuit carried by the moving body. In this case the action at a given distance will be the stronger the larger the area inclosed by the conductor and the greater the rate of change of the current. If the latter were generated in the ordinary ways, the rate of change, and consequently the distance at which the action would be practically available for the present purpose, would be very small; but by adopting such means as I have devised—that is,

either by passing through the conducting-path currents of a specially-designed high-frequency alternator or, better still, those of a strongly-charged condenser—a very high rate of change may be obtained and the effective range of the influence thus extended over a vast area, and by carefully adjusting the circuit on the moving body so as to be in exact electromagnetic synchronism with the primary disturbances this influence may be utilized at great distances.

Another way to carry out my invention is to direct the currents or discharges of a high-frequency machine or condenser through a circuit one terminal of which is connected directly or inductively with the ground and the other to a body, preferably of large surface and at an elevation. In this case if the circuit on the moving body be similarly arranged or connected differences of potential on the terminals of the circuit either by conduction or electrostatic induction are produced and the same object is attained. Again, to secure the best action the receiving-circuit should be adjusted so as to be in electromagnetic synchronism with the primary source, as before; but in this instance it will be understood by those skilled in the art that if the number of vibrations per unit of time be the same the circuit should now have a length of conductor only one-half of that used in the former case.

Still another way is to pass the currents simply through the ground by connecting both the terminals of the source of high-frequency currents to earth at different and remote points and to utilize the currents spreading through the ground for affecting a receiving-circuit properly placed and adjusted. Again, in this instance if only one of the terminals of the receiving-circuit be connected to the ground, the other terminal being insulated, the adjustment as to synchronism with the source will require that under otherwise equal conditions the length of wire be half of that which would be used if both the terminals be connected or, generally, if the circuit be in the form of a closed loop or coil. Obviously also in the latter case the relative position of the receiving and transmitting circuits is of importance, whereas if the circuit be of the former kind—that is, open—the relative position of the circuits is, as a rule, of little or no consequence.

Finally, I may avail myself, in carrying out my invention, of electrical oscillations which do not follow any particular conducting-path, but propagate in straight lines through space, of rays, waves, pulses, or disturbances of any kind capable of bringing the mechanism of the moving body into action from a distance and at the will of the operator by their effect upon suitable controlling devices.

In the following detailed description I shall confine myself to an explanation of that method and apparatus only which I have found to be the most practical and effectual; but obviously my invention in its broad features is not limited to the special mode and appliances which I have devised and shall here describe.

In any event—that is to say, whichever of the above or similar plans I may adopt—and particularly when the influence exerted from a distance upon the receiving-circuit be too small to directly and reliably affect and actuate the controlling apparatus I employ auxiliary sensitive relays or, generally speaking, means capable of being brought into action by the feeblest influences in order to effect the control of the movements of the distant body with the least possible expenditure of energy and at the greatest practicable distance, thus extending the range and usefulness of my invention.

A great variety of electrical and other devices more or less suitable for the purpose of detecting and utilizing feeble actions are now well known to scientific men and artisans and need not be all enumerated here. Confining myself merely to the electrical as the most practicable of such means and referring only to those which, while not the most sensitive, are perhaps more readily available from the more general knowledge which exists regarding them, I may state that a contrivance may be used which has long been known and used as a lightning-arrester in connection with telephone-switchboards for operating annunciators and like devices, comprising a battery the poles of which are connected to two conducting-terminals separated by a minute thickness of dielectric. The electromotive force of the battery should be such as to strain the thin dielectric layer very nearly to the point of breaking down in order to increase the sensitiveness. When an electrical disturbance reaches a circuit so arranged and adjusted, additional strain is put upon the insulating-film, which gives way and allows the passage of a current which can be utilized to operate any form of circuit-controlling apparatus.

Again, another contrivance capable of being utilized in detecting feeble electrical effects consists of two conducting plates or terminals which have, preferably, wires of some length attached to them and are bridged by a mass of minute particles of metal or other conducting material. Normally these particles lying loose do not connect the metal plates; but under the influence of an electrical disturbance produced at a distance, evidently owing to electrostatic attraction, they are pressed firmly against each other, thus establishing a good electrical connection between the two terminals. This change of state may be made use of in a number of ways for the above purpose.

Still another modified device, which may be said to embody the features of both the former, is obtained by connecting the two conducting plates or terminals above referred to permanently with the poles of a battery

which should be of very constant electromotive force. In this arrangement a distant electrical disturbance produces a twofold effect on the conducting particles and insulating-films between them. The former are brought nearer to each other in consequence of the sudden increase of electrostatic attraction, and the latter, owing to this, as well as by being reduced in thickness or in number, are subjected to a much greater strain, which they are unable to withstand.

It will be obviously noted from the preceding that whichever of these or similar contrivances be used the sensitiveness and, what is often still more important, the reliability of operation is very materially increased by a close adjustment of the periods of vibration of the transmitting and receiving circuits, and, although such adjustment is in many cases unnecessary for the successful carrying out of my invention, I nevertheless make it a rule to bestow upon this feature the greatest possible care, not only because of the above-mentioned advantages, which are secured by the observance of the most favorable conditions in this respect, but also and chiefly with the object of preventing the receiving-circuit from being affected by waves or disturbances emanating from sources not under the control of the operator. The narrower the range of vibrations which are still capable of perceptibly affecting the receiving-circuit the safer will the latter be against extraneous disturbances. To secure the best result, it is necessary, as is well known to experts, to construct the receiving-circuit or that part of the same in which the vibration chiefly occurs so that it will have the highest possible self-induction and at the same time the least possible resistance. In this manner I have demonstrated the practicability of providing a great number of such receiving-circuits—fifty or a hundred, or more—each of which may be called up or brought into action whenever desired without the others being interfered with. This result makes it possible for one operator to direct simultaneously the movements of a number of bodies as well as to control the action of a number of devices located on the same body, each of which may have a distinct duty to fulfil. In the following description, however, I shall show a still further development in this direction—namely, how, by making use of merely one receiving-circuit, a great variety of devices may be actuated and any number of different functions performed at the will and command of the distant operator.

It should be stated in advance in regard to the sensitive devices above mentioned, which may be broadly considered as belonging to one class, inasmuch as the operation of all of them involves the breaking down of a minute thickness of highly-strained dielectric, that it is necessary to make some provision for automatically restoring to the dielectric its original unimpaired insulating qualities in order to enable the device to be used in successive operations. This is usually accomplished by a gentle tapping or vibration of the electrodes or particles or continuous rotation of the same; but in long experience with many forms of these devices I have found that such procedures, while suitable in simple and comparatively unimportant operations, as ordinary signaling, when it is merely required that the succeeding effects produced in the receiving-circuit should differ in regard to their relative duration only, in which case it is of little or no consequence if some of the individual effects be altered or incomplete or even entirely missed, do not yield satisfactory results in many instances, when it may be very important that the effects produced should all be exactly such as desired and that none should fail. To illustrate, let it be supposed that an official directing the movements of a vessel in the manner described should find it necessary to bring into action a special device on the latter or to perform a particular operation, perhaps of vital moment, at an instant's notice and possibly when, by design or accident, the vessel itself or any mark indicating its presence is hidden from his view. In this instance a failure or defective action of any part of the apparatus might have disastrous consequences and such cases in which the sure and timely working of the machinery is of paramount importance may often present themselves in practice, and this consideration has impressed me with the necessity of doing away with the defects in the present devices and procedures and of producing an apparatus which while being sensitive will also be most reliable and positive in its action. In the arrangement hereinafter described these defects are overcome in a most satisfactory manner, enabling thousands of successive operations, in all respects alike, being performed by the controlling apparatus without a single irregularity or miss being recorded. For a better understanding of these and other details of the invention as I now carry them out I would refer to the accompanying drawings, in which—

Figure 1 is a plan view of a vessel and mechanism within the same. Fig. 2 is a longitudinal section of the same, showing the interior mechanism in side elevation. Fig. 3 is a plan view, partially diagrammatical, of the vessel, apparatus, and circuit connections of the same. Fig. 4 is a plan view, on an enlarged scale, of a portion of the controlling mechanism. Fig. 5 is an end view of the same. Fig. 6 shows the same mechanism in side elevation. Fig. 7 is a side view of a detail of the mechanism. Fig. 8 is a central sectional view, on a larger scale, of a sensitive device forming part of the receiving-circuit. Fig. 9 is a diagrammatic illustration of the system in its preferred form. Fig. 10 is a view of the various mechanisms employed, but on a larger scale, and leaving out or indi-

cating conventionally certain parts of well-understood character.

Referring to Figs. 1 and 2, A designates any type of vessel or vehicle which is capable of being propelled and directed, such as a boat, a balloon, or a carriage. It may be designed to carry in a suitable compartment B objects of any kind, according to the nature of the uses to which it is to be applied. The vessel—in this instance a boat—is provided with suitable propelling machinery, which is shown as comprising a screw-propeller C, secured to the shaft of an electromagnetic motor D, which derives its power from storage batteries E E E E. In addition to the propelling engine or motor the boat carries also a small steering-motor F, the shaft of which is extended beyond its bearings and provided with a worm which meshes with a toothed wheel G. This latter is fixed to a sleeve b, freely movable on a vertical rod H, and is rotated in one or the other direction, according to the direction of rotation of the motor F.

The sleeve b on rod H is in gear, through the cog-wheels H′ and H″, with a spindle G, mounted in vertical bearings at the stem of the boat and carrying the rudder F′.

The apparatus by means of which the operation of both the propelling and steering mechanisms is controlled involves, primarily, a receiving-circuit, which for reasons before stated is preferably both adjusted and rendered sensitive to the influence of waves or impulses emanating from a remote source, the adjustment being so that the period of oscillation of the circuit is either the same as that of the source or a harmonic thereof.

The receiving-circuit proper (diagrammatically shown in Figs. 3 and 10) comprises a terminal E′, conductor C′, a sensitive device A′, and a conductor A″, leading to the ground conveniently through a connection to the metal keel B′ of the vessel. The terminal E′ should present a large conducting-surface and should be supported as high as practicable on a standard D′, which is shown as broken in Fig. 2; but such provisions are not always necessary. It is important to insulate very well the conductor C′ in whatever manner it be supported.

The circuit or path just referred to forms also a part of a local circuit, which latter includes a relay-magnet a and a battery a', the electromotive force of which is, as before explained, so determined that although the dielectric layers in the sensitive device A′ are subjected to a great strain, yet normally they withstand the strain and no appreciable current flows through the local circuit; but when an electrical disturbance reaches the circuit the dielectric films are broken down, the resistance of the device A′ is suddenly and greatly diminished, and a current traverses the relay-magnet A.

The particular sensitive device employed is shown in general views and in detail in Figs. 4, 6, 7, and 8. It consists of a metal cylinder c, with insulating-heads c', through which passes a central metallic rod c''. A small quantity of grains d of conducting material, such as an oxidized metal, is placed in the cylinder. A metallic strip d', secured to an insulated post d'', bears against the side of the cylinder c, connecting it with the conductor C′, forming one part of the circuit. The central rod c'' is connected to the frame of the instrument and so to the other part of the circuit through the forked metal arm e, the ends of which are fastened with two nuts to the projecting ends of the rod, by which means the cylinder c is supported.

In order to interrupt the flow of battery-current which is started through the action of the sensitive device A′, special means are provided, which are as follows: The armature e' of the magnet a, when attracted by the latter, closes a circuit containing a battery b' and magnet f. The armature-lever f' of this magnet is fixed to a rock-shaft f'', to which is secured an anchor-escapement g, which controls the movements of a spindle g', driven by a clock-train K. The spindle g' has fixed to it a disk g'' with four pins b'', so that for each oscillation of the escapement g the spindle g' is turned through one-quarter of a revolution. One of the spindles in the clock-train, as h, is geared so as to make one-half of a revolution for each quarter-revolution of spindle g'. The end of the former spindle extends through the side of the frame and carries an eccentric cylinder h', which passes through a slot in a lever h'', pivoted to the side of the frame. The forked arm e, which supports the cylinder c, is pivoted to the end of eccentric h', and the eccentric and said arm are connected by a spiral spring l. Two pins i' i' extend out from the lever h'', and one of these is always in the path of a projection on arm e. They operate to prevent the turning of cylinder c with the spindle h and the eccentric. It will be evident that a half-revolution of the spindle h will wind up the spring i and at the same time raise or lower the lever h'', and these parts are so arranged that just before the half-revolution of the spindle is completed the pin i', in engagement with projection or stop-pin p, is withdrawn from its path, and the cylinder c, obeying the force of the spring i, is suddenly turned end for end, its motion being checked by the other pin i'. The adjustment relatively to armature f' of magnet f is furthermore so made that the pin i' is withdrawn at the moment when the armature has nearly reached its extreme position in its approach toward the magnet—that is, when the lever l, which carries the armature f', almost touches the lower one of the two stops s s, Fig. 5—which limits its motion in both directions.

The arrangement just described has been the result of long experimenting with the object of overcoming certain defects in devices of this kind, to which reference has been made before. These defects I have found to

be due to many causes, as the unequal size, weight, and shape of the grains, the unequal pressure which results from this and from the manner in which the grains are usually agitated, the lack of uniformity in the conductivity of the surface of the particles owing to the varying thickness of the superficial oxidized layer, the varying condition of the gas or atmosphere in which the particles are immersed, and to certain deficiencies, well known to experts, of the transmitting apparatus as heretofore employed, which are in a large measure reduced by the use of my improved high-frequency coils. To do away with the defects in the sensitive device, I prepare the particles so that they will be in all respects as nearly alike as possible. They are manufactured by a special tool, insuring their equality in size, weight, and shape, and are then uniformly oxidized by placing them for a given time in an acid solution of predetermined strength. This secures equal conductivity of their surfaces and stops their further deterioration, thus preventing a change in the character of the gas in the space in which they are inclosed. I prefer not to rarefy the atmosphere within the sensitive device, as this has the effect of rendering the former less constant in regard to its dielectric properties, but merely secure an air-tight inclosure of the particles and rigorous absence of moisture, which is fatal to satisfactory working.

The normal position of the cylinder *c* is vertical, and when turned in the manner described the grains in it are simply shifted from one end to the other; but inasmuch as they always fall through the same space and are subjected to the same agitation they are brought after each operation of the relay to precisely the same electrical condition and offer the same resistance to the flow of the battery-current until another impulse from afar reaches the receiving-circuit.

The relay-magnet *a* should be of such character as to respond to a very weak current and yet be positive in its action. To insure the retraction of its armature *e'* after the current has been established through the magnet *f* and interrupted by the inversion of the sensitive device *c*, a light rod *k* is supported in guides on the frame in position to be lifted by an extension *k'* of the armature-lever *l* and to raise slightly the armature *e*. As a feeble current may normally flow through the sensitive device and the relay-magnet *a*, which would be sufficient to hold though not draw the armature down, it is well to observe this precaution.

The operation of the relay-magnet *a* and the consequent operation of the electromagnet *f*, as above described, are utilized to control the operation of the propelling-engine and the steering apparatus in the following manner: On the spindle *g'*, which carries the escapement-disk *g''*, Figs. 4 and 6, is a cylinder *j* of insulating material with a conducting plate or head at each end. From these two heads, respectively, contact plates or segments *j' j''* extend on diametrically opposite sides of the cylinder. The plate *j''* is in electrical connection with the frame of the instrument through the head from which it extends, while insulted strips or brushes J J' bear upon the free end or head of the cylinder and the periphery of the same, respectively. Three terminals are thus provided, one always in connection with plate *j'*, the other always in connection with the plate *j''*, and the third adapted to rest on the strips *j'* and *j''* in succession or upon the intermediate insulating-spaces, according to the position in which the commutator is brought by the clock-train and the anchor-escapement *g*.

K' K'', Figs. 1, 3, and 10, are two relay-magnets conveniently placed in the rear of the propelling-engine. One terminal of a battery *k''* is connected to one end of each of the relay-coils, the opposite terminal to the brush J', and the opposite ends of the relay-coils to the brush J and to the frame of the instrument, respectively. As a consequence of this arrangement either the relay K' or K'' will be energized as the brush J' bears upon the plate *j'* or *j''*, respectively, or both relays will be inactive while the brush J' bears upon an insulating-space between the plates *j'* and *j''*. While one relay, as K', is energized, its armature closes a circuit through the motor F, which is rotated in a direction to throw the rudder to port. On the other hand, when relay K'' is active another circuit through the motor F is closed, which reverses its direction of rotation and shifts the rudder to starboard. These circuits, however, are at the same time utilized for other purposes, and their course is, in part, through apparatus which I shall describe before tracing their course.

The fixed rod H carries an insulating disk or head L, Fig. 2, to the under side of which are secured six brushes, 1, 2, 3, 4, 5, and 6, Fig. 3. The sleeve *b*, which surrounds the rod and is turned by the steering-motor F, carries a disk L', upon the upper face of which are two concentric circles of conducting contact-plates. Brushes 1, 2, 3, and 4 bear upon the inner circle of contacts, while the brushes 5 and 6 bear upon the outer circle of contacts. The outer circle of contacts comprises two long plates 7 and 8 on opposite sides of the disk and a series of shorter plates 9, 10, 11, 12, 13, and 14 in the front and rear. Flexible conductors *l' l''* connect the plates 7 and 8 with the terminals of the propelling-motor D, and the poles of the main battery E are connected to the brushes 5 and 6, respectively, so that while the rudder is straight or turned up to a certain angle to either side the current is conveyed through the brushes 5 and 6 and segments 7 and 8 to the propelling-motor D. The steering-motor F is also driven by current taken from the main battery E in the following manner: A conductor 15 from one pole of the battery

leads to one of the commutator-brushes, and from the other brush runs a conductor 16 to one of the contacts of each relay K′ K″. When one of these relays, as K″, is active, it continues this circuit through a wire 19 through one field-coil or set of coils on the motor F and thence to the brush 1. In a similar manner when the other relay K′ is active the circuit is continued from wire 18 through a wire 20, the second or reversing set of field-coils, and to brush 2.

Both brushes 1 and 2 at all times when the rudder is not turned more than about forty-five degrees to one side are in contact with a long conducting-plate 21, and one brush in any position of the rudder is always in contact with said plate, and the latter is connected by a flexible conductor 22 with the opposite pole of the main battery. Hence the motor F may always be caused to rotate in one direction whatever may be the position of the rudder, and may be caused to rotate in either direction whenever the position of the rudder is less than a predetermined angle, conveniently forty-five degrees from the center position. In order, however, to prevent the rudder from being turned too far in either direction, the isolated plate 23 is used. Any movement of the rudder beyond a predetermined limit brings this plate under one or the other of the brushes 1 2 and breaks the circuit of motor F, so that the rudder can be driven no farther in that direction, but, as will be understood, the apparatus is in condition to turn the rudder over to the other side. In like manner the circuit of the propelling-motor D is controlled through brushes 5 and 6 and the segments on the outer circle of contacts of head L. If the short segments on either side of the circle are insulated, the motor D will be stopped whenever one of the brushes 5 or 6 passes onto one of them from the larger segments 7 8.

It is important to add that on all contact-points where a break occurs provision should be made to overcome the sparking and prevent the oscillation of electrical charges in the circuits, as such sparks and oscillations may affect the sensitive device. It is this consideration chiefly which makes it advisable to use the two relays K′ K″, which otherwise might be dispensed with. They should be also placed as far as practicable from the sensitive device in order to guard the latter against any action of strong varying currents.

In addition to the mechanism described the vessel may carry any other devices or apparatus as might be required for accomplishing any special object of more or less importance. By way of illustration a small motor *m* is shown, Figs. 1 and 3, which conveniently serves for a number of purposes. This motor is shown connected in series with the armature of the steering-motor F, so that whenever either one of the circuits of the latter is closed through relays K′ K″ the motor *m* is likewise rotated, but in all cases in the same direction. Its rotation is opposed by a spring *m′*, so that in normal operation, owing to the fact that the circuits of motor F are closed but a short time, the lever *m″*, which is fastened to one of the wheels of clockwork M, with which the armature of the motor is geared, will move but a short distance and upon cessation of the current return to a stop P; but if the circuits of the motor F are closed and opened rapidly in succession, which operation leaves the rudder unaffected, then the lever *m″* is moved to a greater angle, coming in contact with a metal plate *n*, and finally, if desired, with a post *n′*. Upon the lever *m″* coming in contact with plate *n* the current of the main battery passes either through one or other or both of the lights supported on standards *q q*, according to the position of brushes 3 and 4 relatively to the insulating-segment 23; but since the head L, carrying the segments, is geared to the rudder the position of the latter is in a general way determined by observing the lights. Both of the lights may be colored, and by flashing them up whenever desired the operator may guide at night the vessel in its course. For such purposes also the standards *r r* are provided, which should be painted in lively colors, so as to be visible by day at great distances. By opening and closing the circuits of motor F a greater number of times, preferably determined beforehand, the lever *m″* is brought in contact with post *n′*, thus closing the circuit of the main battery through a device *o* and bringing the latter into action at the moment desired. By similar contrivances or such as will readily suggest themselves to mechanicians any number of different devices may be operated.

Referring now to Fig. 9, which illustrates diagrammatically the system as practiced when directing the movements of a boat, in this figure S designates any source of electrical disturbance or oscillations the generation of which is controlled by a suitable switch contained in box T. The handle of the switch is movable in one direction only and stops on four points *t t′ u u′*, so that as the handle passes from stop to stop oscillations are produced by the source during a very short time interval. There are thus produced four disturbances during one revolution and the receiving-circuit is affected four times; but it will be understood from the foregoing description of the controlling devices on the vessel that the rudder will be moved twice, once to right and once to left. Now I preferably place the handle of the switch so that when it is arrested on points *t t′*—that is, to the right or left of the operator—he is reminded that the vessel is being deflected to the right or left from its course, by which means the control is facilitated. The normal positions of the handle are therefore at *u u′* when the rudder is not acted upon, and it remains on the points *u u′* only so long as necessary. Since, as before stated, the working of the apparatus is

very sure, the operator is enabled to perform any such operations as provision is made for without even seeing the vessel.

The manner of using the apparatus and the operation of the several instrumentalities comprising the same is in detail as follows: Normally the plate L′ is turned so that brush 2 rests upon the insulated segment 23 and brush 6 upon one of the insulated short segments in the rear of the circle. Under these conditions the rudder will be turned to starboard and the circuit of motor D interrupted between brushes 5 and 6. At the same time only one of the circuits of motor F—that controlled by relay K′—is capable of being closed, since brush 2, which connects with the other, is out of contact with the long segment 21. Assuming now that it is desired to start the vessel and direct it to a given point, the handle T is turned from its normal position on point u' to the point t on the switch-box. This sends out an electrical disturbance, which, passing through the receiving-circuit on the vessel, affects the sensitive device A′ and starts the flow of current through the local circuit, including said device, the relay a, and the battery a'. This, as has been previously explained, turns the cylinder j and causes the brush J′ to pass from insulation onto the contact j'. The battery k'' is thus closed through relay K″, and the latter closes that circuit of the motor F which, starting from plate 22, which is permanently connected with one pole of the main battery, is completed through the brush 1, the field of motor F, wire 19, the armature of relay K″, wire 16, the motor m, the brushes and commutator of motor F, and wire 15 to the opposite terminal of the battery E. Motor F is thus set in operation to shift the rudder to port; but the movement of plate L′ which follows brings the brush 6 back onto segment 8 and closes the circuit of the propelling-motor which starts the vessel. The motor F is permitted to run until the rudder has been turned sufficiently to steer the vessel in the desired direction, when the handle T is turned to the point u. This produces another action of the relay a and brush J′ is shifted onto insulation and both relays K′ and K″ are inactive. The rudder remains in the position to which it has been shifted by the motor F. If it be then desired to shift it to starboard, or in the opposite direction to that in which it was last moved, the handle T is simply turned to point t' and allowed to remain there until the motor F, which is now operated by relay K′, the circuit of which is closed by strip J″ coming into contact with plate j'', has done its work. The movement of handle T to the next point throws out both relays K′ and K″, and the next movement causes a shifting of the rudder to port, and so on. Suppose, however, that after the rudder has been set at any angle to its middle position it be desired to shift it still farther in the same direction. In such case the handle is moved quickly over two points, so that the circuit which would move the rudder in the opposite direction is closed for too short a time interval to produce an appreciable effect and is allowed to rest on the third point until the rudder is shifted to the desired position, when the handle is moved to the next point, which again throws out both relays K′ and K″. It will be understood that if the handle be held for a sufficiently long time upon either point t or t' the motor F will simply turn the plate L′ in one direction or the other until the circuits of motors D and F are broken. It is furthermore evident that one relay K′ or K″ will always be operative to start the motor F.

As previously explained, the longest period of operation of which the motor F is capable under ordinary conditions of use does not permit the motor m to shift the arm m' into contact with the plate n; but if the handle T be turned with a certain rapidity a series of current impulses will be directed through motor m; but as these tend to rotate the motor F in opposite directions they do not sensibly affect the latter, but act to rotate the motor m against the force of the coiled spring.

The invention which I have described will prove useful in many ways. Vessels or vehicles of any suitable kind may be used, as life, despatch, or pilot boats or the like, or for carrying letters, packages, provisions, instruments, objects, or materials of any description, for establishing communication with inaccessible regions and exploring the conditions existing in the same, for killing or capturing whales or other animals of the sea, and for many other scientific, engineering, or commercial purposes; but the greatest value of my invention will result from its effect upon warfare and armaments, for by reason of its certain and unlimited destructiveness it will tend to bring about and maintain permanent peace among nations.

Having now described my invention, what I claim is—

1. The improvement in the art of controlling the movements and operation of a vessel or vehicle herein described, which consists in producing waves or disturbances which are conveyed to the vessel by the natural media, actuating thereby suitable apparatus on the vessel and effecting the control of the propelling-engine, the steering and other mechanism by the operation of the said apparatus, as set forth.

2. The improvement in the art of controlling the movements and operation of a vessel or vehicle, herein described, which consists in establishing a region of waves or disturbances, and actuating by their influence exerted at a distance the devices on such vessel or vehicle, which control the propelling, steering and other mechanism thereon, as set forth.

3. The improvement in the art of controlling the movements and operation of a vessel

or vehicle, herein described, which consists in establishing a region of electrical waves or disturbances, and actuating by their influence, exerted at a distance, the devices on said vessel or vehicle, which control the propelling, steering and other mechanism thereon, as set forth.

4. The improvement in the art of controlling the movements and operation of a vessel or vehicle, herein described, which consists in providing on the vessel a circuit controlling the propelling, steering and other mechanism, adjusting or rendering such circuit sensitive to waves or disturbances of a definite character, establishing a region of such waves or disturbances, and rendering by their means the controlling-circuit active or inactive, as set forth.

5. The combination with a source of electrical waves or disturbances of a moving vessel or vehicle, and mechanism thereon for propelling, steering or operating the same, and a controlling apparatus adapted to be actuated by the influence of the said waves or disturbances at a distance from the source, as set forth.

6. The combination with a source of electrical waves or disturbances of a moving vessel or vehicle, mechanism for propelling, steering or operating the same, a circuit and means therein for controlling said mechanism, and means for rendering said circuit active or inactive through the influence of the said waves or disturbances exerted at a distance from the source, as set forth.

7. The combination with a source of electrical waves or disturbances and means for starting and stopping the same, of a vessel or vehicle, propelling and steering mechanism carried thereby, a circuit containing or connected with means for controlling the operation of said mechanism and adjusted or rendered sensitive to the waves or disturbances of the source, as set forth.

8. The combination with a source of electrical waves or disturbances, and means for starting and stopping the operation of the same, of a vessel or vehicle, propelling and steering mechanism carried thereby, local circuits controlling said mechanisms, a circuit sensitive to the waves or disturbances of the source and means therein adapted to control the said local circuits, as and for the purpose set forth.

9. The sensitive device herein described comprising in construction a receptacle containing a material such as particles of oxidized metal forming a part of the circuit, and means for turning the same end for end when the material has been rendered active by the passage through it of an electric discharge, as set forth.

10. The sensitive device herein described, comprising in combination a receptacle containing a material such as particles of oxidized metal forming a part of an electric circuit, an electromagnet in said circuit, and devices controlled thereby for turning the receptacle end for end when said magnet is energized, as set forth.

11. The sensitive device herein described, comprising in combination a receptacle containing a material such as particles of oxidized metal forming part of an electric circuit, a motor for rotating the receptacle, an electromagnet in circuit with the material, and an escapement controlled by said magnet and adapted to permit a half-revolution of the receptacle when the said magnet is energized, as set forth.

12. The combination with a movable body or vehicle, of a propelling-motor, a steering-motor and electrical contacts carried by a moving portion of the steering mechanism, and adapted in certain positions of the latter to interrupt the circuit of the propelling-motor, a local circuit and means connected therewith for controlling the steering-motor, and a circuit controlling the local circuit and means for rendering said controlling-circuit sensitive to the influence of electric waves or disturbances exerted at a distance from their source, at set forth.

13. The combination with the steering-motor, a local circuit for directing current through the same in opposite directions, a controlling-circuit rendered sensitive to the influence of electric waves or disturbances exerted at a distance from their source, a motor in circuit with the steering-motor but adapted to run always in the same direction, and a local circuit or circuits controlled by said motor, as set forth.

NIKOLA TESLA.

Witnesses:
RAPHAËL NETTER,
GEORGE SCHERFF.

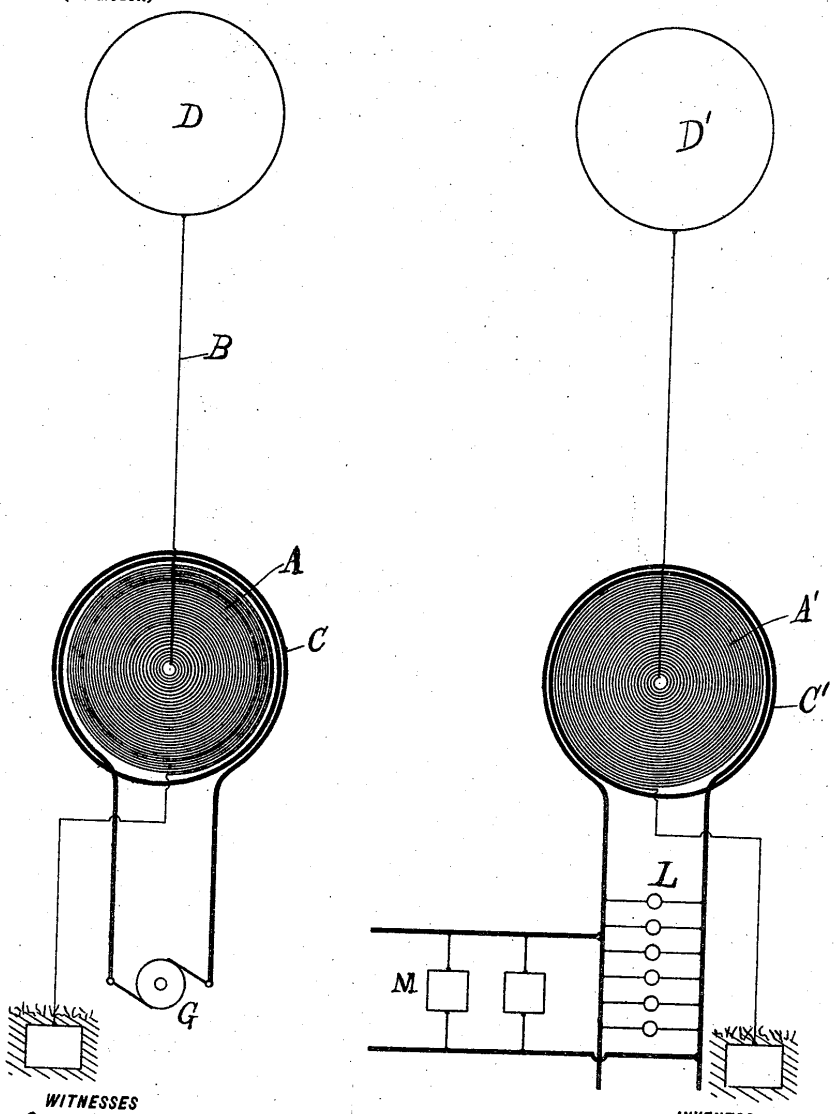
No. 645,576.

N. TESLA. Patented Mar. 20, 1900.

SYSTEM OF TRANSMISSION OF ELECTRICAL ENERGY.

(Application filed Sept. 2, 1897.)

(No Model.)



WITNESSES

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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

SYSTEM OF TRANSMISSION OF ELECTRICAL ENERGY.

SPECIFICATION forming part of Letters Patent No. 645,576, dated March 20, 1900.

Application filed September 2, 1897. Serial No. 650,343. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Systems of Transmission of Electrical Energy, of which the following is a specification, reference being had to the drawing accompanying and forming a part of the same.

It has been well known heretofore that by rarefying the air inclosed in a vessel its insulating properties are impaired to such an extent that it becomes what may be considered as a true conductor, although one of admittedly very high resistance. The practical information in this regard has been derived from observations necessarily limited in their scope by the character of the apparatus or means heretofore known and the quality of the electrical effects producible thereby. Thus it has been shown by William Crookes in his classical researches, which have so far served as the chief source of knowledge of this subject, that all gases behave as excellent insulators until rarefied to a point corresponding to a barometric pressure of about seventy-five millimeters, and even at this very low pressure the discharge of a high-tension induction-coil passes through only a part of the attenuated gas in the form of a luminous thread or arc, a still further and considerable diminution of the pressure being required to render the entire mass of the gas inclosed in a vessel conducting. While this is true in every particular so long as electromotive or current impulses such as are obtainable with ordinary forms of apparatus are employed, I have found that neither the general behavior of the gases nor the known relations between electrical conductivity and barometric pressure are in conformity with these observations when impulses are used such as are producible by methods and apparatus devised by me and which have peculiar and hitherto unobserved properties and are of effective electromotive forces, measuring many hundred thousands or millions of volts. Through the continuous perfection of these methods and apparatus and the investigation of the actions of these current impulses I have been led to the discovery of certain highly-important and useful facts which have hitherto been unknown. Among these and bearing directly upon the subject of my present application are the following: First, that atmospheric or other gases, even under normal pressure, when they are known to behave as perfect insulators, are in a large measure deprived of their dielectric properties by being subjected to the influence of electromotive impulses of the character and magnitude I have referred to and assume conducting and other qualities which have been so far observed only in gases greatly attenuated or heated to a high temperature, and, second, that the conductivity imparted to the air or gases increases very rapidly both with the augmentation of the applied electrical pressure and with the degree of rarefaction, the law in this latter respect being, however, quite different from that heretofore established. In illustration of these facts a few observations, which I have made with apparatus devised for the purposes here contemplated, may be cited. For example, a conductor or terminal, to which impulses such as those here considered are supplied, but which is otherwise insulated in space and is remote from any conducting-bodies, is surrounded by a luminous flame-like brush or discharge often covering many hundreds or even as much as several thousands of square feet of surface, this striking phenomenon clearly attesting the high degree of conductivity which the atmosphere attains under the influence of the immence electrical stresses to which it is subjected. This influence is, however, not confined to that portion of the atmosphere which is discernible by the eye as luminous and which, as has been the case in some instances actually observed, may fill the space within a spherical or cylindrical envelop of a diameter of sixty feet or more, but reaches out to far remote regions, the insulating qualities of the air being, as I have ascertained, still sensibly impaired at a distance many hundred times that through which the luminous discharge projects from the terminal and in all probability much farther. The distance extends with the increase of the electromotive force of the impulses, with the diminution of the density of the atmosphere, with the elevation of the active terminal above the ground, and also, apparently, in a slight measure, with the degree of moisture contained in

the air. I have likewise observed that this region of decidedly-noticeable influence continuously enlarges as time goes on, and the discharge is allowed to pass not unlike a conflagration which slowly spreads, this being possibly due to the gradual electrification or ionization of the air or to the formation of less insulating gaseous compounds. It is, furthermore, a fact that such discharges of extreme tensions, approximating those of lightning, manifest a marked tendency to pass upward away from the ground, which may be due to electrostatic repulsion, or possibly to slight heating and consequent rising of the electrified or ionized air. These latter observations make it appear probable that a discharge of this character allowed to escape into the atmosphere from a terminal maintained at a great height will gradually leak through and establish a good conducting-path to more elevated and better conducting air strata, a process which possibly takes place in silent lightning discharges frequently witnessed on hot and sultry days. It will be apparent to what an extent the conductivity imparted to the air is enhanced by the increase of the electromotive force of the impulses when it is stated that in some instances the area covered by the flame discharge mentioned was enlarged more than sixfold by an augmentation of the electrical pressure, amounting scarcely to more than fifty per cent. As to the influence of rarefaction upon the electric conductivity imparted to the gases it is noteworthy that, whereas the atmospheric or other gases begin ordinarily to manifest this quality at something like seventy-five millimeters barometric pressure with the impulses of excessive electromotive force to which I have referred, the conductivity, as already pointed out, begins even at normal pressure and continuously increases with the degree of tenuity of the gas, so that at, say, one hundred and thirty millimeters pressure, when the gases are known to be still nearly perfect insulators for ordinary electromotive forces, they behave toward electromotive impulses of several millions of volts like excellent conductors, as though they were rarefied to a much higher degree. By the discovery of these facts and the perfection of means for producing in a safe, economical, and thoroughly-practicable manner current impulses of the character described it becomes possible to transmit through easily-accessible and only moderately-rarefied strata of the atmosphere electrical energy not merely in insignificant quantities, such as are suitable for the operation of delicate instruments and like purposes, but also in quantities suitable for industrial uses on a large scale up to practically any amount and, according to all the experimental evidence I have obtained, to any terrestrial distance. To conduce to a better understanding of this method of transmission of energy and to distinguish it clearly, both in its theoretical aspect and in its practical bearing, from other known modes of transmission, it is useful to state that all previous efforts made by myself and others for transmitting electrical energy to a distance without the use of metallic conductors, chiefly with the object of actuating sensitive receivers, have been based, in so far as the atmosphere is concerned, upon those qualities which it possesses by virtue of its being an excellent insulator, and all these attempts would have been obviously recognized as ineffective if not entirely futile in the presence of a conducting atmosphere or medium. The utilization of any conducting properties of the air for purposes of transmission of energy has been hitherto out of the question in the absence of apparatus suitable for meeting the many and difficult requirements, although it has long been known or surmised that atmospheric strata at great altitudes—say fifteen or more miles above sea-level—are, or should be, in a measure, conducting; but assuming even that the indispensable means should have been produced then still a difficulty, which in the present state of the mechanical arts must be considered as insuperable, would remain—namely, that of maintaining terminals at elevations of fifteen miles or more above the level of the sea. Through my discoveries before mentioned and the production of adequate means the necessity of maintaining terminals at such inaccessible altitudes is obviated and a practical method and system of transmission of energy through the natural media is afforded essentially different from all those available up to the present time and possessing, moreover, this important practical advantage, that whereas in all such methods or systems heretofore used or proposed but a minute fraction of the total energy expended by the generator or transmitter was recoverable in a distant receiving apparatus by my method and appliances it is possible to utilize by far the greater portion of the energy of the source and in any locality however remote from the same.

Expressed briefly, my present invention, based upon these discoveries, consists then in producing at one point an electrical pressure of such character and magnitude as to cause thereby a current to traverse elevated strata of the air between the point of generation and a distant point at which the energy is to be received and utilized.

In the accompanying drawing a general arrangement of apparatus is diagrammatically illustrated such as I contemplate employing in the carrying out of my invention on an industrial scale—as, for instance, for lighting distant cities or districts from places where cheap power is obtainable.

Referring to the drawing, A is a coil, generally of many turns and of a very large diameter, wound in spiral form either about a magnetic core or not, as may be found necessary. C is a second coil, formed of a conductor of much larger section and smaller

length, wound around and in proximity to the coil A. In the transmitting apparatus the coil A constitutes the high-tension secondary and the coil C the primary of much lower tension of a transformer. In the circuit of the primary C is included a suitable source of current G. One terminal of the secondary A is at the center of the spiral coil, and from this terminal the current is led by a conductor B to a terminal D, preferably of large surface, formed or maintained by such means as a balloon at an elevation suitable for the purposes of transmission, as before described. The other terminal of the secondary A is connected to earth and, if desired, also to the primary in order that the latter may be at substantially the same potential as the adjacent portions of the secondary, thus insuring safety. At the receiving-station a transformer of similar construction is employed; but in this case the coil A′, of relatively-thin wire, constitutes the primary and the coil C′, of thick wire or cable, the secondary of the transformer. In the circuit of the latter are included lamps L, motors M, or other devices for utilizing the current. The elevated terminal D′ is connected with the center of the coil A′, and the other terminal of said coil is connected to earth and preferably, also, to the coil C′ for the reasons above stated.

It will be observed that in coils of the character described the potential gradually increases with the number of turns toward the center, and the difference of potential between the adjacent turns being comparatively small a very high potential, impracticable with ordinary coils, may be successfully obtained. It will be, furthermore, noted that no matter to what an extent the coils may be modified in design and construction, owing to their general arrangement and manner of connection, as illustrated, those portions of the wire or apparatus which are highly charged will be out of reach, while those parts of the same which are liable to be approached, touched, or handled will be at or nearly the same potential as the adjacent portions of the ground, this insuring, both in the transmitting and receiving apparatus and regardless of the magnitude of the electrical pressure used, perfect personal safety, which is best evidenced by the fact that although such extreme pressures of many millions of volts have been for a number of years continuously experimented with no injury has been sustained neither by myself or any of my assistants.

The length of the thin-wire coil in each transformer should be approximately one-quarter of the wave length of the electric disturbance in the circuit, this estimate being based on the velocity of propagation of the disturbance through the coil itself and the circuit with which it is designed to be used. By way of illustration if the rate at which the current traverses the circuit, including the coil, be one hundred and eighty-five thousand miles per second then a frequency of nine hundred and twenty-five per second would maintain nine hundred and twenty-five stationary waves in a circuit one hundred and eighty-five thousand miles long and each wave would be two hundred miles in length. For such a low frequency, to which I shall resort only when it is indispensable to operate motors of the ordinary kind under the conditions above assumed, I would use a secondary of fifty miles in length. By such an adjustment or porportioning of the length of wire in the secondary coil or coils the points of highest potential are made to coincide with the elevated terminals D D′, and it should be understood that whatever length be given to the wires this condition should be complied with in order to attain the best results.

As the main requirement in carrying out my invention is to produce currents of an excessively-high potential, this object will be facilitated by using a primary current of very considerable frequency, since the electromotive force obtainable with a given length of conductor is proportionate to the frequency; but the frequency of the current is in a large measure arbitrary, for if the potential be sufficiently high and if the terminals of the coils be maintained at the proper altitudes the action described will take place, and a current will be transmitted through the elevated air strata, which will encounter little and possibly even less resistance than if conveyed through a copper wire of a practicable size. Accordingly the construction of the apparatus may be in many details greatly varied; but in order to enable any person skilled in the mechanical and electrical arts to utilize to advantage in the practical applications of my system the experience I have so far gained the following particulars of a model plant which has been long in use and which was constructed for the purpose of obtaining further data to be used in the carrying out of my invention on a large scale are given. The transmitting apparatus was in this case one of my electrical oscillators, which are transformers of a special type, now well known and characterized by the passage of oscillatory discharges of a condenser through the primary. The source G, forming one of the elements of the transmitter, was a condenser of a capacity of about four one-hundredths of a microfarad and was charged from a generator of alternating currents of fifty thousand volts pressure and discharged by means of a mechanically-operated break five thousand times per second through the primary C. The latter consisted of a single turn of stout stranded cable of inappreciable resistance and of an inductance of about eight thousand centimeters, the diameter of the loop being very nearly two hundred and forty-four centimeters. The total inductance of the primary circuit was approximately ten thousand centimeters, so that the primary circuit vibrated generally according to adjustment,

from two hundred and thirty thousand to two hundred and fifty thousand times per second. The high-tension coil A in the form of a flat spiral was composed of fifty turns of heavily-insulated cable No. 8 wound in one single layer, the turns beginning close to the primary loop and ending near its center. The outer end of the secondary or high-tension coil A was connected to the ground, as illustrated, while the free end was led to a terminal placed in the rarefied air stratum through which the energy was to be transmitted, which was contained in an insulating-tube of a length of fifty feet or more, within which a barometric pressure varying from about one hundred and twenty to one hundred and fifty millimeters was maintained by means of a mechanical suction-pump. The receiving-transformer was similarly proportioned, the ratio of conversion being the reciprocal of that of the transmitter, and the primary high-tension coil A′ was connected, as illustrated, with the end near the low-tension coil C′ to the ground and with the free end to a wire or plate likewise placed in the rarefied air stratum and at the distance named from the transmitting-terminal. The primary and secondary circuits in the transmitting apparatus being carefully synchronized, an electromotive force from two to four million volts and more was obtainable at the terminals of the secondary coil A, the discharge passing freely through the attenuated air stratum maintained at the above barometric pressures, and it was easy under these conditions to transmit with fair economy considerable amounts of energy, such as are of industrial moment, to the receiving apparatus for supplying from the secondary coil C′ lamps L or kindred devices. The results were particularly satisfactory when the primary coil or system A′, with its secondary C′, was carefully adjusted, so as to vibrate in synchronism with the transmitting coil or system A C. I have, however, found no difficulty in producing with apparatus of substantially the same design and construction electromotive forces exceeding three or four times those before mentioned and have ascertained that by their means current impulses can be transmitted through much-denser air strata. By the use of these I have also found it practicable to transmit notable amounts of energy through air strata not in direct contact with the transmitting and receiving terminals, but remote from them, the action of the impulses, in rendering conducting air of a density at which it normally behaves as an insulator, extending, as before remarked, to a considerable distance. The high electromotive force obtained at the terminals of coil or conductor A was, as will be seen, in the preceding instance, not so much due to a large ratio of transformation as to the joint effect of the capacities and inductances in the synchronized circuits, which effect is enhanced by a high frequency, and it will be obviously understood that if the latter be reduced a greater ratio of transformation should be resorted to, especially in cases in which it may be deemed of advantage to suppress as much as possible, and particularly in the transmitting-coil A, the rise of pressure due to the above effect and to obtain the necessary electromotive force solely by a large transformation ratio.

While electromotive forces such as are produced by the apparatus just described may be sufficient for many purposes to which my system will or may be applied, I wish to state that I contemplate using in an industrial undertaking of this kind forces greatly in excess of these, and with my present knowledge and experience in this novel field I would estimate them to range from twenty to fifty million volts and possibly more. By the use of these much greater forces larger amounts of energy may be conveyed through the atmosphere to remote places or regions, and the distance of transmission may be thus extended practically without limit.

As to the elevation of the terminals D D′ it is obvious that it will be determined by a number of things, as by the amount and quality of the work to be performed, by the local density and other conditions of the atmosphere, by the character of the surrounding country, and such considerations as may present themselves in individual instances. Thus if there be high mountains in the vicinity the terminals should be at a greater height, and generally they should always be, if practicable, at altitudes much greater than those of the highest objects near them in order to avoid as much as possible the loss by leakage. In some cases when small amounts of energy are required the high elevation of the terminals, and more particularly of the receiving-terminal D′, may not be necessary, since, especially when the frequency of the currents is very high, a sufficient amount of energy may be collected at that terminal by electrostatic induction from the upper air strata, which are rendered conducting by the active terminal of the transmitter or through which the currents from the same are conveyed.

With reference to the facts which have been pointed out above it will be seen that the altitudes required for the transmission of considerable amounts of electrical energy in accordance with this method are such as are easily accessible and at which terminals can be safely maintained, as by the aid of captive balloons supplied continuously with gas from reservoirs and held in position securely by steel wires or by any other means, devices, or expedients, such as may be contrived and perfected by ingenious and skilled engineers. From my experiments and observations I conclude that with electromotive impulses not greatly exceeding fifteen or twenty million volts the energy of many thousands of horse-power may be transmitted over vast distances, measured by many hundreds and

even thousands of miles, with terminals not more than thirty to thirty-five thousand feet above the level of the sea, and even this comparatively-small elevation will be required chiefly for reasons of economy, and, if desired, it may be considerably reduced, since by such means as have been described practically any potential that is desired may be obtained, the currents through the air strata may be rendered very small, whereby the loss in the transmission may be reduced.

It will be understood that the transmitting as well as the receiving coils, transformers, or other apparatus may be in some cases movable—as, for example, when they are carried by vessels floating in the air or by ships at sea. In such a case, or generally, the connection of one of the terminals of the high-tension coil or coils to the ground may not be permanent, but may be intermittently or inductively established, and any such or similar modifications I shall consider as within the scope of my invention.

While the description here given contemplates chiefly a method and system of energy transmission to a distance through the natural media for industrial purposes, the principles which I have herein disclosed and the apparatus which I have shown will obviously have many other valuable uses—as, for instance, when it is desired to transmit intelligible messages to great distances, or to illuminate upper strata of the air, or to produce, designedly, any useful changes in the condition of the atmosphere, or to manufacture from the gases of the same products, as nitric acid, fertilizing compounds, or the like, by the action of such current impulses, for all of which and for many other valuable purposes they are eminently suitable, and I do not wish to limit myself in this respect. Obviously, also, certain features of my invention here disclosed will be useful as disconnected from the method itself—as, for example, in other systems of energy transmission, for whatever purpose they may be intended, the transmitting and receiving transformers arranged and connected as illustrated, the feature of a transmitting and receiving coil or conductor, both connected to the ground and to an elevated terminal and adjusted so as to vibrate in synchronism, the proportioning of such conductors or coils, as above specified, the feature of a receiving-transformer with its primary connected to earth and to an elevated terminal and having the operative devices in its secondary, and other features or particulars, such as have been described in this specification or will readily suggest themselves by a perusal of the same.

I do not claim in this application a transformer for developing or converting currents of high potential in the form herewith shown and described and with the two coils connected together, as and for the purpose set forth, having made these improvements the subject of a patent granted to me November 2, 1897, No. 593,138, nor do I claim herein the apparatus employed in carrying out the method of this application when such apparatus is specially constructed and arranged for securing the particular object sought in the present invention, as these last-named features are made the subject of an application filed as a division of this application on February 19, 1900, Serial No. 5,780.

What I now claim is—

1. The method hereinbefore described of transmitting electrical energy through the natural media, which consists in producing at a generating-station a very high electrical pressure, causing thereby a propagation or flow of electrical energy, by conduction, through the earth and the air strata, and collecting or receiving at a distant point the electrical energy so propagated or caused to flow.

2. The method hereinbefore described of transmitting electrical energy, which consists in producing at a generating-station a very high electrical pressure, conducting the current caused thereby to earth and to a terminal at an elevation at which the atmosphere serves as a conductor therefor, and collecting the current by a second elevated terminal at a distance from the first.

3. The method hereinbefore described of transmitting electrical energy through the natural media, which consists in producing between the earth and a generator-terminal elevated above the same, at a generating-station, a sufficiently-high electromotive force to render elevated air strata conducting, causing thereby a propagation or flow of electrical energy, by conduction, through the air strata, and collecting or receiving at a point distant from the generating-station the electrical energy so propagated or caused to flow.

4. The method hereinbefore described of transmitting electrical energy through the natural media, which consists in producing between the earth and a generator-terminal elevated above the same, at a generating-station, a sufficiently-high electromotive force to render the air strata at or near the elevated terminal conducting, causing thereby a propagation or flow of electrical energy, by conduction, through the air strata, and collecting or receiving at a point distant from the generating-station the electrical energy so propagated or caused to flow.

5. The method hereinbefore described of transmitting electrical energy through the natural media, which consists in producing between the earth and a generator-terminal elevated above the same, at a generating-station, electrical impulses of a sufficiently-high electromotive force to render elevated air strata conducting, causing thereby current impulses to pass, by conduction, through the air strata, and collecting or receiving at a point distant from the generating-station, the energy of the current impulses by means of a circuit synchronized with the impulses.

6. The method hereinbefore described of

transmitting electrical energy through the natural media, which consists in producing between the earth and a generator-terminal elevated above the same, at a generating-station, electrical impulses of a sufficiently-high electromotive force to render the air strata at or near the elevated terminal conducting, causing thereby current impulses to pass through the air strata, and collecting or receiving at a point distant from the generating-station the energy of the current impulses by means of a circuit synchronized with the impulses.

7. The method hereinbefore described of transmitting electrical energy through the natural media, which consists in producing between the earth and a generator-terminal elevated above the same, at a generating-station, electrical impulses of a wave length so related to the length of the generating circuit or conductor as to produce the maximum potential at the elevated terminal, and of sufficiently-high electromotive force to render elevated air strata conducting, causing thereby a propagation of electrical impulses through the air strata, and collecting or receiving at a point distant from the generating-station the energy of such impulses by means of a receiving-circuit having a length of conductor similarly related to the wave length of the impulses.

8. The method hereinbefore described of transmitting electrical energy through the natural media, which consists in producing between the earth and a generator-terminal elevated above the same, at a generating-station, a sufficiently-high electromotive force to render elevated air strata conducting, causing thereby a propagation or flow of electrical energy through the air strata, by conduction, collecting or receiving the energy so transmitted by means of a receiving-circuit at a point distant from the generating-station, using the receiving-circuit to energize a secondary circuit, and operating translating devices by means of the energy so obtained in the secondary circuit.

9. The method hereinbefore described of transmitting electrical energy through the natural media, which consists in generating current impulses of relatively-low electromotive force at a generating-station, utilizing such impulses to energize the primary of a transformer, generating by means of such primary circuit impulses in a secondary surrounding by the primary and connected to the earth and to an elevated terminal, of sufficiently-high electromotive force to render elevated air strata conducting, causing thereby impulses to be propagated through the air strata, collecting or receiving the energy of such impulses, at a point distant from the generating-station, by means of a receiving-circuit connected to the earth and to an elevated terminal, and utilizing the energy so received to energize a secondary circuit of low potential surrounding the receiving-circuit.

NIKOLA TESLA.

Witnesses:
M. LAWSON DYER,
G. W. MARTLING.

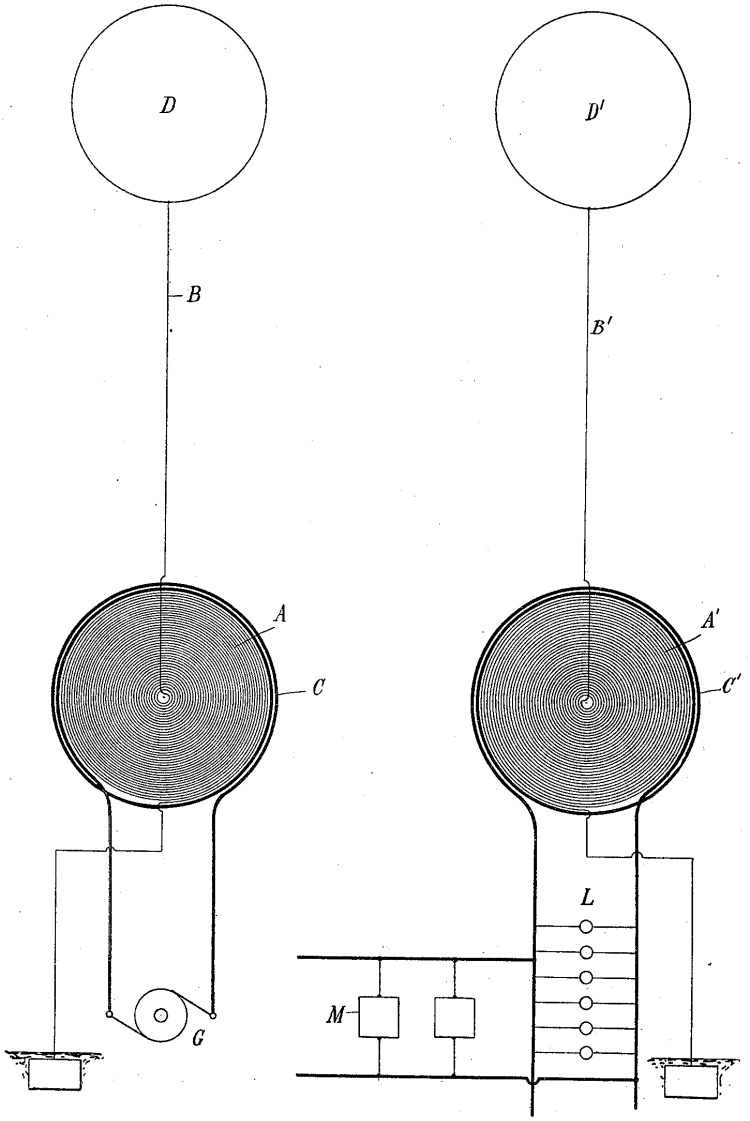
No. 649,621. Patented May 15, 1900.

N. TESLA.

APPARATUS FOR TRANSMISSION OF ELECTRICAL ENERGY.

(Application filed Feb. 19, 1900.)

(No Model.)



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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

APPARATUS FOR TRANSMISSION OF ELECTRICAL ENERGY.

SPECIFICATION forming part of Letters Patent No. 649,621, dated May 15, 1900.

Original application filed September 2, 1897, Serial No. 650,343. Divided and this application filed February 19, 1900. Serial No. 5,780. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at the borough of Manhattan, in the city of New York, county and State of New York, have invented certain new and useful Improvements in Apparatus for the Transmission of Electrical Energy, of which the following is a specification, reference being had to the drawing accompanying and forming a part of the same.

This application is a division of an application filed by me on September 2, 1897, Serial No. 650,343, entitled "Systems of transmissions of electrical energy," and is based upon new and useful features and combinations of apparatus shown and described in said application for carrying out the method therein disclosed and claimed.

The invention which forms the subject of my present application comprises a transmitting coil or conductor in which electrical currents or oscillations are produced and which is arranged to cause such currents or oscillations to be propagated by conduction through the natural medium from one point to another remote therefrom and a receiving coil or conductor at such distant point adapted to be excited by the oscillations or currents propagated from the transmitter.

This apparatus is shown in the accompanying drawing, which is a diagrammatic illustration of the same.

A is a coil, generally of many turns and of a very large diameter, wound in spiral form either about a magnetic core or not, as may be desired. C is a second coil formed by a conductor of much larger size and smaller length wound around and in proximity to the coil A.

The apparatus at one point is used as a transmitter, the coil A in this case constituting a high-tension, secondary, and the coil C the primary, of much lower tension, of a transformer. In the circuit of the primary C is included a suitable source of current G. One terminal of the secondary A is at the center of the spiral coil, and from this terminal the current is led by a conductor B to a terminal D, preferably of large surface, formed or maintained by such means as a balloon at an elevation suitable for the purposes of transmission. The other terminal of the secondary A is connected to earth, and, if desired, to the primary also, in order that the latter may be at substantially the same potential as the adjacent portions of the secondary, thus insuring safety. At the receiving-station a transformer of similar construction is employed; but in this case the longer coil A′ constitutes the primary, and the shorter coil C′ the secondary, of the transformer. In the circuit of the latter are connected lamps L, motors M, or other devices for utilizing the current. The elevated terminal D′ connects with the center of the coil A′, and the other terminal of said coil is connected to earth and preferably, also, to the coil C′ for the reasons above stated.

The length of the thin wire coil in each transformer should be approximately one-quarter of the wave length of the electric disturbance in the circuit, this estimate being based on the velocity of propagation of the disturbance through the coil itself and the circuit with which it is designed to be used. By way of illustration, if the rate at which the current traverses the circuit including the coil be one hundred and eighty-five thousand miles per second then a frequency of nine hundred and twenty-five per second would maintain nine hundred and twenty-five stationary moves in a circuit one hundred and eighty-five thousand miles long and each wave would be two hundred miles in length.

For such a low frequency, which would be resorted to only when it is indispensable for the operation of motors of the ordinary kind under the conditions above assumed, I would use a secondary of fifty miles in length. By such an adjustment or proportioning of the length of wire in the secondary coil or coils the points of highest potential are made to coincide with the elevated terminals D D′, and it should be understood that whatever length be given to the wires this requirement should be complied with in order to obtain the best results.

It will be readily understood that when the above-prescribed relations exist the best conditions for resonance between the transmit-

ting and receiving circuits are attained, and owing to the fact that the points of highest potential in the coils or conductors A A′ are coincident with the elevated terminals the maximum flow of current will take place in the two coils, and this, further, necessarily implies that the capacity and inductance in each of the circuits have such values as to secure the most perfect condition of synchronism with the impressed oscillations.

When the source of current G is in operation and produces rapidly pulsating or oscillating currents in the circuit of coil C, corresponding induced currents of very much higher potential are generated in the secondary coil A, and since the potential in the same gradually increases with the number of turns toward the center and the difference of potential between the adjacent turns is comparatively small a very high potential impracticable with ordinary coils may be successively obtained.

As the main object for which the apparatus is designed is to produce a current of excessively-high potential, this object is facilitated by using a primary current of very considerable frequency; but the frequency of the currents is in a large measure arbitrary, for if the potential be sufficiently high and the terminals of the coils be maintained at the proper elevation where the atmosphere is rarefied the stratum of air will serve as a conducting medium for the current produced and the latter will be transmitted through the air, with, it may be, even less resistance than through an ordinary conductor.

As to the elevation of the terminals D D′, it is obvious that this is a matter which will be determined by a number of things, as by the amount and quality of the work to be performed, by the condition of the atmosphere, and also by the character of the surrounding country. Thus if there be high mountains in the vicinity the terminals should be at a greater height, and generally they should always be at an altitude much greater than that of the highest objects near them. Since by the means described practically any potential that is desired may be produced, the currents through the air strata may be very small, thus reducing the loss in the air.

The apparatus at the receiving-station responds to the currents propagated from the transmitter in a manner which will be well understood from the foregoing description. The primary circuit of the receiver—that is, the thin wire coil A′—is excited by the currents propagated by conduction through the intervening natural medium from the transmitter, and these currents induce in the secondary coil C′ other currents which are utilized for operating the devices included in the circuit thereof.

Obviously the receiving-coils, transformers, or other apparatus may be movable—as, for instance, when they are carried by a vessel floating in the air or by a ship at sea. In the former case the connection of one terminal of the receiving apparatus to the ground might not be permanent, but might be intermittently or inductively established without departing from the spirit of my invention.

It is to be noted that the phenomenon here involved in the transmission of electrical energy is one of true conduction and is not to be confounded with the phenomena of electrical radiation which have heretofore been observed and which from the very nature and mode of propagation would render practically impossible the transmission of any appreciable amount of energy to such distances as are of practical importance.

What I now claim as my invention is—

1. The combination with a transmitting coil or conductor connected to ground and to an elevated terminal respectively, and means for producing therein electrical currents or oscillations, of a receiving coil or conductor similarly connected to ground and to an elevated terminal, at a distance from the transmitting-coil and adapted to be excited by currents caused to be propagated from the same by conduction through the intervening natural medium, a secondary conductor in inductive relation to the receiving-conductor and devices for utilizing the current in the circuit of said secondary conductor, as set forth.

2. The combination with a transmitting coil or conductor having its ends connected to ground and to an elevated terminal respectively, a primary coil in inductive relation thereto and a source of electrical oscillations in said primary circuit, of a receiving conductor or coil having its ends connected to ground and to an elevated terminal respectively and adapted to be excited by currents caused to be propagated from the transmitter through the natural medium and a secondary circuit in inductive relation to the receiving-circuit and receiving devices connected therewith, as set forth.

3. The combination with a transmitting instrument comprising a transformer having its secondary connected to ground and to an elevated terminal respectively, and means for impressing electrical oscillations upon its primary, of a receiving instrument comprising a transformer having its primary similarly connected to ground and to an elevated terminal, and a translating device connected with its secondary, the capacity and inductance of the two transformers having such values as to secure synchronism with the impressed oscillations, as set forth.

4. The combination with a transmitting instrument comprising an electrical transformer having its secondary connected to ground and to an elevated terminal respectively, and means for impressing electrical oscillations upon its primary, of a receiving instrument comprising a transformer having its primary similarly connected to ground and to an elevated terminal, and a translat-

ing device connected with its secondary, the capacity and inductance of the secondary of the transmitting and primary of the receiving instruments having such values as to secure synchronism with the impressed oscillations, as set forth.

5. The combination with a transmitting coil or conductor connected to ground and an elevated terminal respectively, and means for producing electrical currents or oscillations in the same, of a receiving coil or conductor similarly connected to ground and to an elevated terminal and synchronized with the transmitting coil or conductor, as set forth.

6. The combination with a transmitting instrument comprising an electrical transformer, having its secondary connected to ground and to an elevated terminal respectively, of a receiving instrument comprising a transformer, having its primary similarly connected to ground and to an elevated terminal, the receiving-coil being synchronized with that of the transmitter, as set forth.

7. The combination with a transmitting coil or conductor connected to ground and to an elevated terminal respectively, and means for producing electrical currents or oscillations in the same, of a receiving coil or conductor similarly connected to ground and to an elevated terminal, the said coil or coils having a length equal to one-quarter of the wave length of the disturbance propagated, as set forth.

8. The combination with a transmitting coil or conductor connected to ground and to an elevated terminal respectively, and adapted to cause the propagation of currents or oscillations by conduction through the natural medium, of a receiving-circuit similarly connected to ground and to an elevated terminal, and of a capacity and inductance such that its period of vibration is the same as that of the transmitter, as set forth.

9. The transmitting or receiving circuit herein described, connected to ground and an elevated terminal respectively, and arranged in such manner that the elevated terminal is charged to the maximum potential developed in the circuit, as set forth.

10. The combination with a transmitting coil or conductor connected to ground and to an elevated terminal respectively of a receiving-circuit having a period of vibration corresponding to that of the transmitting-circuit and similarly connected to ground and to an elevated terminal and so arranged that the elevated terminal is charged to the highest potential developed in the circuit, as set forth.

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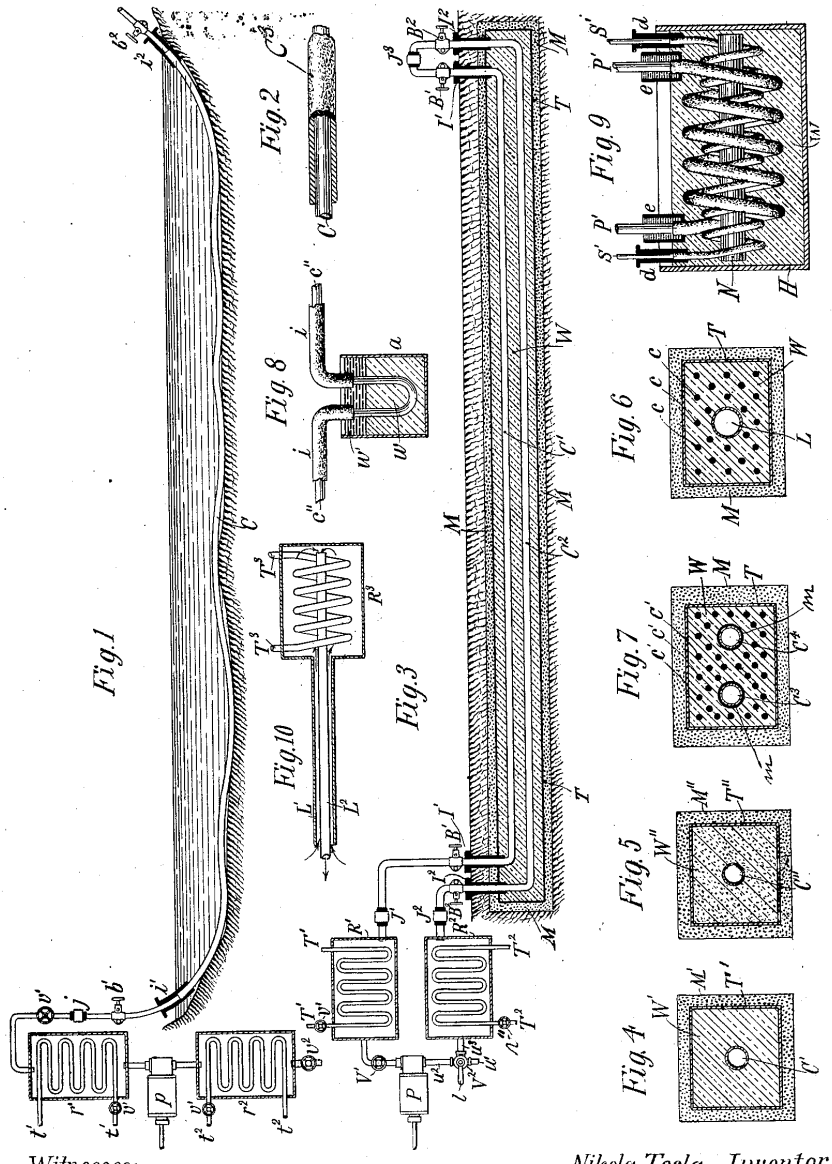
No. 655,838. Patented Aug. 14, 1900.

N. TESLA.

METHOD OF INSULATING ELECTRIC CONDUCTORS.

(Application filed June 15, 1900.)

(No Model.)



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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

METHOD OF INSULATING ELECTRIC CONDUCTORS.

SPECIFICATION forming part of Letters Patent No. 655,838, dated August 14, 1900.

Application filed June 15, 1900. Serial No. 20,405. (No specimens.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing in the borough of Manhattan, in the city, county, and State of New York, have invented certain new and useful Improvements in Methods of Insulating Electric Conductors, of which the following is a specification, reference being had to the accompanying drawings.

It has long been known that many substances which are more or less conducting when in the fluid condition become insulators when solidified. Thus water, which is in a measure conducting, acquires insulating properties when converted into ice. The existing information on this subject, however, has been heretofore of a general nature only and chiefly derived from the original observations of Faraday, who estimated that the substances upon which he experimented, such as water and aqueous solutions, insulate an electrically-charged conductor about one hundred times better when rendered solid by freezing, and no attempt has been made to improve the quality of the insulation obtained by this means or to practically utilize it for such purposes as are contemplated in my present invention. In the course of my own investigations, more especially those of the electric properties of ice, I have discovered some novel and important facts, of which the more prominent are the following: first, that under certain conditions, when the leakage of the electric charge ordinarily taking place is rigorously prevented, ice proves itself to be a much better insulator than has heretofore appeared; second, that its insulating properties may be still further improved by the addition of other bodies to the water; third, that the dielectric strength of ice or other frozen aqueous substance increases with the reduction of temperature and corresponding increase of hardness, and, fourth, that these bodies afford a still more effective insulation for conductors carrying intermittent or alternating currents, particularly of high rates, surprisingly-thin layers of ice being capable of withstanding electromotive forces of many hundreds and even thousands of volts. These and other observations have led me to the invention of a novel method of insulating conductors, rendered practicable by reason of the above facts and advantageous in the utilization of electrical energy for industrial and commercial purposes. Broadly stated, the method consists in insulating an electric conductor by freezing or solidifying and maintaining in such state, by the circulation of a cooling agent, the material surrounding or contiguous to the conductor.

In the practical carrying out of my method I may employ a hollow conductor and pass the cooling agent through the same, thus freezing the water or other medium in contact with or close to such conductor, or I may use expressly for the circulation of the cooling agent an independent channel and freeze or solidify the adjacent substance, in which any number of conductors may be embedded. The conductors may be bare or covered with some material which is capable of keeping them insulated when it is frozen or solidified. The frozen mass may be in direct touch with the surrounding medium or it may be in a degree protected from contact with the same by an inclosure more or less impervious to heat. The cooling agent may be any kind of liquid, preferably of low freezing-point, as brine, or it may be a gas, as atmospheric air, oxygen, carbonic acid, ammonia, illuminating-gas, or hydrogen. It may be forced through the channel by gravity, pressure, or suction, produced mechanically or otherwise, or by any other kind of force. It may be continually renewed or indefinitely used by being alternately volatilized and condensed or evaporated and absorbed and mechanically driven back and forth or steadily circulated in a closed path under any suitable conditions as regards pressure, density, temperature, and velocity.

To conduce to a better understanding of the invention, reference is now made to the accompanying drawings, in which—

Figures 1, 3, 6, 7, 8, and 9 illustrate in longitudinal section typical ways of carrying out my invention; and Figs. 2, 4, 5, and 10, in section or partly so, constructive details to be described.

In Fig. 1, C is a hollow conductor, such as a steel tube, laid in a body of water and communicating with a reservoir r', but electrically insulated from the same at j. A pump or compressor p of any suitable construction

connects r' with another similar tank r^2, provided with an inlet-valve v^2. The air or other gas which is used as the cooling agent entering through the valve v^2 is drawn through the tank r^2 and pump p into the reservoir r', escaping thence through the conductor C under any desired pressure, which may be regulated by a valve v'. Both the reservoirs r' and r^2 are kept at a low temperature by suitable means, as by coils or tubes l' l' and l^2 l^2, through which any kind of refrigerating fluid may be circulated, some provision being preferably made for adjusting the flow of the same, as by valves v'. The gas continuously passing through the tube or conductor C being very cold will freeze and maintain in this state the water in contact with or adjacent to the conductor and so insulate it. Flanged bushings i' i^2 of non-conducting material may be used to prevent the leakage of the current which would otherwise occur, owing to the formation of a superficial film of moisture over the ice projecting out of the water. The tube, being kept insulated by this means, may then be employed in the manner of an ordinary telegraphic or other cable by connecting either or both of the terminals b' b^2 in a circuit including the earth.

In many cases it will be of advantage to cover the hollow conductor with a thick layer of some cheap material, as felt, this being indicated by C^3 in Fig. 2. Such a covering, penetrable by water, would be ordinarily of little or no use; but when embedded in the ice it improves the insulating qualities of the same. In this instance it furthermore serves to greatly reduce the quantity of ice required, its rate of melting, and the influx of heat from the outside, thus diminishing the expenditure of energy necessary for the maintenance of normal working conditions. As regards this energy and other particulars of importance they will vary according to the special demands in each case.

Generally considered, the cooling agent will have to carry away heat at a rate sufficient to keep the conductor at the desired temperature and to maintain a layer of the required thickness of the substance surrounding it in a frozen state, compensating continually for the heat flowing in through the layer and wall of the conductor and that generated by mechanical and electrical friction. To meet these conditions, its cooling capacity, which is dependent on the temperature, density, velocity, and specific heat, will be calculated by the help of data and formulæ familiar to engineers. Air will be, as a rule, suitable for the use contemplated; but in exceptional instances some other gas, as hydrogen, may be resorted to, which will permit a much-greater rate of cooling and a lower temperature to be reached. Obviously whichever gas be employed it should before entering the hollow conductor or channel be thoroughly dried and separated from all which by condensation and deposition or otherwise might cause an obstruction to its passage. For these purposes apparatus may be employed which is well known and which it is unnecessary to show in detail.

Instead of being wasted at the distant station the cooling agent may be turned to some profitable use. Evidently in the industrial and commercial exploitation of my invention any kind of fluid capable of meeting the requirements may be conveyed from one to another station and there utilized for refrigeration, power, heating, lighting, sanitation, chemical processes, or any other purpose to which it may lend itself, and thus the revenue of the plant may be increased.

As to the temperature of the conductor it will be determined by the nature of its use and considerations of economy. For instance, if it be employed for the transmission of telegraphic messages, when the loss in electrical friction may be of no consequence, a very low temperature may not be required; but if it be used for transmitting large amounts of electrical energy, when the frictional waste may be a serious drawback, it will be desirable to keep it extremely cold. The attainment of this object will be facilitated by any provision for reducing as much as possible the flowing in of the heat from the surrounding medium. Clearly the lower the temperature of the conductor the smaller will be the loss in electrical friction; but, on the other hand, the colder the conductor the greater will be the influx of heat from the outside and the cost of the cooling agent. From such and similar considerations the temperature securing the highest economy will be ascertained.

Most frequently in the distribution of electricity for industrial purposes, as in my system of power transmission by alternate currents, more than one conductor will be required, and in such cases it may be convenient to circulate the cooling agent in a closed path formed by the conductors. A plan of this kind is illustrated in Fig. 3, in which C' and C^2 represent two hollow conductors embedded in a frozen mass underground and communicating, respectively, with the reservoirs R' and R^2, which are connected by a reciprocating or other suitable pump P. Cooling coils or tubes T' T'' and T^2 T^2 with regulating-valves v' v'' are employed, which are similar to and serve the same purpose as those shown in Fig. 1. Other features of similarity, though unnecessary, are illustrated to facilitate an understanding of the plan. A three-way valve V^2 is provided, which when placed with its lever l as indicated allows the cooling agent to enter through the tubes u' u^2 and pump P, thus filling the reservoirs R' R^2 and hollow conductors C' C^2; but when turned ninety degrees the valve shuts off the communication to the outside through the tube u' and establishes a connection between the reservoir R^2 and pump P through the tubes u^2 and u^3, thus permitting the fluid to be

circulated in the closed path C′ C² R² w^3 w^2 P R′ by the action of the pump. Another valve V′ of suitable construction may be used for regulating the flow of the cooling agent. The conductors C′ C² are insulated from the reservoirs R′ R² and from each other at the joints J′ J² J³, and they are, furthermore, protected at the places where they enter and leave the ground by flanged bushings I′ I′ I² I², of insulating material, which extend into the frozen mass in order to prevent the current from leaking, as above explained. Binding-posts B′ B′ and B² B² are provided for connecting the conductors to the circuit at each station.

In laying the conductors, as C′ C², whatever be their number, a trench will generally be dug and a trough, round or square, as T, of smaller dimensions than the trench placed in the same, the intervening space being packed with some material (designated by M M M) more or less impervious to heat, as sawdust, ashes, or the like. Next, the conductors will be put in position and temporarily supported in any convenient manner, and finally the trough will be filled with water or other substance W, which will be gradually frozen by circulating the cooling agent in the closed path, as before described. Usually the trench will not be level, but will follow the undulations of the ground, and this will make it necessary to subdivide the trough in sections or to effect the freezing of the substance filling it successively in parts. This being done and the conductors thus insulated and fixed, a layer of the same or similar material M M M will be placed on the top and the whole covered with earth or pavement. The trough may be of metal, as sheet-iron, and in cases where the ground is used as return-circuit it may serve as a main or it may be of any kind of material more or less insulating. Figs. 4 and 5 illustrate in cross-section two such underground troughs T′ and T″, of metal sheet, with their adiathermanous inclosures, (designated M′ and M″, respectively,) each trough containing a single central hollow conductor, as C′ and C″. In the first case the insulation W′ is supposed to be ice, obtained by freezing water preferably freed of air in order to exclude the formation of dangerous bubbles or cavities, while in the second case the frozen mass W″ is some aqueous or other substance or mixture highly insulating when in this condition.

It should be stated that in many instances it may be practicable to dispense with a trough by resorting to simple expedients in the placing and insulating of the conductors. In fact, for some purposes it may be sufficient to simply cover the latter with a moist mass, as cement or other plastic material, which so long as it is kept at a very low temperature and frozen hard will afford adequate insulation.

Another typical way of carrying out my invention, to which reference has already been made, is shown in Fig. 6, which represents the cross-section of a trough, the same in other respects as those before shown, but containing instead of a hollow conductor any kind of pipe or conduit L. The cooling agent may be driven in any convenient manner through the pipe for the purpose of freezing the water or other substance filling the trough, thus insulating and fixing a number of conductors *c c c*. Such a plan may be particularly suitable in cities for insulating and fixing telegraph and telephone wires or the like. In such cases an exceedingly-low temperature of the cooling agent may not be required, and the insulation will be obtained at the expense of little power. The conduit L may, however, be used simultaneously for conveying and distributing any kind of fluid for which there is a demand through the district. Obviously two such conduits may be provided and used in a similar manner as the conductors C′ C².

It will often be desirable to place in the same trough a great number of wires or conductors serving for a variety of purposes. In such a case a plan may be adopted which is illustrated in Fig. 7, showing a trough similar to that in Fig. 6, with the conductors in cross-section. The cooling agent may be in this instance circulated, as in Fig. 3 or otherwise, through the two hollow conductors C³ and C⁴, which, if found advantageous, may be covered with a layer of cheap material *m m*, such as will improve their insulation, but not prevent the freezing or solidification of the surrounding substance W. The tubular conductors C′ C², preferably of iron, may then serve to convey heavy currents for supplying light and power, while the small ones *c′ c′ c′*, embedded in the ice or frozen mass, may be used for any other purposes.

While my invention contemplates, chiefly, the insulation of conductors employed in the transmission of electrical energy to a distance, it may be, obviously, otherwise usefully applied. In some instances, for example, it may be desirable to insulate and support a conductor in places as ordinarily done by means of glass or porcelain insulators. This may be effected in many ways by conveying a cooling agent either through the conductor or through an independent channel and freezing or solidifying any kind of substance, thus enabling it to serve the purpose. Such an artificial insulating-support is illustrated in Fig. 8, in which *a* represents a vessel filled with water or other substance *w*, frozen by the agent circulating through the hollow conductor C″, which is thus insulated and supported. To improve the insulation on the top, where it is most liable to give way, a layer of some substance *w′*, as oil, may be used, and the conductor may be covered near the support with insulation *i i*, as shown, the same extending into the oil for reasons well understood.

Another typical application of my inven-

tion is shown in Fig. 9, in which P′ and S′ represent, respectively, the primary and secondary conductors, bare or insulated, of a transformer, which are wound on a core N and immersed in water or other substance W, containing a jar H and, as before stated, preferably freed of air by boiling or otherwise. The cooling agent is circulated in any convenient manner, as through the hollow primary P′, for the purpose of freezing the substance W. Flanged bushings *d d* and oil-cups *e e*, extending into the frozen mass, illustrate suitable means for insulating the ends of the two conductors and preventing the leakage of the currents. A transformer, as described, is especially fitted for use with currents of high frequency, when a low temperature of the conductors is particularly desirable, and ice affords an exceptionally-effective insulation.

It will be understood that my invention may be applied in many other ways, that the special means here described will be greatly varied according to the necessities, and that in each case many expedients will be adopted which are well known to engineers and electricians and on which it is unnecessary to dwell. However, it may be useful to state that in some instances a special provision will have to be made for effecting a uniform cooling of the substance surrounding the conductor throughout its length. Assuming in Fig. 1 the cooling agent to escape at the distant end freely into the atmosphere or into a reservoir maintained at low pressure, it will in passing through the hollow conductor C move with a velocity steadily increasing toward the end, expanding isothermally, or nearly so, and hence it will cause an approximately-uniform formation of ice along the conductor. In the plan illustrated in Fig. 3 a similar result will be in a measure attained, owing to the compensating effect of the hollow conductors C′ and C^2, which may be still further enhanced by reversing periodically the direction of the flow in any convenient manner; but in many cases special arrangements will have to be employed to render the cooling more or less uniform. For instance, referring to Figs. 4, 5, and 6, instead of a single channel two concentric channels L′ and L^2 may be provided and the cooling agent passed through one and returned through the other, as indicated diagrammatically in Fig. 10. In this and any similar arrangement when the flow takes place in opposite directions the object aimed at will be more completely attained by reducing the temperature of the circulating cooling agent at the distant station, which may be done by simply expanding it into a large reservoir, as R^3, or cooling it by means of a tube or coil T^3, or otherwise. Evidently in the case illustrated the concentric tubes may be used as independent conductors, insulated from each other by the intervening fluid and from the ground by the frozen or solidified substance.

Generally in the transmission of electrical energy in large amounts, when the quantity of heat to be carried off may be considerable, refrigerating apparatus thoroughly protected against the inflow of heat from the outside, as usual, will be employed at both the stations and, when the distance between them is very great, also at intermediate points, the machinery being advantageously operated by the currents transmitted or fluids conveyed. In such cases a fairly-uniform freezing of the insulating substance will be attained without difficulty by the compensating effect of the oppositely-circulating cooling agents. In large plants of this kind, when the saving of electrical energy in the transmission is the most important consideration or when the chief object is to reduce the cost of the mains by the employment of cheap metal, as iron, or otherwise, every effort will be made to maintain the conductors at the lowest possible temperature, and well-known refrigerating processes, as those based on the regenerative principle, may be resorted to, and in this and any other case the hollow conductors or channels instead of merely serving the purpose of conveying the cooling agent may themselves form active parts of the refrigerating apparatus.

From the above description it will be readily seen that my invention forms a fundamental departure in principle from the established methods of insulating conductors employed in the industrial and commercial application of electricity. It aims, broadly, at obtaining insulation by the continuous expenditure of a moderate amount of energy instead of securing it only by virtue of an inherent physical property of the material used, as heretofore. More especially its object is to provide, when and wherever required, insulation of high quality, of any desired thickness and exceptionally cheap, and to enable the transmission of electrical energy under conditions of economy heretofore unattainable and at distances until now impracticable by dispensing with the necessity of using costly conductors and insulators.

What I claim as my invention is—

1. The method of insulating electric conductors herein described which consists in imparting insulating properties to a material surrounding or contiguous to the said conductor by the continued action thereon of a cooling agent, as set forth.

2. The method of insulating electric conductors herein described which consists in reducing to and maintaining in a frozen or solidified condition the material surrounding or contiguous to the said conductor by the action thereon of a cooling agent maintained in circulation through one or more channels as set forth.

3. The method of insulating electric conductors herein described which consists in surrounding or supporting the conductor by material which acquires insulating properties when in a frozen or solidified state, and main-

taining the material in such a state by the circulation through one or more channels extending through it of a cooling agent, as set forth.

4. The method of insulating an electric conductor which consists in surrounding or supporting said conductor by a material which acquires insulating properties when frozen or solidified, and maintaining the material in such state by passing a cooling agent continuously through a channel in said conductor, as set forth.

5. The method of insulating electric conductors, which consists in surrounding or supporting the said conductors by a material which acquires insulating properties when in a frozen or solidified state, and maintaining the material in such state by the continued application thereto of a cooling agent, as set forth.

6. The method of insulating conductors herein set forth which consists in surrounding or supporting the conductors by a material which acquires insulating properties when in a frozen or solidified state, and maintaining the material in such state by the circulation of a cooling agent through a circuit of pipes or tubes extending through the said material as set forth.

7. The method of insulating electric conductors which consists in laying or supporting the conductors in a trough or conduit filling the trough with a material which acquires insulating properties when frozen or solidified, and then causing a cooling agent to circulate through one or more channels extending through the material in the trough so as to freeze or solidify the material, as set forth.

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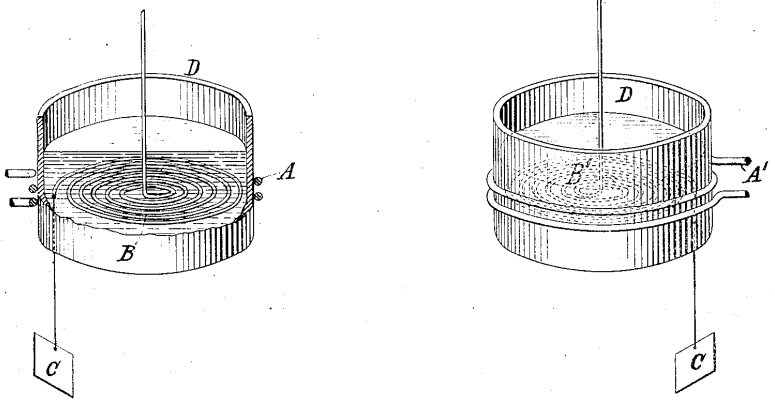
No. 685,012. Patented Oct. 22, 1901.

N. TESLA.

MEANS FOR INCREASING THE INTENSITY OF ELECTRICAL OSCILLATIONS.

(Application filed Mar. 21, 1900. Renewed July 3, 1901.)

(No Model.)



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UNITED STATES PATENT OFFICE.

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MEANS FOR INCREASING THE INTENSITY OF ELECTRICAL OSCILLATIONS.

SPECIFICATION forming part of Letters Patent No. 685,012, dated October 22, 1901.

Application filed March 21, 1900. Renewed July 3, 1901. Serial No. 66,980. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at the borough of Manhattan, in the city, county, and State of New York, have invented certain new and useful Improvements in Means for Increasing the Intensity of Electrical Oscillations, of which the following is a specification, reference being had to the drawings accompanying and forming part of the same.

In many scientific and practical uses of electrical impulses or oscillations—as, for example, in systems of transmitting intelligence to distant points—it is of great importance to intensify as much as possible the current impulses or vibrations which are produced in the circuits of the transmitting and receiving instruments, particularly of the latter.

It is well known that when electrical impulses are impressed upon a circuit adapted to oscillate freely the intensity of the oscillations developed in the same is dependent on the magnitude of its physical constants and the relation of the periods of the impressed and of the free oscillations. For the attainment of the best result it is necessary that the periods of the impressed should be the same as that of the free oscillations, under which conditions the intensity of the latter is greatest and chiefly dependent on the inductance and resistance of the circuit, being directly proportionate to the former and inversely to the latter. In order, therefore, to intensify the impulses or oscillations excited in the circuit—in other words, to produce the greatest rise of current or electrical pressure in the same—it is desirable to make its inductance as large and its resistance as small as practicable. Having this end in view I have devised and used conductors of special forms and of relatively very large cross-section; but I have found that limitations exist in regard to the increase of the inductance as well as to the diminution of the resistance. This will be understood when it is borne in mind that the resonant rise of current or pressure in a freely-oscillating circuit is proportionate to the frequency of the impulses and that a large inductance in general involves a slow vibration. On the other hand, an increase of the section of the conductor with the object of reducing its resistance is, beyond a certain limit, of little or no value, principally because electrical oscillations, particularly those of high frequency, pass mainly through the superficial conducting layers, and while it is true that this drawback may be overcome in a measure by the employment of thin ribbons, tubes, or stranded cables, yet in practice other disadvantages arise, which often more than offset the gain.

It is a well-established fact that as the temperature of a metallic conductor rises its electrical resistance increases, and in recognition of this constructors of commercial electrical apparatus have heretofore resorted to many expedients for preventing the coils and other parts of the same from becoming heated when in use, but merely with a view to economizing energy and reducing the cost of construction and operation of the apparatus.

Now I have discovered that when a circuit adapted to vibrate freely is maintained at a low temperature the oscillations excited in the same are to an extraordinary degree magnified and prolonged, and I am thus enabled to produce many valuable results which have heretofore been wholly impracticable.

Briefly stated, then, my invention consists in producing a great increase in the intensity and duration of the oscillations excited in a freely-vibrating or resonating circuit by maintaining the same at a low temperature.

Ordinarily in commercial apparatus such provision is made only with the object of preventing wasteful heating, and in any event its influence upon the intensity of the oscillations is very slight and practically negligible, for as a rule impulses of arbitrary frequency are impressed upon a circuit, irrespective of its own free vibrations, and a resonant rise is expressly avoided.

My invention, it will be understood, does not primarily contemplate the saving of energy, but aims at the attainment of a distinctly novel and valuable result—that is, the increase to the greatest practicable degree of the intensity and duration of free oscillations. It may be usefully applied in all cases when this special object is sought, but offers exceptional advantages in those instances in which the freely-oscillating discharges of a condenser are utilized.

The best and most convenient manner of

carrying out the invention of which I am now aware is to surround the freely-vibrating circuit or conductor, which is to be maintained at a low temperature, with a suitable cooling medium, which may be any kind of freezing mixture or agent, such as liquid air, and in order to derive the fullest benefit from the improvement the circuit should be primarily constructed so as to have the greatest possible self-induction and the smallest practicable resistance, and other rules of construction which are now recognized should be observed. For example, when in a system of transmission of energy for any purpose through the natural media the transmitting and receiving conductors are connected to earth and to an insulated terminal, respectively, the lengths of these conductors should be one-quarter of the wave length of the disturbance propagated through them.

In the accompanying drawing I have shown graphically a disposition of apparatus which may be used in applying practically my invention.

The drawing illustrates in perspective two devices, either of which may be the transmitter, while the other is the receiver. In each there is a coil of few turns and low resistance, (designated in one by A and in the other by A'.) The former coil, supposed to be forming part of the transmitter, is to be connected with a suitable source of current, while the latter is to be included in circuit with a receiving device. In inductive relation to said coils in each instrument is a flat spirally-wound coil B or B', one terminal of which is shown as connected to a ground-plate C, while the other, leading from the center, is adapted to be connected to an insulated terminal, which is generally maintained at an elevation in the air. The coils B B' are placed in insulating-receptacles D, which contain the freezing agent and around which the coils A and A' are wound.

Coils in the form of a flat spiral, such as those described, are eminently suited for the production of free oscillations; but obviously conductors or circuits of any other form may be used, if desired.

From the foregoing the operation of the apparatus will now be readily understood. Assume, first, as the simplest case that upon the coil A of the transmitter impulses or oscillations of an arbitrary frequency and irrespective of its own free vibrations are impressed. Corresponding oscillations will then be induced in the circuit B, which, being constructed and adjusted, as before indicated, so as to vibrate at the same rate, will greatly magnify them, the increase being directly proportionate to the product of the frequency of the oscillations and the inductance of circuit B and inversely to the resistance of the latter. Other conditions remaining the same, the intensity of the oscillations in the resonating-circuit B will be increased in the same proportion as its resistance is reduced. Very often, however, the conditions may be such that the gain sought is not realized directly by diminishing the resistance of the circuit. In such cases the skilled expert who applies the invention will turn to advantage the reduction of resistance by using a correspondingly longer conductor, thus securing a much greater self-induction, and under all circumstances he will determine the dimensions of the circuit, so as to get the greatest value of the ratio of its inductance to its resistance, which determines the intensity of the free oscillations. The vibrations of coil B, greatly strengthened, spread to a distance and on reaching the tuned receiving-conductor B' excite corresponding oscillations in the same, which for similar reasons are intensified, with the result of inducing correspondingly stronger currents or oscillations in circuit A', including the receiving device. When, as may be the case in the transmission of intelligible signals, the circuit A is periodically closed and opened, the effect upon the receiver is heightened in the manner above described not only because the impulses in the coils B and B' are strengthened, but also on account of their persistence through a longer interval of time. The advantages offered by the invention are still more fully realized when the circuit A of the transmitter instead of having impulses of an arbitrary frequency impressed upon it is itself permitted to vibrate at its own rate, and more particularly so if it be energized by the freely-oscillating high-frequency discharges of a condenser. In such a case the cooling of the conductor A, which may be effected in any suitable manner, results in an extraordinary magnification of the oscillation in the resonating-circuit B, which I attribute to the increased intensity as well as greater number of the high-frequency oscillations obtained in the circuit A. The receiving-coil B' is energized stronger in proportion and induces currents of greater intensity in the circuit A'. It is evident from the above that the greater the number of the freely-vibrating circuits which alternately receive and transmit energy from one to another the greater, relatively, will be the gain secured by applying my invention.

I do not of course intend to limit myself to the specific manner and means described of artificial cooling, nor to the particular forms and arrangements of the circuits shown. By taking advantage of the facts above pointed out and of the means described I have found it possible to secure a rise of electrical pressure in an excited circuit very many times greater than has heretofore been obtainable, and this result makes it practicable, among other things, to greatly extend the distance of transmission of signals and to exclude much more effectively interference with the same than has been possible heretofore.

Having now described my invention, what I claim is—

1. The combination with a circuit adapted

to vibrate freely, of means for artificially cooling the same to a low temperature, as herein set forth.

2. In an apparatus for transmitting or receiving electrical impulses or oscillations, the combination with a primary and a secondary circuit, adapted to vibrate freely in response to the impressed oscillations, of means for artificially cooling the same to a low temperature, as herein set forth.

3. In a system for the transmission of electrical energy, a circuit upon which electrical oscillations are impressed, and which is adapted to vibrate freely, in combination with a receptacle containing an artificial refrigerant in which said circuit is immersed, as herein set forth.

4. The means of increasing the intensity of the electrical impulses or oscillations impressed upon a freely-vibrating circuit, consisting of an artificial refrigerant combined with and applied to such circuit and adapted to maintain the same at a low temperature.

5. The means of intensifying and prolonging the electrical oscillations produced in a freely-vibrating circuit, consisting of an artificial refrigerant applied to such circuit and adapted to maintain the same at a uniformly-low temperature.

6. In a system for the transmission of energy, a series of transmitting and receiving circuits adapted to vibrate freely, in combination with means for artificially maintaining the same at a low temperature, as set forth.

NIKOLA TESLA.

Witnesses:
JOHN C. KERR,
M. LAWSON DYER.

No. 685,953. Patented Nov. 5, 1901.

N. TESLA.

METHOD OF INTENSIFYING AND UTILIZING EFFECTS TRANSMITTED THROUGH NATURAL MEDIA.

(Application filed June 24, 1899. Renewed May 29, 1901.)

(No Model.)

Fig. 1.

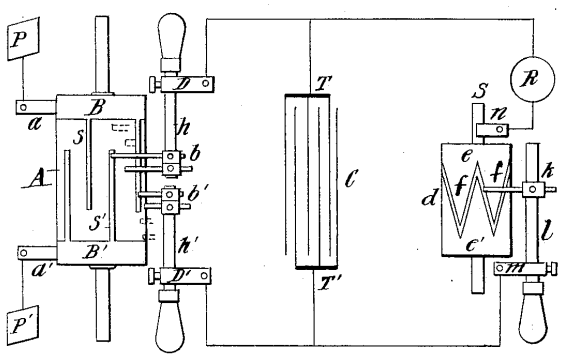
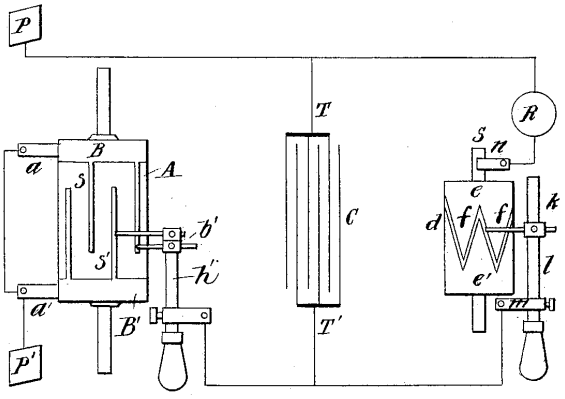


Fig. 2.



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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

METHOD OF INTENSIFYING AND UTILIZING EFFECTS TRANSMITTED THROUGH NATURAL MEDIA.

SPECIFICATION forming part of Letters Patent No. 685,953, dated November 5, 1901.

Application filed June 24, 1899. Renewed May 29, 1901. Serial No. 62,315. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at New York, in the county and State of New York, have invented a new and useful Improvement in Methods of Intensifying and Utilizing Effects Transmitted Through the Natural Media, of which the following is a specification, reference being had to the accompanying drawings, which form a part of the same.

The subject of my present invention is an improvement in the art of utilizing effects transmitted from a distance to a receiving device through the natural media; and it consists in a novel method by means of which results hitherto unattainable may be secured.

Several ways or methods of transmitting electrical disturbances through the natural media and utilizing them to operate distant receivers are now known and have been applied with more or less success for accomplishing a variety of useful results. One of these ways consists in producing by a suitable apparatus rays or radiations—that is, disturbances—which are propagated in straight lines through space, directing them upon a receiving or recording apparatus at a distance, and thereby bringing the latter into action. This method is the oldest and best known and has been brought particularly into prominence in recent years through the investigations of Heinrich Hertz. Another method consists in passing a current through a circuit, preferably one inclosing a very large area, inducing thereby in a similar circuit situated at a distance another current and affecting by the same in any convenient way a receiving device. Still another way, which has also been known for many years, is to pass in any suitable manner a current through a portion of the ground, as by connecting to two points of the same, preferably at a considerable distance from each other, the two terminals of a generator and to energize by a part of the current diffused through the earth a distant circuit which is similarly arranged and grounded at two points widely apart and which is made to act upon a sensitive receiver. These various methods have their limitations, one especially, which is common to all, being that the receiving circuit or instrument must be maintained in a definite position with respect to the transmitting apparatus, which often imposes great disadvantages upon the use of the apparatus.

In several applications filed by me and patents granted to me I have disclosed other methods of accomplishing results of this nature, which may be briefly described as follows: In one system the potential of a point or region of the earth is varied by imparting to it intermittent or alternating electrifications through one of the terminals of a suitable source of electrical disturbances which, to heighten the effect, has its other terminal connected to an insulated body, preferably of large surface and at an elevation. The electrifications communicated to the earth spread in all directions through the same, reaching a distant circuit which generally has its terminals arranged and connected similarly to those of the transmitting source and operates upon a highly-sensitive receiver. Another method is based upon the fact that the atmospheric air which behaves as an excellent insulator to currents generated by ordinary apparatus becomes a conductor under the influence of currents or impulses of enormously-high electromotive force which I have devised means for generating. By such means air strata, which are easily accessible, are rendered available for the production of many desired effects at distances, however great. This method, furthermore, allows advantage to be taken of many of those improvements which are practicable in the ordinary systems of transmission involving the use of a metallic conductor.

Obviously whatever method be employed it is desirable that the disturbances produced by the transmitting apparatus should be as powerful as possible, and by the use of certain forms of high-frequency apparatus which I have devised and which are now well known important practical advantages are in this respect secured. Furthermore, since in most cases the amount of energy conveyed to the distant circuit is but a minute fraction of the total energy emanating from the source it is necessary for the attainment of the best results that whatever the character of the receiver and the nature of the disturbances as much as possible of the energy conveyed should be made available for the operation

of the receiver, and with this object in view I have heretofore among other means employed a receiving-circuit of high self-induction and very small resistance and of a period such as to vibrate in synchronism with the disturbances, whereby a number of separate impulses from the source were made to coöperate, thus magnifying the effect exerted upon and insuring the action of the receiving device. By these means decided advantages have been secured in many instances; but very often the improvement is either not applicable at all or, if so, the gain is very slight. Evidently when the source is one producing a continuous pressure or delivering impulses of long duration it is impracticable to magnify the effects in this manner and when, on the other hand, it is one furnishing short impulses of extreme rapidity of succession the advantage obtained in this way is insignificant, owing to the radiation and the unavoidable frictional waste in the receiving-circuit. These losses reduce greatly both the intensity and the number of the coöperative impulses, and since the initial intensity of each of these is necessarily limited only an insignificant amount of energy is thus made available for a single operation of the receiver. As this amount is consequently dependent on the energy conveyed to the receiver by one single impulse it is evidently necessary to employ either a very large and costly, and therefore objectionable, transmitter or else to resort to the equally objectionable use of a receiving device too delicate and too easily deranged. Furthermore, the energy obtained through the coöperation of the impulses is in the form of extremely rapid vibrations and, because of this, unsuitable for the operation of ordinary receivers, the more so as this form of energy imposes narrow restrictions in regard to the mode and time of its application to such devices.

To overcome these and other limitations and disadvantages which have heretofore existed in such systems of transmission of signals or intelligence is the main object of my present invention, which comprises a novel method of accomplishing these ends.

The method, briefly stated, consists in producing arbitrarily-varied or intermittent disturbances or effects, transmitting such disturbances or effects through the natural media to a distant receiving-station, utilizing energy derived from such disturbances or effects at the receiving-station to charge a condenser, and using the accumulated potential energy so obtained to operate a receiving device.

An apparatus by means of which this method may be practiced is illustrated in the drawings hereto annexed, in which—

Figure 1 is a diagrammatic illustration of the apparatus, and Fig. 2 is a modified form or arrangement of the same.

In the practical application of my method I usually proceed as follows: At any two points in the transmitting medium between which there exists or may be obtained in any manner through the action of the disturbances or effects to be investigated or utilized a difference of electrical potential of any magnitude I arrange two plates or electrodes so that they may be oppositely charged through the agency of such effects or disturbances, and I connect these electrodes to the terminals of a highly-insulated condenser, generally of considerable capacity. To the condenser-terminals I also connect the receiver to be operated in series with a device of suitable construction, which performs the function of periodically discharging the condenser through the receiver at and during such intervals of time as may be best suitable for the purpose contemplated. This device may merely consist of two stationary electrodes separated by a feeble dielectric layer of minute thickness or it may comprise terminals one or more of which are movable and actuated by any suitable force and are adapted to be brought into and out of contact with each other in any convenient manner. It will now be readily seen that if the disturbances of whatever nature they may be cause definite amounts of electricity of the same sign to be conveyed to each of the plates or electrodes above mentioned, either continuously or at intervals of time which are sufficiently long, the condenser will be charged to a certain potential, and an adequate amount of energy being thus stored during the time determined by the device effecting the discharge of the condenser the receiver will be periodically operated by the electrical energy so accumulated; but very often the character of the impulses and the conditions of their use are such that without further provision not enough potential energy would be accumulated in the condenser to operate the receiving device. This is the case when, for example, each of the plates or terminals receives electricity of rapidly-changing sign or even when each receives electricity of the same sign, but only during periods which are short as compared with the intervals separating them. In such instances I resort to the use of a special device which I insert in the circuit between the plates and the condenser for the purpose of conveying to each of the terminals of the latter electrical charges of the proper quality and order of succession to enable the required amount of potential energy to be stored in the condenser.

There are a number of well-known devices, either without any moving parts or terminals or with elements reciprocated or rotated by the application of a suitable force, which offer a more ready passage to impulses of one sign or direction than to those of the other, or permit only impulses of one kind or order of succession to traverse a path, and any of these or similar devices capable of fulfilling the requirements may be used in carrying my invention into practice. One such device of

familiar construction which will serve to convey a clear understanding of this part of my invention and enable a person skilled in the art to apply the same is illustrated in the annexed drawings. It consists of a cylinder A of insulating material, which is moved at a uniform rate of speed by clockwork or other suitable motive power and is provided with two metal rings B B', upon which bear brushes *a* and *a'*, which are connected, respectively, in the manner shown to the terminal plates P and P', above referred to. From the rings B B' extend narrow metallic segments *s* and *s'*, which by the rotation of the cylinder A are brought alternately into contact with double brushes *b* and *b'*, carried by and in contact with conducting-holders *h* and *h'*, which are adjustable longitudinally in the metallic supports D and D', as shown. The latter are connected to the terminals T and T' of a condenser C, and it should be understood that they are capable of angular displacement, as ordinary brush-supports. The object of using two brushes, as *b* and *b'*, in each of the holders *h* and *h'* is to vary at will the duration of the electric contact of the plates P and P' with the terminals T and T', to which is connected a receiving-circuit including a receiver R and a device *d* of the kind above referred to, which performs the duty of closing the receiving-circuit at predetermined intervals of time and discharging the stored energy through the receiver. In the present case this device consists of a cylinder *d*, made partly of conducting and partly of insulating material *e* and *e'*, respectively, which is rotated at the desired rate of speed by any suitable means. The conducting part *e* is in good electrical connection with the shaft S and is provided with tapering segments *f f*, upon which slides a brush *k*, supported on a conducting-rod *l*, capable of longitudinal adjustment in a metallic support *m*. Another brush *n* is arranged to bear upon the shaft S, and it will be seen that whenever one of the segments *f* comes in contact with the brush *k* the circuit, including the receiver R, is completed and the condenser discharged through the same. By an adjustment of the speed of rotation of the cylinder *d* and a displacement of the brush *k* along the cylinder the circuit may be made to open and close in as rapid succession and remain open or closed during such intervals of time as may be desired. The plates P and P', through which the electrifications are conveyed to the brushes *a* and *a'*, may be at a considerable distance from each other and both in the ground or both in the air, or one in the ground and the other in the air, preferably at some height, or they may be connected to conductors extending to some distance or to the terminals of any kind of apparatus supplying electrical energy which is obtained from the energy of the impulses or disturbances transmitted from a distance through the natural media.

In illustration of the operation of the devices described let it be assumed that alternating electrical impulses from a distant generator, as G, are transmitted through the earth and that it is desired to utilize those impulses in accordance with my method. This may be the case, for example, when such a generator is used for purposes of signaling in one of the ways before enumerated, as by having its terminals connected to two points of the earth distant from each other. In this case the plates P and P' are first connected to two properly-selected points of the earth. The speed of rotation of the cylinder A is varied until it is made to turn in synchronism with the alternate impulses of the generator, and, finally, the position of the brushes *b* and *b'* is adjusted by angular displacement, as usual, or in other ways, so that they are in contact with the segments *s* and *s'* during the periods when the impulses are at or near the maximum of their intensity. Only ordinary electrical skill and knowledge are required to make these adjustments, and a number of devices for effecting synchronous movement being well known, and it being the chief object of my present application to set forth a novel method of utilizing or applying a principle, a detailed description of such devices is not considered necessary. I may state, however, that for practical purposes in the present case it is only necessary to shift the brushes forward or back until the maximum effect is secured. The above requirements being fulfilled, electrical charges of the same sign will be conveyed to each of the condenser-terminals as the cylinder A is rotated, and with each fresh impulse the condenser will be charged to a higher potential. The speed of rotation of the cylinder *d* being adjustable at will, the energy of any number of separate impulses may thus be accumulated in potential form and discharged through the receiver R upon the brush *k* coming in contact with one of the segments *f*. It will be of course understood that the capacity of the condenser should be such as to allow the storing of a much greater amount of energy than is required for the ordinary operation of the receiver. Since by this method a relatively great amount of energy and in a suitable form may be made available for the operation of a receiver, the latter need not be very sensitive; but of course when the impulses are very feeble, as when coming from a great distance or when it is desired to operate a receiver very rapidly, then any of the well-known devices capable of responding to very feeble influences may be used in this connection.

If instead of the alternating impulses short impulses of the same direction are conveyed to the plates P and P', the apparatus described may still readily be used, and for this purpose it is merely necessary to shift the brushes *b* and *b'* into the position indicated by the dotted lines while maintaining the

same conditions in regard to synchronism as before, so that the succeeding impulses will be permitted to pass into the condenser, but prevented from returning to the ground or transmitting medium during the intervals between them, owing to the interruption during such intervals of the connections leading from the condenser-terminals to the plates.

Another way of using the apparatus with impulses of the same direction is to take off one pair of brushes, as *b*, disconnect the plate P from brush *a* and join it directly to the terminal T of the condenser, and to connect brush *a* with brush *a'*. The apparatus thus modified would appear as shown in Fig. 2. Operated in this manner and assuming the speed of rotation of cylinder A to be the same, the apparatus will now be evidently adapted for a number of impulses per unit of time twice as great as in the preceding case. In all cases it is evidently important to adjust the duration of contact of segments *s* and *s'* with brushes *b b'* in the manner indicated.

When the method and apparatus I have described are used in connection with the transmission of signals or intelligence, it will of course be understood that the transmitter is operated in such a way as to produce disturbances or effects which are varied or intermitted in some arbitrary manner—for example, to produce longer and shorter successions of impulses corresponding to the dashes and dots of the Morse alphabet—and the receiving device will respond to and indicate these variations or intermittences, since the storage device will be charged and discharged a number of times corresponding to the duration of the successions of impulses received.

Obviously the special appliances used in carrying out my invention may be varied in many ways without departing from the spirit of the same.

It is to be observed that it is the function of the cylinder A, with its brushes and connections, to render the electrical impulses coming from the plates P and P' suitable for charging the condenser (assuming them to be unsuitable for this purpose in the form in which they are received) by rectifying them when they are originally alternating in direction or by selecting such parts of them as are suitable when all are not, and any other device performing this function will obviously answer the purpose. It is also evident that a device such as I have already referred to which offers a more ready passage to impulses of one sign or permits only impulses of the same sign to pass may also be used to perform this selective function in many cases when alternating impulses are received. When the impulses are long and all of the same direction, and even when they are alternating, but sufficiently long in duration and sustained in electromotive force, the brushes *b* and *b'* may be adjusted so as to bear on the parts B B' of the cylinder A, or the cylinder and its brushes may be omitted and the terminals of the condenser connected directly to the plates P and P'.

It will be seen that by the use of my invention results hitherto unattainable in utilizing disturbances or effects transmitted through natural media may be readily attained, since however great the distance of such transmission and however feeble or attenuated the impulses received enough energy may be accumulated from them by storing up the energy of succeeding impulses for a sufficient interval of time to render the sudden liberation of it highly effective in operating a receiver. In this way receivers of a variety of forms may be made to respond effectively to impulses too feeble to be detected or to be made to produce any sensible effect in any other way of which I am aware, a result of great value in various applications to practical use.

I do not claim herein an apparatus by means of which the above-described method is or may be practiced either in the special form herein shown or in other forms which are possible, having made claims to such apparatus in another application, Serial No. 729,812, filed September 8, 1899, as a division of the present case.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. The method of transmitting and utilizing electrical energy herein described, which consists in producing arbitrarily varied or intermitted electrical disturbances or effects, transmitting the same to a distant receiving-station, charging, for succeeding and predetermined periods of time a condenser with energy derived from such effects or disturbances, and operating a receiving device by discharging at arbitrary intervals, the accumulated potential energy so obtained, as set forth.

2. The method of transmitting and utilizing electrical energy herein described, which consists in producing electrical disturbances or effects capable of being transmitted to a distance through the natural media, charging a condenser at a distant receiving-station with energy derived from such effects or disturbances, and using for periods of time, predetermined as to succession and duration, the potential energy so obtained to operate a receiving device.

3. The method of transmitting and utilizing electrical energy herein described, which consists in producing electrical disturbances or effects capable of being transmitted to a distance through the natural media, charging a condenser at a distant receiving-station for succeeding and predetermined periods of time, with energy derived from such effects or disturbances, and using for periods of time predetermined as to succession and duration, the accumulated energy so obtained to operate a receiving device.

4. The method hereinbefore described of producing arbitrarily varied or intermitted

electrical disturbances or effects, transmitting such disturbances or effects through the natural media to a distant receiving-station, storing in a condenser energy derived from a succession of such disturbances or effects for periods of time which correspond in succession to such effects or disturbances and are predetermined as to duration, and using the accumulated potential energy so obtained to operate a receiving device.

5. The method herein described of producing arbitrarily varied or intermitted electrical disturbances or effects, transmitting such disturbances or effects through the natural media to a distant receiving-station, establishing thereby a flow of electrical energy in a circuit at such station, charging a condenser with energy from such circuit, and using the accumulated potential energy so obtained to operate a receiving device.

6. The method herein described of producing arbitrarily varied or intermitted electrical disturbances or effects, transmitting such disturbances or effects through the natural media to a distant receiving-station, establishing thereby a flow of electrical energy in a circuit at such station, charging a condenser with electrical energy from such circuit, and discharging the accumulated potential energy so obtained into or through a receiving device at arbitrary intervals of time.

7. The method herein described of producing arbitrarily varied or intermitted electrical disturbances or effects, transmitting such disturbances or effects to a distant receiving-station, establishing thereby a flow of electrical energy in a circuit at such station, selecting or directing the impulses in said circuit so as to render them suitable for charging a condenser, charging a condenser with the impulses so selected or directed, and discharging the accumulated potential energy so obtained into, or through a receiving device.

8. The method herein described of producing arbitrarily varied or intermitted electrical disturbances or effects, transmitting such disturbances or effects through the natural media to a distant receiving-station, establishing thereby a flow of electrical energy in a circuit at such station, selecting or directing the impulses in said circuit so as to render them suitable for charging a condenser, charging a condenser with the impulses so selected or directed, and discharging the accumulated potential energy so obtained into, or through a receiving device at arbitrary intervals of time.

9. The method hereinbefore described of transmitting signals or intelligence, which consists in producing at the sending-station arbitrarily varied or intermitted disturbances or effects, transmitting such disturbances or effects through the natural media to a receiving-station, utilizing energy derived from such disturbances or effects at the receiving-station to charge a condenser and using the accumulated potential energy so obtained to operate a receiving device.

10. The method hereinbefore described of transmitting signals or intelligence through the natural media from a sending-station to a receiving-station, which consists in producing at the sending-station, arbitrarily varied or intermitted electrical effects or disturbances, transmitting the same through the natural media to the receiving-station, utilizing the energy derived from such disturbances or effects at the receiving-station to charge a condenser, and discharging the accumulated potential energy so obtained through a receiving device at arbitrary intervals of time.

11. The method hereinbefore described of transmitting signals or intelligence from a sending to a distant receiving station, which consists in producing at the former, arbitrarily varied or intermitted electrical disturbances or effects, transmitting the same to the receiving-station, charging by the energy derived from such disturbances or effects at the receiving-station a condenser, and using for periods of time predetermined as to succession and duration, the potential energy so obtained to operate a receiving device, as set forth.

NIKOLA TESLA.

Witnesses:
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A. E. SKINNER.

No. 685,954. Patented Nov. 5, 1901.

N. TESLA.

METHOD OF UTILIZING EFFECTS TRANSMITTED THROUGH NATURAL MEDIA.

(Application filed Aug. 1, 1899. Renewed May 29, 1901.)

(No Model.) 2 Sheets—Sheet 1.

Fig 1.

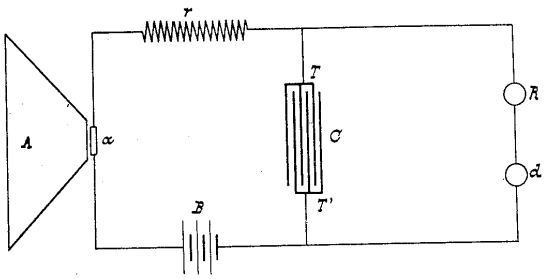
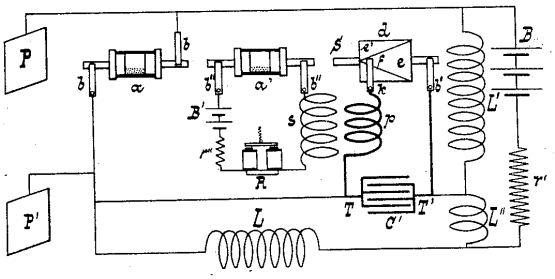


Fig 2.



WITNESSES

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THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

No. 685,954. Patented Nov. 5, 1901.

N. TESLA.

METHOD OF UTILIZING EFFECTS TRANSMITTED THROUGH NATURAL MEDIA.

(Application filed Aug. 1, 1899. Renewed May 29, 1901.)

(No Model.) 2 Sheets—Sheet 2.

Fig. 3

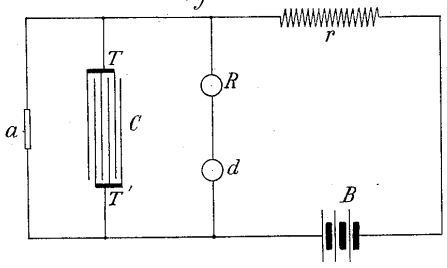


Fig. 4

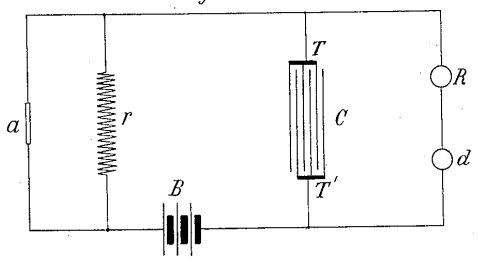
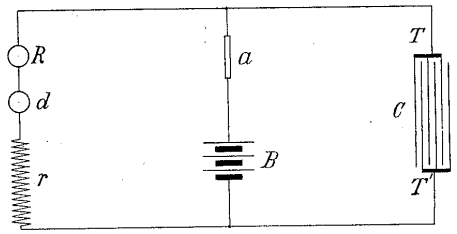


Fig. 5



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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

METHOD OF UTILIZING EFFECTS TRANSMITTED THROUGH NATURAL MEDIA.

SPECIFICATION forming part of Letters Patent No. 685,954, dated November 5, 1901.

Application filed August 1, 1899. Renewed May 29, 1901. Serial No. 62,316. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at New York city, in the county and State of New York, have invented a new and useful Improvement in Methods of Utilizing Effects Transmitted from a Distance to a Receiving Device Through the Natural Media, of which the following is a specification, reference being had to the accompanying drawings, which form a part of the same.

The subject of my present invention is an improvement in the art of utilizing effects transmitted from a distance to a receiving device through the natural media; and it consists in a novel method hereinafter described.

My invention is particularly useful in connection with methods and apparatus for operating distant receiving devices by means of electrical disturbances produced by proper transmitters and conveyed to such receiving devices through the natural media; but it obviously has a wider range of applicability and may be employed, for example, in the investigation or utilization of terrestrial, solar, or other disturbances produced by natural causes.

Several ways or methods of transmitting electrical disturbances through the natural media and utilizing them to operate distant receivers are now known and have been applied with more or less success for accomplishing a variety of useful results. One of these ways consists in producing by a suitable apparatus rays or radiations—that is, disturbances—which are propagated in straight lines through space, directing them upon a receiving or recording apparatus at a distance, and thereby bringing the latter into action. This method is the oldest and best known and has been brought particularly into prominence in recent years through the investigations of Heinrich Hertz. Another method consists in passing a current through a circuit, preferably one inclosing a very large area, inducing thereby in a similar circuit situated at a distance another current and affecting by the same in any convenient way a receiving device. Still another way, which has also been known for many years, is to pass in any suitable manner a current through a portion of the ground, as by connecting to two points of the same, preferably at a considerable distance from each other, the two terminals of a generator and to energize by a part of the current diffused through the earth a distant circuit, which is similarly arranged and grounded at two points widely apart and which is made to act upon a sensitive receiver. These various methods have their limitations, one especially, which is common to all, being that the receiving circuit or instrument must be maintained in a definite position with respect to the transmitting apparatus, which often imposes great disadvantages upon the use of the apparatus.

In several applications filed by me and patents granted to me I have disclosed other methods of accomplishing results of this nature which may be briefly described as follows: In one system the potential of a point or region of the earth is varied by imparting to it intermittent or alternating electrifications through one of the terminals of a suitable source of electrical disturbances, which to heighten the effect has its other terminal connected to an insulated body, preferably of large surface and at an elevation. The electrifications communicated to the earth spread in all directions through the same, reaching a distant circuit, which generally has its terminals arranged and connected similarly to those of the transmitting source and operates upon a highly-sensitive receiver. Another method is based upon the fact that the atmospheric air, which behaves as an excellent insulator to currents generated by ordinary apparatus, becomes a conductor under the influence of currents or impulses of enormously high electromotive force which I have devised means for generating. By such means air strata, which are easily accessible, are rendered available for the production of many desired effects at distances however great. This method, furthermore, allowed advantage to be taken of many of those improvements which are practicable in the ordinary systems of transmission involving the use of a metallic conductor.

Obviously whatever method be employed it is desirable that the disturbances produced by the transmitting apparatus should be as powerful as possible, and by the use of certain forms of high-frequency apparatus which

I have devised and which are now well known important practical advantages are in this respect secured. Furthermore, since in most cases the amount of energy conveyed to the distant circuit is but a minute fraction of the total energy emanating from the source it is necessary for the attainment of the best results that whatever the character of the receiver and the nature of the disturbances as much as possible of the energy conveyed should be made available for the operation of the receiver, and with this object in view I have heretofore, among other means, employed a receiving-circuit of high self-induction and very small resistance and of a period such as to vibrate in synchronism with the disturbances, whereby a number of separate impulses from the source were made to cooperate, thus magnifying the effect exerted upon and insuring the action of the receiving device. By these means decided advantages have been secured in many instances; but very often the improvement is either not applicable at all, or if so the gain is very slight. Evidently when the source is one producing a continuous pressure or delivering impulses of long duration it is impracticable to magnify the effects in this manner, and when, on the other hand, it is one furnishing short impulses of extreme rapidity of succession the advantage obtained in this way is insignificant, owing to the radiation and the unavoidable frictional waste in the receiving-circuit. These losses reduce greatly both the intensity and the number of the coöperative impulses, and since the initial intensity of each of these is necessarily limited only an insignificant amount of energy is thus made available for a single operation of the receiver. As this amount is consequently dependent on the energy conveyed to the receiver by one single impulse, it is evidently necessary to employ either a very large and costly and therefore objectionable transmitter or else to resort to the equally objectionable use of a receiving device too delicate and too easily deranged. Furthermore, the energy obtained through the coöperation of the impulses is in the form of extremely-rapid vibrations and because of this unsuitable for the operation of ordinary receivers, the more so as this form of energy imposes narrow restrictions in regard to the mode and time of its application to such devices. To overcome these and other limitations and disadvantages that have heretofore existed in such systems of transmission of signals or intelligence and to render possible an investigation of impulses or disturbances propagated through the natural media from any kind of source and their practical utilization for any purpose to which they are applicable, I have devised a novel method, which I have described in a pending application filed June 24, 1899, Serial No. 721,790, and which, broadly stated, consists in effecting during any desired time interval a storage of energy derived from such impulses and utilizing the potential energy so obtained for operating a receiving device.

My present invention is intended for the same general purposes, and it comprises a modified method and apparatus by means of which similar results may be obtained.

The chief feature which distinguishes my present from my former invention just referred to is that the energy stored is not, as in the former instance, obtained from the energy of the disturbances or effects transmitted from a distance, but from an independent source.

Expressed generally, my present method consists in charging a storage device with energy from an independent source controlling the charging of said device by the action of the effects or disturbances transmitted through the natural media and coincidentally using the stored energy for operating a receiving device.

A great variety of disturbances produced either by suitably-constructed transmitters or by natural causes are at present known to be propagated through the natural media, and there are also a variety of means or devices enabling energy to be stored, and in view of this I wish to say that I consider the utilization of any such disturbances and the employment of any of these means as within the scope of my present invention so long as the use of the general method hereinbefore stated is involved.

The best way of carrying out my invention which I at present know is to store electrical energy obtained from a suitable electrical generator in a condenser and to control the storage or the application of this energy by means of a sensitive device acted upon by the effects or disturbances, and thereby cause the operation of the receiver.

In the practical application of this method I usually proceed as follows: At any point where I desire to investigate or to utilize for any purpose effects or disturbances propagated through the natural media from any kind of source I provide a suitable generator of electricity—as, for example, a battery and a condenser—which I connect to the poles of the generator in series with a sensitive device capable of being modified in its electrical resistance or other property by the action of the disturbances emitted from the source. To the terminals of the condenser I connect the receiver which is to be operated in series with another device of suitable construction which performs the function of periodically discharging the condenser through the receiver at and during such intervals of time as may be best suitable for the purpose contemplated. This latter device may merely consist of two stationary electrodes separated by a feeble dielectric layer of minute thickness, but sufficient to greatly reduce or practically interrupt the current in the circuit under normal conditions, or it may comprise terminals one or more of which are movable

and actuated by any suitable force and are adapted to be brought into and out of contact with each other in any convenient manner. The sensitive device may be any of the many devices of this kind which are known to be affected by the disturbances, impulses, or effects propagated through the media, and it may be of such a character that normally—that is, when not acted upon—it entirely prevents the passage of electricity from the generator to the condenser, or it may be such that it allows a gradual leaking through of the current and a charging of the condenser at a slow rate. In any case it will be seen that if the disturbances, of whatever nature they may be, cause an appreciable diminution in the electrical resistance of the sensitive device the current from the battery will pass more readily into the condenser, which will be charged at a more rapid rate, and consequently each of its discharges through the receiver, periodically effected by the special device before referred to which performs this function, will be stronger than normally—that is, when the sensitive device is not acted upon by the disturbances. Evidently, then, if the receiver be so adjusted that it does not respond to the comparatively feeble normal discharges of the condenser, if they should occur, but only to those stronger ones which take place upon the diminution of the resistance of the sensitive device, it will be operated only when this device is acted upon by the disturbances, thus making it possible to investigate and to utilize the latter for any desired purpose.

The general principle underlying my invention and the operation of the various devices used will be clearly understood by reference to the accompanying drawings, in which—

Figure 1 is a diagram illustrating a typical arrangement of apparatus which may be used in carrying my method into practice, and Figs. 2, 3, 4, and 5 similar diagrams of modified arrangements of apparatus for the same purpose.

In Fig. 1, C is a condenser, to the terminals T and T′ of which is connected a charging-circuit including a battery B, a sensitive device *a*, and a resistance *r*, all connected in series, as illustrated. The battery should be preferably of very constant electromotive force and of an intensity carefully determined to secure the best results. The resistance *r*, which may be a frictional or an inductive one, is not absolutely necessary; but it is of advantage to use it in order to facilitate adjustment, and for this purpose it may be made variable in any convenient and preferably continuous manner. Assuming that the disturbances which are to be investigated or utilized for some practical end are rays identical with or resembling those of ordinary light, the sensitive device *a* may be a selenium cell properly prepared, so as to be highly susceptible to the influence of the rays, the action of which should be intensified by the use of a reflector A, shown in the drawings. It is well known that when cells of this kind are exposed to such rays of greatly-varying intensity they undergo corresponding modifications of their electrical resistance; but in the ways they have been heretofore used they have been of very limited utility. In addition to the circuit including the sensitive device or cell *a* another circuit is provided, which is likewise connected to the terminals T T′ of the condenser. This circuit, which may be called the "receiving-circuit," includes the receiver R and in series with it a device *d*, before referred to, which performs the duty of periodically discharging the condenser through the receiver. It will be noted that, as shown in Fig. 1, the receiving-circuit is in permanent connection with the battery and condenser terminal T, and it should be stated that it is sometimes desirable to entirely insulate the receiving-circuit at all times except the moments when the device *d* operates to discharge the condenser, thus preventing any disturbing influence which might otherwise be caused in this circuit by the battery or the condenser during the period when the receiver should not be acted upon. In such a case two devices, as *d*, may be used—one in each connection from the condenser to the receiving-circuit—or else one single device of this kind, but of a suitably-modified construction, so that it will make and break simultaneously and at proper intervals of time both of the connections of this circuit with the condenser T and T′.

From the foregoing the operation of the apparatus as illustrated in Fig. 1 will be at once understood. Normally—that is, when it is not influenced by the rays at all or very slightly—the cell *a* being of a comparatively high resistance permits only a relatively feeble current to pass from the battery into the condenser, and hence the latter is charged at too slow a rate to accumulate during the time interval between two succeeding operations of the device *d* sufficient energy to operate the receiver or, generally speaking, to produce the required change in the receiving-circuit. This condition is readily secured by a proper selection and adjustment of the various devices described, so that the receiver will remain unresponsive to the feeble discharges of the condenser which may take place when the cell *a* is acted upon but slightly or not at all by the rays or disturbances; but if now new rays are permitted to fall upon the cell or if the intensity of those already acting upon it be increased by any cause then its resistance will be diminished and the condenser will be charged by the battery at a more rapid rate, enabling sufficient potential energy to be stored in the condenser during the period of inaction of the device *d* to operate the receiver or to bring about any desired change in the receiving-circuit when the device *d* acts. If the rays acting upon the

cell or sensitive device *a* are varied or intermitted in any arbitrary manner, as when transmitting intelligence in the usual way from a distant station by means of short and long signals, the apparatus may readily be made to record or to enable an operator to read the message, since the receiver, supposing it to be an ordinary magnetic relay, for example, will be operated by each signal from the sending-station a certain number of times having some relation to the duration of each signal. It will be readily seen, however, that if the rays are varied in any other way, as by impressing upon them changes in intensity, the succeeding condenser discharges will undergo corresponding changes in intensity, which may be indicated or recorded by a suitable receiver and distinguished irrespectively of duration.

With reference to Fig. 1, it may be useful to state that the electrical connections of the various devices illustrated may be made in many different ways. For instance, the sensitive device instead of being in series, as shown, may be in a shunt to the condenser, this modification being illustrated in Fig. 3, in which the devices already described are indicated by similar letters to correspond with those of Fig. 1. In this case it will be observed that the condenser which is being charged from the battery B through the resistance *r*, preferably inductive and properly related to the capacity of the condenser, will store less energy when the sensitive device *a* is energized by the rays and its resistance thereby diminished. The adjustment of the various instruments may then be such that the receiver will be operated only when the rays are diminished in intensity or interrupted and entirely prevented from falling upon the sensitive cell, or the sensitive device may be placed, as shown in Fig. 4, in a shunt to the resistance *r* or inserted in any suitable way in the circuit containing the receiver—for example, as illustrated in Fig. 5—in both of which figures the various devices are lettered to correspond with those in Fig. 1, so that the figures become self-explanatory. Again, the several instruments may be connected in the manner of a Wheatstone bridge, as will be hereinafter explained with reference to Fig. 2, or otherwise connected or related; but in each case the sensitive device will have the same duty to perform—that is, to control the energy stored and utilized in some suitable way for causing the operation of the receiver in correspondence with the intermittences or variations of the effects or disturbances, and in each instance by a judicious selection of the devices and careful adjustment the advantages of my method may be more or less completely secured. I find it preferable, however, to follow the plan which I have illustrated and described.

It will be observed that the condenser is an important element in the combination. I have shown that by reason of its unique properties it greatly adds to the efficacy of this method. It allows the energy accumulated in it to be discharged instantaneously, and therefore in a highly-effective manner. It magnifies in a large degree the current supplied from the battery, and owing to these features it permits energy to be stored and discharged at practically any rate desired, and thereby makes it possible to obtain in the receiving-circuit very great changes of the current strength by impressing upon the battery-current very small variations. Other means of storage possessing these characteristics to a useful degree may be employed without departing from the broad spirit of my invention; but I prefer to use a condenser, since in these respects it excels any other storage device of which I have knowledge.

In Fig. 2 a modified arrangement of apparatus is illustrated which is particularly adapted for the investigation and utilization of very feeble impulses or disturbances, such as may be used in conveying signals or producing other desired effects at very great distances. In this case the energy stored in the condenser is passed through the primary of a transformer the secondary circuit of which contains the receiver, and in order to render the apparatus still more suitable for use in detecting feeble impulses in addition to the sensitive device which is acted upon by the impulses another such device is included in the secondary circuit of the transformer. The scheme of connections is in the main that of a Wheatstone bridge the four branches of which are formed by the sensitive device *a* and resistances L, L′, and L″, all of which should be preferably inductive and also adjustable in a continuous manner or at least by very small steps. The condenser C′, which is generally made of considerable capacity, is connected to two opposite points of the bridge, while a battery B, in series with a continuously-adjustable non-inductive resistance *r*′, is connected to the other pair of opposite points, as usual. The four resistances included in the branches of the bridge—namely, *a*, L, L′, and L″—are of a suitable size and so proportioned that under normal conditions—that is, when the device *a* is not influenced at all or only slightly by the disturbances—there will be no difference of potential or in any case the minimum of the same at the terminals T and T′ of the condenser. It is assumed in the present instance that the disturbances to be investigated or utilized are such as will produce a difference of electric potential, however small, between two points or regions in the natural media—as the earth, the water, or the air—and in order to apply this potential difference effectively to the sensitive device *a* the terminals of the same are connected to two plates P and P′, which should be of as large a surface as practicable and so located in the media that the largest possible difference of potential will be produced by the disturbances between the terminals of

the sensitive device. This device is in the present case one of familiar construction, consisting of an insulating-tube, which is indicated by the heavy lines in the drawings and which has its ends closed tightly by two conducting-plugs with reduced extensions, upon which bear two brushes *b b*, through which the currents are conveyed to the device. The tubular space between the plugs is partially filled with a conducting sensitive powder, as indicated, the proper amount of the same and the size of its grains being determined and adjusted beforehand by experiment. This tube I rotate by clockwork or other means at a uniform and suitable rate of speed, and under these conditions I find that this device behaves toward disturbances of the kind before assumed in a manner similar to that of a stationary cell of celenium toward rays of light. Its electrical resistance is diminished when it is acted upon by the disturbances and is automatically restored upon the cessation of their influence. It is of advantage to employ round grains of powder in the tube, and in any event it is important that they should be of as uniform size and shape as possible and that provision should be made for maintaining an unchanging and very dry atmosphere in the tube. To the terminals T and T′ of the condenser C′ is connected a coil *p*, usually consisting of a few turns of a conductor of very small resistance, which is the primary of the transformer before referred to, in series with a device *d*, which effects the discharge of the condenser through the coil *p* at predetermined intervals of time. In the present case this device consists of a cylinder made partly of conducting and partly of insulating material *e* and *e′*, respectively, which is rotated at the desired rate of speed by any suitable means. The conducting part *e* is in good electrical connection with shaft S and is provided with tapering segments, as *f*, upon which slides a brush *k*, which should preferably be capable of longitudinal adjustment along the cylinder. Another brush *b′*, which is connected to the condenser-terminal T′, being arranged to bear upon the shaft S, it will be seen that whenever the brush *k* comes in contact with a conducting-segment *f* the circuit including the primary *p* will be completed and the condenser, if energized, discharged through the same. By an adjustment of the speed of rotation of the cylinder and a displacement of the brush *k* along the axis of the same the circuit may be made to open and close in as rapid succession and remain open or closed during such intervals of time as may be desired. In inductive relation to the primary *p* is a secondary coil *s*, usually of much thinner wire and of many more turns than the former, to which are connected in a series a receiver R, (illustrated as an ordinary magnetic relay,) a continuously-adjustable non-inductive resistance *r″*, a battery B′ of a properly determined and very constant electromotive force, and finally a sensitive device *a′* of the same or similar construction as *a*, which is likewise rotated at a uniform speed and which with its brushes *b″ b″* closes the secondary circuit. The electromotive force of the battery B′ is so graduated by means of the adjustable resistance *r″* that the dielectric layers in the sensitive device *a′* are strained very nearly to the point of breaking down and give way upon a slight increase of the electrical pressure on the terminals of the device. It will of course be understood that the resistance *r″* is used mainly because of convenience and that it may be dispensed with, in which case the adjustment may be effected in many other ways, as by determining the proper amount or coarseness of the sensitive powder or by varying the distance apart of the metallic plugs in the ends of the tube. The same may be said of the resistance *r′*, which is in series with the battery B and serves to graduate the force of the latter, so that the dielectric layers of the sensitive device *a* are subjected to a similar strain and maintained in a state of delicate poise. The various instruments being connected and adjusted in the manner described, it will now be readily seen from the foregoing that under normal conditions, the device *a* being unaffected by the disturbances, or practically so, and there being no or only a very insignificant amount of energy stored in the condenser, the periodical closure of the primary circuit of the transformer through the operation of the device *d* will have no appreciable effect upon the primary coil *p*, and hence no currents will be generated in the secondary coil *s*, at least not such as would disturb the state of delicate balance existing in the secondary circuit including the receiver, and therefore the latter will not be actuated by the battery B′; but when, owing to the disturbances or impulses propagated through the media from a distant source, an additional electromotive force, however small, is created between the terminals of the device *a* the dielectric layers in the same, unable to support the increased strain, give way and allow the current of the battery B to pass through, thus causing a difference of potential at the terminals T and T′ of the condenser. A sufficient amount of energy being now stored in this instrument during the time interval between each two succeeding operations of the device *d*, each closure of the primary circuit by the latter results in the passage of a sudden current impulse through the coil *p*, which induces a corresponding current of relatively high electromotive force in the secondary coil *s*. Owing to this the dielectric in the device *a′* gives way, and the current of the battery B′ being allowed to pass the receiver R is operated, but only for a moment, since by the rotation of the devices *a*, *a′*, and *d*, which may be all driven from the same shaft, the original conditions are restored, assuming, of course, that the electromotive force set up by the disturbances

at the terminals of the sensitive device *a* is only momentary or of a duration not longer than the time of closure of the primary circuit; otherwise the receiver will be actuated a number of times and so long as the influence of the disturbances upon the device *a* continues. In order to render the discharged energy of the condenser more effective in causing the operation of the receiver, the resistance of the primary circuit should be very small and the secondary coil *s* should have a number of turns many times greater than that of the primary coil *p*. It will be noted that since the condenser under the above assumptions is always charged in the same direction the strongest current impulse in the secondary coil, which is induced at the moment when the brush *k* comes in contact with segment *f*, is also of unchanging direction, and for the attainment of the best results it is necessary to connect the secondary coil so that the electromotive force of this impulse will be added to that of the battery and will momentarily strengthen the same. However, under certain conditions, which are well understood by those skilled in the art, the devices will operate whichever way the secondary be connected. It is preferable to make the inductive resistances L and L′ relatively large, as they are in a shunt to the device *a* and might if made too small impair its sensitiveness. On the other hand, the resistance L″ should not be too large and should be related to the capacity of the condenser and the number of makes and breaks effected by the device *d* in well-known ways. Similar considerations apply, of course, to the circuits including the primary *p* and secondary *s*, respectively.

By carefully observing well-known rules of scientific design and adjustment of the instruments the apparatus may be made extremely sensitive and capable of responding to the feeblest influences, thus making it possible to utilize impulses or disturbances transmitted from very great distances and too feeble to be detected or utilized in any of the ways heretofore known, and on this account the method here described lends itself to many scientific and practical uses of great value. Obviously the character of the devices and the manner in which they are connected or related may be greatly varied without departing from the spirit of my invention.

What I claim as new, and desire to secure by Letters Patent, is—

1. The method hereinbefore described of utilizing effects or disturbances transmitted through the natural media, which consists in charging a storage device with energy from an independent source, controlling the charging of said device by the action of the effects or disturbances, and coincidently using the stored energy for operating a receiving device.

2. The method hereinbefore described of utilizing effects or disturbances transmitted from a distant source, which consists in charging the storage device with electrical energy from an independent source, controlling the charging of said device by the action of the effects or disturbances, and coincidently using the stored electrical energy for operating the receiving device.

3. The method hereinbefore described of utilizing effects or disturbances transmitted through the natural media, which consists in controlling, by means of such effects or disturbances, the charging of an electrical storage device from an independent source and discharging the stored energy through a receiving-circuit.

4. The method hereinbefore described of utilizing effects or disturbances transmitted through the natural media, which consists in controlling, by means of such effects or disturbances, the charging of an electrical condenser from an independent source, and discharging the stored energy through a receiving-circuit.

5. The method hereinbefore described of utilizing effects or disturbances transmitted through the natural media, which consists in effecting a storage during any desired time interval and under control of such effects or disturbances, of energy derived from an independent source, and utilizing the potential energy so obtained for operating a receiving device.

6. The method hereinbefore described of utilizing effects or disturbances transmitted through the natural media, which consists in effecting a storage, during any desired time interval and under the control of such disturbances or effects of electrical energy derived from an independent source, and utilizing the potential energy so obtained for operating a receiving device.

7. The method hereinbefore described of utilizing effects or disturbances transmitted through the natural media, which consists in effecting a storage in a condenser during any desired time interval and under the control of such disturbances or effects, of electrical energy derived from an independent source, and utilizing the potential energy so obtained for operating a receiving device.

8. The method hereinbefore described of utilizing effects or disturbances transmitted through the natural media from a distant source, which consists in storing, during succeeding intervals of time determined by means of such effects or disturbances, electrical energy derived from an independent source, and utilizing the potential energy so accumulated to operate a receiving device.

9. The method hereinbefore described of utilizing effects or disturbances transmitted through the natural media from a distant source, which consists in storing in a condenser during succeeding intervals of time determined by means of such effects or disturbances, electrical energy derived from an independent source, and utilizing the poten-

tial energy so accumulated to operate a receiving device.

10. The method hereinbefore described of utilizing effects or disturbances transmitted through the natural media from a distant source, which consists in storing, during succeeding intervals of time determined by means of such effects or disturbances, electrical energy derived from an independent source, and using, for periods of time predetermined as to succession and duration, the accumulated energy so obtained to operate a receiving device.

11. The method hereinbefore described of utilizing effects or disturbances transmitted through the natural media from a distant source, which consists in storing in a condenser during succeeding intervals of time determined by means of such effects or disturbances, electrical energy derived from an independent source, and using, for periods of time predetermined as to succession and duration, the accumulated energy so obtained to operate a receiving device.

12. The method hereinbefore described of utilizing electrical effects or disturbances transmitted through the natural media from a distant source, which consists in effecting by means of such disturbances or effects a storage in a storage device of electrical energy derived from an independent source for periods of time corresponding in succession and duration to such disturbances or effects, and discharging the electrical energy so accumulated into or through a receiving device at predetermined intervals of time.

13. The method hereinbefore described of utilizing electrical effects or disturbances transmitted from a distant source, which consists in effecting by means of such disturbances or effects a storage in a condenser of electrical energy derived from an independent source for periods of time corresponding in succession and duration to such disturbances or effects, and discharging the electrical energy so accumulated into or through a receiving device at predetermined intervals of time.

14. The method hereinbefore described of utilizing electrical effects or disturbances transmitted from a distant source, which consists in producing, by means of such effects or disturbances, variations of resistance in a circuit including an independent electrical source and a device adapted to be charged with electrical energy therefrom, thereby causing the storage device to be charged with energy from such independent source, and using the potential electrical energy so accumulated to operate a receiving device.

15. The method hereinbefore described of utilizing effects or disturbances transmitted through the natural media from a distant source, which consists in producing, by means of such effects or disturbances, variations of resistance in a circuit including an independent electrical source and a condenser, thereby causing the condenser to be charged with energy from the independent source, and using the potential electrical energy so accumulated to operate a receiving device.

16. The method hereinbefore described of utilizing effects or disturbances transmitted through the natural media from a distant source, which consists in causing, by means of such effects or disturbances, electrical energy from an independent source to be stored in a storage device, using the electrical energy so accumulated to operate a transformer and employing the secondary currents from such transformer to operate a receiving device.

17. The method hereinbefore described of utilizing effects or disturbances transmitted through the natural media from a distant source, which consists in causing, by means of such effects or disturbances, electrical energy from an independent source to be stored in a condenser, using the electrical energy so accumulated to operate a transformer and employing the secondary currents from such transformer to operate a receiving device.

18. The method hereinbefore described of utilizing effects or disturbances transmitted through the natural media from a distant source, which consists in causing, by means of such disturbances, variations of resistance in a circuit including an independent source of electricity and a storage device and thereby causing the storage device to be charged from such independent source, discharging the energy so accumulated in the storage device through the primary of a transformer at predetermined intervals of time, and operating a receiver by the currents so developed in the secondary of the transformer.

19. The method hereinbefore described of utilizing effects or disturbances transmitted through the natural media from a distant source, which consists in causing, by means of such disturbances, variations of resistance in a circuit including an independent source of electricity and a condenser and thereby causing the condenser to be charged from such independent source, discharging the energy so accumulated in the condenser through the primary of a transformer at predetermined intervals of time and operating a receiver by the currents so developed in the secondary of the transformer.

NIKOLA TESLA.

Witnesses:
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No. 685,955. Patented Nov. 5, 1901.

N. TESLA.

APPARATUS FOR UTILIZING EFFECTS TRANSMITTED FROM A DISTANCE TO A RECEIVING DEVICE THROUGH NATURAL MEDIA.

(Application filed Sept. 8, 1899. Renewed May 29, 1901.)

(No Model.)

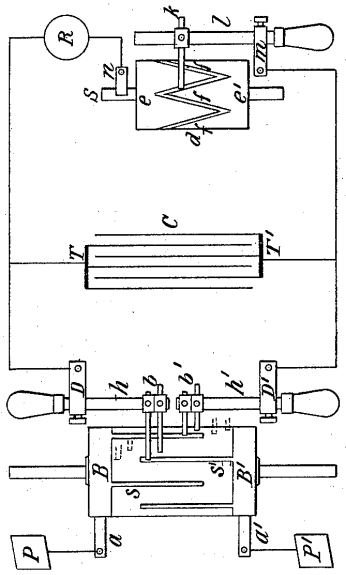

Fig. 1

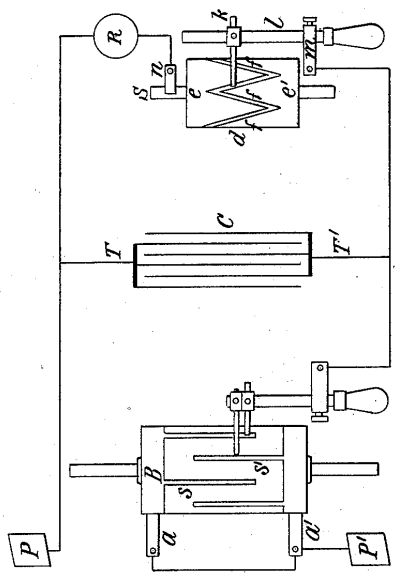

Fig. 2

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UNITED STATES PATENT OFFICE.

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APPARATUS FOR UTILIZING EFFECTS TRANSMITTED FROM A DISTANCE TO A RECEIVING DEVICE THROUGH NATURAL MEDIA.

SPECIFICATION forming part of Letters Patent No. 685,955, dated November 5, 1901.

Original application filed June 24, 1899, Serial No. 721,790. Divided and this application filed September 8, 1899. Re ewed May 29, 1901. Serial No. 62,317. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at the borough of Manhattan, in the city, county, and State of New York, have invented certain new and useful Improvements in Apparatus for Utilizing Effects Transmitted from a Distance to a Receiving Device Through the Natural Media, of which the following is a specification, reference being had to the accompanying drawings, which form a part of the same.

This application is a division of an application filed by me June 24, 1899, Serial No. 721,790, in which a method of utilizing effects or disturbances transmitted through the natural media from a distant source is described and made the subject of the claims. The invention of my present application consists in the apparatus hereinafter described and claimed, by the use of which the method claimed in my said prior application may be practiced and by means of which results hitherto unattainable may be secured.

Several ways or methods of transmitting electrical disturbances through the natural media and utilizing them to operate distant receivers are now known and have been applied with more or less success for accomplishing a variety of useful results. One of these ways consists in producing by a suitable apparatus rays or radiations—that is, disturbances—which are propagated in straight lines through space, directing them upon a receiving or recording apparatus at a distance, and thereby bringing the latter into action. This method is the oldest and best known, and has been brought particularly into prominence in recent years through the investigations of Heinrich Hertz. Another method consists in passing a current through a circuit, preferably one inclosing a very large area, inducing thereby in a similar circuit, situated at a distance, another current and affecting by the same in any convenient way a receiving device. Still another way, which has also been known for many years, is to pass in any suitable manner a current through a portion of the ground, as by connecting to two points of the same, preferably at a considerable distance from each other, the two terminals of a generator and to energize by a part of the current diffused through the earth a distant circuit, which is similarly arranged and grounded at two points widely apart and which is made to act upon a sensitive receiver. These various methods have their limitations, one, especially, which is common to all, being that the receiving circuit or instrument must be maintained in a definite position with respect to the transmitting apparatus, which often imposes great disadvantages upon the use of the apparatus.

In several applications filed by me and patents granted to me I have disclosed other methods of accomplishing results of this nature, which may be briefly described as follows: In one system the potential of a point or region of the earth is varied by imparting to it intermittent or alternating electrifications through one of the terminals of a suitable source of electrical disturbances, which to heighten the effect has its other terminal connected to an insulated body, preferably of large surface and at an elevation. The electrifications communicated to the earth spread in all directions through the same, reaching a distant circuit, which generally has its terminals arranged and connected similarly to those of the transmitting source, and operates upon a highly-sensitive receiver. Another method is based upon the fact that the atmospheric air, which behaves as an excellent insulator to currents generated by ordinary apparatus, becomes a conductor under the influence of currents of impulses of enormously high electromotive force which I have devised means for generating. By such means air strata, which are easily accessible, are rendered available for the production of many desired effects at distances, however great. This method, furthermore, allows advantage to be taken of many of those improvements which are practicable in the ordinary systems of transmission involving the use of a metallic conductor.

Obviously whatever method be employed it is desirable that the disturbances produced by the transmitting apparatus should be as powerful as possible, and by the use of certain forms of high-frequency apparatus which

I have devised and which are now well known important practical advantages are in this respect secured. Furthermore, since in most cases the amount of energy conveyed to the distant circuit is but a minute fraction of the total energy emanating from the source, it is necessary for the attainment of the best results that whatever the character of the receiver and the nature of the disturbances as much as possible of the energy conveyed should be made available for the operation of the receiver, and with this object in view I have heretofore, among other means, employed a receiving-circuit of high self-induction and very small resistance and of a period such as to vibrate in synchronism with the disturbances, whereby a number of separate impulses from the source were made to coöperate, thus magnifying the effect exerted upon and insuring the action of the receiving device. By these means decided advantages have been secured in many instances; but very often the improvement is either not applicable at all or if so the gain is very slight. Evidently when the source is one producing a continuous pressure or delivering impulses of long duration it is impracticable to magnify the effects in this manner, and when, on the other hand, it is one furnishing short impulses of extreme rapidity of succession the advantage obtained in this way is insignificant, owing to the radiation and the unavoidable frictional waste in the receiving-circuit. These losses reduce greatly both the intensity and the number of the coöperative impulses, and since the initial intensity of each of these is necessarily limited only an insignificant amount of energy is thus made available for a single operation of the receiver. As this amount is consequently dependent on the energy conveyed to the receiver by one single impulse, it is evidently necessary to employ either a very large and costly, and therefore objectionable transmitter, or else resort to the equally objectionable use of a receiving device too delicate and too easily deranged. Furthermore, the energy obtained through the coöperation of the impulses is in the form of extremely-rapid vibrations and because of this unsuitable for the operation of ordinary receivers, the more so as this form of energy imposes narrow restrictions in regard to the mode and time of its application to such devices. To overcome these and other limitations and disadvantages which have heretofore existed in such systems of transmission of signals or intelligence is the object of my invention, which comprises a novel form of apparatus for accomplishing these results.

The apparatus which is employed at the receiving-station, described in general terms, consists in the combination of a storage device included in a circuit connecting points at a distance from the source of the disturbances and between which a difference of potential is created by such disturbances, a receiving-circuit connected with the storage device, a receiver included in such receiving-circuit, and means for closing the receiving-circuit at any desired moment, and thereby causing the receiver to be operated by the energy with which the storage device has been charged.

The best form of apparatus for carrying out my invention of which I am now aware and the manner of using the same will be understood from the following description and the accompanying drawings, in which—

Figure 1 is a diagrammatic illustration of such apparatus, and Fig. 2 a modified form or arrangement of the same.

At any two points in the transmitting medium between which there exists or may be obtained in any manner through the action of the disturbances or effects to be investigated or utilized a difference of electrical potential of any magnitude I arrange two plates or electrodes so that they may be oppositely charged through the agency of such effects or disturbances, and I connect these electrodes to the terminals of a highly-insulated condenser, generally of considerable capacity. To the condenser-terminals I also connect the receiver to be operated in series with a device of suitable construction which performs the function of periodically discharging the condenser through the receiver at and during such intervals of time as may be best suitable for the purpose contemplated. This device may merely consist of two stationary electrodes separated by a feeble dielectric layer of minute thickness, or it may comprise terminals one or more of which are movable and actuated by any suitable force and are adapted to be brought into and out of contact with each other in any convenient manner. It will now be readily seen that if the disturbances, of whatever nature they may be, cause definite amounts of electricity of the same sign to be conveyed to each of the plates or electrodes above mentioned either continuously or at intervals of time which are sufficiently long the condenser will be charged to a certain potential and an adequate amount of energy being thus stored during the time determined by the device effecting the discharge of the condenser the receiver will be periodically operated by the electrical energy so accumulated; but very often the character of the impulses and the conditions of their use are such that without further provision not enough potential energy would be accumulated in the condenser to operate the receiving device. This is the case when, for example, each of the plates or terminals receives electricity of rapidly-changing sign or even when each receives electricity of the same sign, but only during periods which are short as compared with the intervals separating them. In such instances I resort to the use of a special device which I insert in the circuit between the plates and the condenser for the purpose of conveying to each of the terminals of the latter electrical charges

of the proper quality and order of succession to enable the required amount of potential energy to be stored in the condenser.

There are a number of well-known devices, either without any moving parts or terminals or with elements reciprocated or rotated by the application of a suitable force, which offer a more ready passage to impulses of one sign or direction than to those of the other or permit only impulses of one kind or order of succession to traverse a path, and any of these or similar devices capable of fulfilling the requirements may be used in carrying my invention into practice. One such device of familiar construction which will serve to convey a clear understanding of this part of my invention and enable a person skilled in the art to apply the same is illustrated in the annexed drawings. It consists of a cylinder A, of insulating material, which is moved at a uniform rate of speed by clockwork or other suitable motive power and is provided with two metal rings B B', upon which bear brushes a and a', which are connected, respectively, in the manner shown to the terminal plates P and P', above referred to. From the rings B B' extend narrow metallic segments s and s', which by the rotation of the cylinder A are brought alternately into contact with double brushes b and b', carried by and in contact with conducting-holders h and h', which are adjustable longitudinally in the metallic supports D and D', as shown. The latter are connected to the terminals T and T' of a condenser C, and it should be understood that they are capable of angular displacement as ordinary brush-supports. The object of using two brushes, as b and b', in each of the holders h and h' is to vary at will the duration of the electric contact of the plates P and P' with the terminals T and T', to which is connected a receiving-circuit, including a receiver R and a device d of the kind above referred to, which performs the duty of closing the receiving-circuit at predetermined intervals of time and discharging the stored energy through the receiver. In the present case this device consists of a cylinder made partly of conducting and partly of insulating material e and e', respectively, which is rotated at the desired rate of speed by any suitable means. The conducting part e is in good electrical connection with the shaft S and is provided with tapering segments f f, upon which slides a brush k, supported on a conducting-rod l, capable of longitudinal adjustment in a metallic support m. Another brush n is arranged to bear upon the shaft S, and it will be seen that whenever one of the segments f comes in contact with the brush k the circuit including the receiver R is completed and the condenser discharged through the same. By an adjustment of the speed of rotation of the cylinder d and a displacement of the brush k along the cylinder the circuit may be made to open and close in as rapid succession and remain open or closed during such intervals of time as may be desired. The plates P and P' through which the electrifications are conveyed to the brushes a and a' may be at a considerable distance from each other and both in the ground or both in the air or one in the ground and the other in the air, preferably at some height, or they may be connected to conductors extending to some distance or to the terminals of any kind of apparatus supplying electrical energy which is obtained from the energy of the impulses or disturbances transmitted from a distance through the natural media.

In illustration of the operation of the devices described let it be assumed that alternating electrical impulses from a distant generator, as G, are transmitted through the earth and that it is desired to utilize these impulses in accordance with my method. This may be the case, for example, when such a generator is used for purposes of signaling in one of the ways before enumerated, as by having its terminals connected at two points of the earth distant from each other. In this case the plates P and P' are first connected to two properly-selected points of the earth, the speed of rotation of the cylinder A is varied until it is made to turn in synchronism with the alternate impulses of the generator, and, finally, the position of the brushes b and b' is adjusted by angular displacement, as usual, or in other ways, so that they are in contact with the segments s and s' during the periods when the impulses are at or near the maximum of their intensity. Only ordinary electrical skill and knowledge are required to make these adjustments, and a number of devices for effecting synchronous movement being well known and it being the chief object of my present application to set forth a novel apparatus embodying a general principle a detailed description of such devices is not considered necessary. I may state, however, that for practical purposes in the present case it is only necessary to shift the brushes back and forth until the maximum effect is secured. The above requirements being fulfilled, electrical charges of the same sign will be conveyed to each of the condenser-terminals as the cylinder A is rotated, and with each fresh impulse the condenser will be charged to a higher potential. The speed of rotation of the cylinder d being adjustable at will, the energy of any number of separate impulses may thus be accumulated in potential form and discharged through the receiver R upon the brush k coming in contact with one of the segments f. It will be of course understood that the capacity of the condenser should be such as to allow the storing of a much greater amount of energy than is required for the ordinary operation of the receiver. Since by this method a relatively great amount of energy and in a suitable form may be made available for the operation of a receiver, the latter need not be very sensitive; but of course when the im-

pulses are very feeble, as when coming from a great distance or when it is desired to operate a receiver very rapidly, then any of the well-known devices capable of responding to very feeble influences may be used in this connection.

If instead of the alternating impulses short impulses of the same direction are conveyed to the plates P and P', the apparatus described may still readily be used, and for this purpose it is merely necessary to shift the brushes *b* and *b'* into the position indicated by the dotted lines, while maintaining the same conditions in regard to synchronism as before, so that the succeeding impulses will be permitted to pass into the condenser, but prevented from returning to the ground or transmitting medium during the intervals between them, owing to the interruption during such intervals of the connections leading from the condenser-terminals to the plates.

Another way of using the apparatus with impulses of the same direction is to take off one pair of brushes, as *b*, disconnect the plate P from brush *a* and join it directly to the terminal T of the condenser, and to connect brush *a* with brush *a'*. When thus modified, the apparatus appears as shown in Fig. 2. Operated in this manner and assuming the speed of rotation of cylinder A to be the same, the apparatus will now be evidently adapted for a number of impulses per unit of time twice as great as in the preceding case. In all cases it is evidently important to adjust the duration of contact of segments *s* and *s'* with brushes *b b'* in the manner indicated.

When the apparatus I have described is used in connection with the transmission of signals or intelligence, it will of course be understood that the transmitter is operated in such a way as to produce disturbances or effects which are varied or intermitted in some arbitrary manner—for example, to produce longer and shorter successions of impulses, corresponding to the dashes and dots of the Morse alphabet—and the receiving device will respond to and indicate these variations or intermittences, since the storage device will be charged and discharged a number of times corresponding to the duration of the successions of impulses received.

Obviously the special appliances used in carrying out my invention may be varied in many ways without departing from the spirit of the same.

It is to be observed that it is the function of the cylinder A, with its brushes and connections, to render the electrical impulses coming from the plates P and P' suitable for charging the condenser (assuming them to be unsuitable for this purpose in the form in which they are received) by rectifying them when they are originally alternating in direction or by selecting such parts of them as are suitable when all are not, and any other device performing this function will obviously answer the purpose. It is also evident that a device such as I have already referred to which offers a more ready passage to impulses of one sign or permits only impulses of the same sign to pass may also be used to perform this selective function in many cases when alternating impulses are received. When the impulses are long and all of the same direction, and even when they are alternating but sufficiently long in duration and sustained in electromotive force, the brushes *b* and *b'* may be adjusted so as to bear on the parts B B' of the cylinder A, or the cylinder and its brushes may be omitted and the terminals of the condenser connected directly to the plates P and P'.

It will be seen that by the use of my invention results hitherto unattainable in utilizing disturbances or effects transmitted through natural media may be readily attained, since however great the distance of such transmission and however feeble or attenuated the impulses received enough energy may be accumulated from them by storing up the energy of succeeding impulses for a sufficient interval of time to render the sudden liberation of it highly effective in operating a receiver. In this way receivers of a variety of forms may be made to respond effectively to impulses too feeble to be detected or to be made to produce any sensible effect in any other way of which I am aware—a result of great value in scientific research as well as in various applications to practical use.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. In an apparatus for utilizing electrical effects or disturbances transmitted through the natural media, the combination with a source of such effects or disturbances of a charging-circuit adapted to be energized by the action of such effects or disturbances, a storage device included in the charging-circuit and adapted to be charged thereby, a receiver, and means for causing the receiver to be operated by the energy accumulated in the storage device at arbitrary intervals of time, substantially as described.

2. In an apparatus for utilizing electrical effects or disturbances transmitted through the natural media, the combination with a source of such effects or disturbances of a charging-circuit adapted to be energized by the action of such effects or disturbances, a storage device included in the charging-circuit and adapted to be charged thereby, means for commutating, directing or selecting the current impulses in the charging-circuit, a receiving-circuit, and means for discharging the storage device through the receiving-circuit, substantially as described.

3. In an apparatus for utilizing electrical effects or disturbances transmitted through the natural media, the combination with a source of such effects or disturbances of a charging-circuit adapted to be energized by the action of such effects or disturbances, a condenser included in the charging-circuit

and adapted to be charged thereby, means for commutating, directing or selecting the current impulses in the charging-circuit, a receiving-circuit, and means for discharging the condenser through the receiving-circuit, substantially as described.

4. In an apparatus for utilizing electrical effects or disturbances transmitted through the natural media, the combination with a source of such effects or disturbances of a charging-circuit adapted to be energized by the action of such effects or disturbances, a storage device included in the charging-circuit and adapted to be charged thereby, means for commutating, directing or selecting the current impulses in the charging-circuit so as to render them suitable for charging the storage device, a receiving-circuit, and means for discharging the storage device through the receiving-circuit, substantially as described.

5. In an apparatus for utilizing electrical effects or disturbances transmitted through the natural media, the combination with a source of such effects or disturbances of a charging-circuit adapted to be energized by the action of such effects or disturbances, a condenser included in the charging-circuit and adapted to be charged thereby, means for commutating, directing or selecting the current impulses in the charging-circuit so as to render them suitable for charging the condenser, a receiving-circuit, and means for discharging the condenser through the receiving-circuit, substantially as described.

6. In an apparatus for utilizing electrical effects or disturbances transmitted through the natural media, the combination with a source of such effects or disturbances of a charging-circuit adapted to be energized by the action of such effects or disturbances, a storage device included in the charging-circuit and adapted to be charged thereby, means for commutating, directing or selecting the current impulses in the charging-circuit so as to render them suitable for charging the storage device, a receiving-circuit, and means for discharging the storage device through the receiving-circuit at arbitrary intervals of time, substantially as described.

7. In an apparatus for utilizing electrical effects or disturbances transmitted to a distant receiving-station, the combination with a source of such effects or disturbances of a circuit distant from the source and adapted to have current impulses set up in it by the action of the effects or disturbances, a storage device, means for commutating, directing or selecting the impulses and connecting the circuit with the storage device at succeeding intervals of time synchronizing with the impulses, a receiving-circuit, and means for periodically discharging the storage device through the receiving-circuit, substantially as described.

8. In an apparatus for utilizing electrical effects or disturbances transmitted to a distant receiving-station, the combination with a source of such effects or disturbances of a circuit distant from the source and adapted to have current impulses set up in it by the action of the effects or disturbances, a condenser, means for commutating, directing or selecting the impulses and connecting the circuit with the condenser at succeeding intervals of time synchronizing with the impulses, a receiving-circuit, and means for periodically discharging the condenser through the receiving-circuit, substantially as described.

9. In an apparatus for utilizing electrical effects or disturbances transmitted through the natural media, the combination with a source of such effects or disturbances of a circuit connecting points at a distance from the source between which a difference of potential is created by such effects or disturbances, a storage device included in such circuit and adapted to be charged with the energy supplied by the same, a receiving-circuit connected with the storage device, a receiver included in such receiving-circuit, and means for closing the receiving-circuit and thereby causing the receiver to be operated by the energy accumulated in the storage device, substantially as described.

10. In an apparatus for utilizing electrical effects or disturbances transmitted through the natural media, the combination with a source of such effects or disturbances of a circuit at a distance from the source which is energized by such effects or disturbances, a storage device adapted to be charged with the energy supplied by such circuit, means for connecting the storage device with the said circuit for periods of time predetermined as to succession and duration, a receiving-circuit connected with the storage device, a receiver included in such receiving-circuit, and means for closing the receiving-circuit and thereby causing the receiver to be operated by the energy accumulated in the storage device, substantially as described.

11. In an apparatus for utilizing electrical effects or disturbances transmitted through the natural media, the combination of a circuit connecting points at a distance from the source between which a difference of potential is created by such effects or disturbances, a storage device included in such circuit and adapted to be charged with the energy supplied by the same, a receiving-circuit, a receiver included in such circuit, and means for connecting the receiving-circuit with the storage device for periods of time predetermined as to succession and duration and thereby causing the receiver to be operated by the energy accumulated in the storage device, substantially as described.

12. In an apparatus for utilizing electrical effects or disturbances transmitted through the natural media, the combination of a circuit connecting points at a distance from the source between which a difference of potential is created by such effects or disturbances, a

storage device adapted to be charged with the energy supplied by such circuit for succeeding and predetermined periods of time, a receiving-circuit, a receiver included in the receiving-circuit, and means for connecting the receiving-circuit with the storage device for periods of time predetermined as to succession and duration and thereby causing the receiver to be operated by the energy accumulated in the storage device, substantially as described.

13. In an apparatus for utilizing electrical effects or disturbances transmitted through the natural media, the combination of a circuit connecting points at a distance from the source, between which a difference of potential is created by such effects or disturbances, a condenser included in such circuit and adapted to be charged by the current in the same, a receiving-circuit connected with the condenser, a receiver included in such receiving-circuit, and a device adapted to close the receiving-circuit at arbitrary intervals of time and thereby cause the receiver to be operated by the electrical energy accumulated in the condenser, substantially as described.

14. In an apparatus for utilizing electrical effects or disturbances transmitted through the natural media, the combination of a charging-circuit distant from the source and energized by the effects or disturbances, a storage device included in the charging-circuit, means included in the charging-circuit and acting in synchronism with the impulses therein for commutating, directing or selecting the impulses, a receiving-circuit and means for periodically discharging the storage device through the receiving-circuit, substantially as described.

15. In an apparatus for utilizing electrical effects or disturbances transmitted through the natural media, the combination of a charging-circuit distant from the source and energized by the effects or disturbances, a condenser included in the charging-circuit, means included in the charging-circuit and acting in synchronism with the impulses therein for commutating, directing or selecting the impulses, a receiving-circuit and means for periodically discharging the condenser through the receiving-circuit, substantially as described.

16. In an apparatus for transmitting signals or intelligence through the natural media from a sending-station to a distant point, the combination of a generator or transmitter adapted to produce arbitrarily varied or intermitted electrical disturbances or effects in the natural media, a charging-circuit at the distant point adapted to receive corresponding electrical impulses or effects from the disturbances or effects so produced, a storage device included in the charging-circuit, means included in the charging-circuit and acting in synchronism with the impulses therein for commutating, directing or selecting the impulses so as to render them suitable for charging the storage device, a receiving-circuit and means for periodically discharging the storage device through the receiving-circuit, substantially as described.

17. In an apparatus for transmitting signals or intelligence through the natural media from a sending-station to a distant point, the combination of a generator or transmitter adapted to produce arbitrarily varied or intermitted electrical disturbances or effects in the natural media, a charging-circuit at the distant point adapted to receive corresponding electrical impulses or effects from the disturbances or effects so produced, a condenser included in the charging-circuit, means included in the charging-circuit and acting in synchronism with the impulses therein for commutating, directing or selecting the impulses so as to render them suitable for charging the condenser, a receiving-circuit and means for periodically discharging the condenser through the receiving-circuit, substantially as described.

18. In an apparatus for transmitting signals or intelligence through the natural media from a sending-station to a distant point, the combination of a generator or transmitter adapted to produce arbitrarily varied or intermitted electrical disturbances or effects in the natural media, a circuit at the distant point adapted to receive corresponding electrical impulses or disturbances from the disturbances or effects so transmitted, a storage device included in such circuit and adapted to be charged thereby, a receiving-circuit connected with the storage device, a receiver included in the receiving-circuit and a device for closing the receiving-circuit at arbitrary intervals of time and thereby causing the receiver to be operated by the energy accumulated in the storage device, substantially as described.

NIKOLA TESLA.

Witnesses:
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LEONARD E. CURTIS.

No. 685,956. Patented Nov. 5, 1901.

N. TESLA.

APPARATUS FOR UTILIZING EFFECTS TRANSMITTED THROUGH NATURAL MEDIA.

(Application filed Nov. 2, 1899. Renewed May 29, 1901.)

(No Model.)

Fig. 1

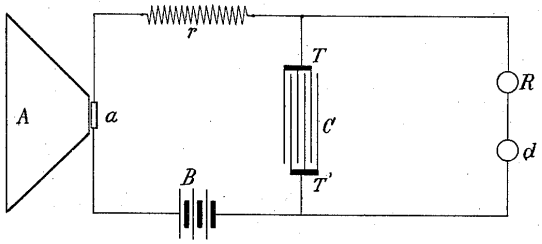


Fig. 2

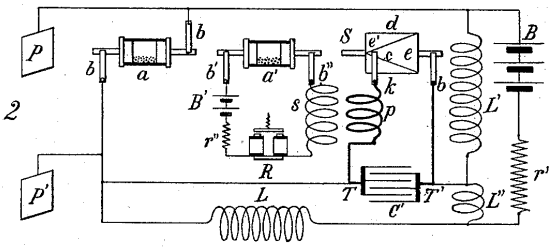


Fig. 3

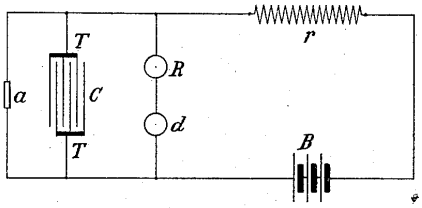


Fig. 4

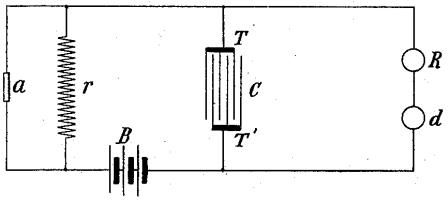
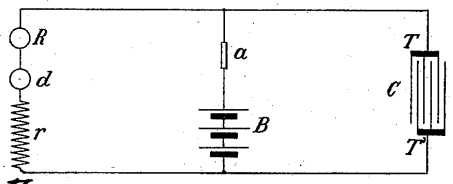


Fig. 5



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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

APPARATUS FOR UTILIZING EFFECTS TRANSMITTED THROUGH NATURAL MEDIA.

SPECIFICATION forming part of Letters Patent No. 685,956, dated November 5, 1901

Original application filed August 1, 1899, Serial No. 725,749. Divided and this application filed November 2, 1899. Renewed May 29, 1901. Serial No. 62,318. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at New York city, in the county and State of New York, have invented a new and useful Improvement in Apparatus for Utilizing Effects Transmitted from a Distance to a Receiving Device Through the Natural Media, of which the following is a specification, reference being had to the accompanying drawings, which form a part of the same.

The subject of my present invention is an improvement in the art of utilizing effects transmitted from a distance to a receiving device through the natural media; and it consists in the novel apparatus hereinafter described.

This application is a division of one filed by me August 1, 1899, Serial No. 725,749, and based upon and claiming the method herein described and which may be practiced by the use of the apparatus forming the subject of this application.

My invention is particularly useful in connection with methods and apparatus for operating distant receiving devices by means of electrical disturbances produced by proper transmitters and conveyed to such receiving devices through the natural media; but it obviously has a wider range of applicability and may be employed, for example, in the investigation or utilization of terrestrial, solar, or other disturbances produced by natural causes.

Several ways or methods of transmitting electrical disturbances through the natural media and utilizing them to operate distant receivers are now known and have been applied with more or less success for accomplishing a variety of useful results. One of these ways consists in producing by a suitable apparatus rays or radiations—that is, disturbances—which are propagated in straight lines through space, directing them upon a receiving or recording apparatus at a distance, and thereby bringing the latter into action. This method is the oldest and best known and has been brought particularly into prominence in recent years through the investigations of Heinrich Hertz. Another method consists in passing a current through a circuit, preferably one inclosing a very large area, inducing thereby in a similar circuit situated at a distance another current and affecting by the same in any convenient way a receiving device. Still another way, which has also been known for many years, is to pass in any suitable manner a current through a portion of the ground, as by connecting to two points of the same, preferably at a considerable distance from each other, the two terminals of a generator and to energize by a part of the current diffused through the earth a distant circuit, which is similarly arranged and grounded at two points widely apart and which is made to act upon a sensitive receiver. These various methods have their limitations, one especially, which is common to all, being that the receiving circuit or instrument must be maintained in a definite position with respect to the transmitting apparatus, which often imposes great disadvantages upon the use of the apparatus.

In several applications filed by me and patents granted to me I have disclosed other methods of accomplishing results of this nature, which may be briefly described as follows: In one system the potential of a point or region of the earth is varied by imparting to it intermittent or alternating electrifications through one of the terminals of a suitable source of electrical disturbances, which, to heighten the effect, has its other terminal connected to an insulated body, preferably of large surface and at an elevation. The electrifications communicated to the earth spread in all directions through the same, reaching a distant circuit, which generally has its terminals arranged and connected similarly to those of the transmitting source and operates upon a highly-sensitive receiver. Another method is based upon the fact that the atmospheric air, which behaves as an excellent insulator to currents generated by ordinary apparatus, becomes a conductor under the influence of currents or impulses of enormously high electromotive force, which I have devised means for generating. By such means air strata, which are easily accessible, are rendered available for the production of many desired effects at distances however great. This method, furthermore, allows ad-

vantage to be taken of many of those improvements which are practicable in the ordinary systems of transmission involving the use of a metallic conductor.

Obviously whatever method be employed it is desirable that the disturbances produced by the transmitting apparatus should be as powerful as possible, and by the use of certain forms of high-frequency apparatus, which I have devised and which are now well known, important practical advantages are in this respect secured. Furthermore, since in most cases the amount of energy conveyed to the distant circuit is but a minute fraction of the total energy emanating from the source it is necessary for the attainment of the best results that whatever the character of the receiver and the nature of the disturbances as much as possible of the energy conveyed should be made available for the operation of the receiver, and with this object in view I have heretofore, among other means, employed a receiving-circuit of high self-induction and very small resistance and of a period such as to vibrate in synchronism with the disturbances, whereby a number of separate impulses from the source were made to coöperate, thus magnifying the effect exerted upon and insuring the action of the receiving device. By these means decided advantages have been secured in many instances; but very often the improvement is either not applicable at all, or, if so, the gain is very slight. Evidently when the source is one producing a continuous pressure or delivering impulses of long duration it is impracticable to magnify the effects in this manner, and when, on the other hand, it is one furnishing short impulses of extreme rapidity of succession the advantage obtained in this way is insignificant, owing to the radiation and the unavoidable frictional waste in the receiving-circuit. These losses reduce greatly both the intensity and the number of the coöperative impulses, and since the initial intensity of each of these is necessarily limited only an insignificant amount of energy is thus made available for a single operation of the receiver. As this amount is consequently dependent on the energy conveyed to the receiver by one single impulse, it is evidently necessary to employ either a very large and costly, and therefore objectionable, transmitter, or else to resort to the equally objectionable use of a receiving device too delicate and too easily deranged. Furthermore, the energy obtained through the coöperation of the impulses is in the form of extremely rapid vibrations and because of this unsuitable for the operation of ordinary receivers, the more so as this form of energy imposes narrow restrictions in regard to the mode and time of its application to such devices. To overcome these and other limitations and disadvantages that have heretofore existed in such systems of transmission of signals or intelligence and to render possible an investigation of impulses or disturbances propagated through the natural media from any kind of source and their practical utilization for any purpose to which they are applicable, I have devised a novel method, which I have described in a pending application, filed June 24, 1899, Serial No. 721,790, and which, broadly stated, consists in effecting during any desired time interval a storage of energy derived from such impulses and utilizing the potential energy so obtained for operating a receiving device.

My present invention is intended for the same general purposes, and it comprises another apparatus by means of which similar results may be obtained.

The chief feature which distinguishes the method of my present from that of my former invention, just referred to, is that the energy stored is not, as in the former instance, obtained from the energy of the disturbances or effects transmitted from a distance, but from an independent source.

Expressed generally, the present method consists in charging a storage device with energy from an independent source, controlling the charging of said device by the action of the effects or disturbances transmitted through the natural media, and coincidently using the stored energy for operating a receiving device.

A great variety of disturbances, produced either by suitably-constructed transmitters or by natural causes, are at present known to be propagated through the natural media, and there are also a variety of means or devices enabling energy to be stored, and in view of this I wish to say that I consider the utilization of any such disturbances and the employment of any of these means as within the scope of my present invention so long as the use of the general method hereinbefore stated is involved.

The best way of carrying out my invention which I at present know is to store electrical energy obtained from a suitable electrical generator in a condenser and to control the storage or the application of this energy by means of a sensitive device acted upon by the effects or disturbances, and thereby cause the operation of the receiver.

In the practical application of this method I usually proceed as follows: At any point where I desire to investigate or to utilize for any purpose effects or disturbances propagated through the natural media from any kind of source I provide a suitable generator of electricity—as, for example, a battery and a condenser—which I connect to the poles of the generator in series with a sensitive device capable of being modified in its electrical resistance or other property by the action of the disturbances emitted from the source. To the terminals of the condenser I connect the receiver which is to be operated in series with another device of suitable construction, which performs the function of periodically discharging the condenser through

the receiver at and during such intervals of time as may be best suitable for the purpose contemplated. This latter device may merely consist of two stationary electrodes separated by a feeble dielectric layer of minute thickness, but sufficient to greatly reduce or practically interrupt the current in the circuit under normal conditions, or it may comprise terminals one or more of which are movable and actuated by any suitable force and are adapted to be brought into and out of contact with each other in any convenient manner. The sensitive device may be any of the many devices of this kind which are known to be affected by the disturbances, impulses, or effects propagated through the media, and it may be of such a character that normally—that is, when not acted upon—it entirely prevents the passage of electricity from the generator to the condenser, or it may be such that it allows a gradual leaking through of the current and a charging of the condenser at a slow rate. In any case it will be seen that if the disturbances, of whatever nature they may be, cause an appreciable diminution in the electrical resistance of the sensitive device the current from the battery will pass more readily into the condenser, which will be charged at a more rapid rate, and consequently each of its discharges through the receiver, periodically effected by the special device before referred to which performs this function, will be stronger than normally—that is, when the sensitive device is not acted upon by the disturbances. Evidently then if the receiver be so adjusted that it does not respond to the comparatively feeble normal discharges of the condenser, if they should occur, but only to those stronger ones which take place upon the diminution of the resistance of the sensitive device it will be operated only when this device is acted upon by the disturbances, thus making it possible to investigate and to utilize the latter for any desired purpose.

The general principle underlying my invention and the operation of the various devices used will be clearly understood by reference to the accompanying drawings, in which—

Figure 1 is a diagram illustrating a typical arrangement of apparatus which may be used in carrying my method into practice, and Figs. 2, 3, 4, and 5 similar diagrams of modified arrangements of apparatus for the same purpose.

In Fig. 1, C is a condenser, to the terminals T and T′ of which is connected a charging-circuit, including a battery B, a sensitive device *a*, and a resistance *r*, all connected in series, as illustrated. The battery should be preferably of very constant electromotive force and of an intensity carefully determined to secure the best results. The resistance *r*, which may be a frictional or an inductive one, is not absolutely necessary; but it is of advantage to use it in order to facilitate adjustment, and for this purpose it may be made variable in any convenient and preferably continuous manner. Assuming that the disturbances which are to be investigated or utilized for some practical end are rays identical with or resembling those of ordinary light, the sensitive device *a* may be a selenium cell properly prepared, so as to be highly susceptible to the influence of the rays, the action of which should be intensified by the use of a reflector A. (Shown in the drawings.) It is well known that when cells of this kind are exposed to such rays of greatly-varying intensity they undergo corresponding modifications of their electrical resistance; but in the ways they have been heretofore used they have been of very limited utility.

In addition to the circuit including the sensitive device or cell *a* another circuit is provided, which is likewise connected to the terminals T T′ of the condenser. This circuit, which may be called the "receiving-circuit," includes the receiver R and in series with it a device *d*, before referred to, which performs the duty of periodically discharging the condenser through the receiver. It will be noted that, as shown in Fig. 1, the receiving-circuit is in permanent connection with the battery and condenser-terminal T, and it should be stated that it is sometimes desirable to entirely insulate the receiving-circuit at all times, except the moments when the device *d* operates to discharge the condenser, thus preventing any disturbing influence which might otherwise be caused in this circuit by the battery or the condenser during the period when the receiver should not be acted upon. In such a case two devices, as *d*, may be used, one in each connection from the condenser to the receiving-circuit, or else one single device of this kind, but of a suitably-modified construction, so that it will make and break simultaneously and at proper intervals of time both of the connections of this circuit with the condenser T and T′.

From the foregoing the operation of the apparatus, as illustrated in Fig. 1, will be at once understood. Normally—that is, when it is not influenced by the rays at all or very slightly—the cell *a*, being of a comparatively high resistance, permits only a relatively feeble current to pass from the battery into the condenser, and hence the latter is charged at too slow a rate to accumulate during the time interval between two succeeding operations of the device *d* sufficient energy to operate the receiver or, generally speaking, to produce the required change in the receiving-circuit. This condition is readily secured by a proper selection and adjustment of the various devices described, so that the receiver will remain unresponsive to the feeble discharges of the condenser which may take place when the cell *a* is acted upon but slightly or not at all by the rays or disturbances; but if now new rays are permitted to fall upon the cell or if the intensity of those already acting upon it be increased by any cause then

its resistance will be diminished and the condenser will be charged by the battery at a more rapid rate, enabling sufficient potential energy to be stored in the condenser during the period of inaction of the device *d* to operate the receiver or to bring about any desired change in the receiving-circuit when the device *d* acts. If the rays acting upon the cell or sensitive device *a* are varied or intermitted in any arbitrary manner, as when transmitting intelligence in the usual way from a distant station by means of short and long signals, the apparatus may readily be made to record or to enable an operator to read the message, since the receiver—supposing it to be an ordinary magnetic relay, for example—will be operated by each signal from the sending-station a certain number of times, having some relation to the duration of each signal. It will be readily seen, however, that if the rays are varied in any other way, as by impressing upon them changes in intensity, the succeeding condenser discharges will undergo corresponding changes in intensity, which may be indicated or recorded by a suitable receiver and distinguished irrespectively of duration.

With reference to Fig. 1 it may be useful to state that the electrical connections of the various devices illustrated may be made in many different ways. For instance, the sensitive device instead of being in series, as shown, may be in a shunt to the condenser, this modification being illustrated in Fig. 3, in which the devices already described are indicated by similar letters to correspond with those of Fig. 1. In this case it will be observed that the condenser, which is being charged from the battery B through the resistance *r*, preferably inductive and properly related to the capacity of the condenser, will store less energy when the sensitive device *a* is energized by the rays, and its resistance thereby diminished. The adjustment of the various instruments may then be such that the receiver will be operated only when the rays are diminished in intensity or interrupted and entirely prevented from falling upon the sensitive cell, or the sensitive device may be placed, as shown in Fig. 4, in a shunt to the resistance *r* or inserted in any suitable way in the circuit containing the receiver—for example, as illustrated in Fig. 5—in both of which figures the various devices are lettered to correspond with those in Fig. 1, so that the figures become self-explanatory. Again, the several instruments may be connected in the manner of a Wheatstone bridge, as will be hereinafter explained with reference to Fig. 2, or otherwise connected or related; but in each case the sensitive device will have the same duty to perform—that is, to control the energy stored and utilized in some suitable way for causing the operation of the receiver in correspondence with the intermittances or variations of the effects or disturbances—and in each instance by a judicious selection of the devices and careful adjustment the advantages of my method may be more or less completely secured. I find it preferable, however, to follow the plan which I have illustrated and described.

It will be observed that the condenser is an important element in the combination. I have shown that by reason of its unique properties it greatly adds to the efficacy of this method. It allows the energy accumulated in it to be discharged instantaneously, and therefore in a highly effective manner. It magnifies in a large degree the current supplied from the battery, and owing to these features it permits energy to be stored and discharged at practically any rate desired, and thereby makes it possible to obtain in the receiving-circuit very great changes of the current strength by impressing upon the battery-current very small variations. Other means of storage possessing these characteristics to a useful degree may be employed without departing from the broad spirit of my invention; but I prefer to use a condenser, since in these respects it excels any other storage device of which I have knowledge.

In Fig. 2 a modified arrangement of apparatus is illustrated which is particularly adapted for the investigation and utilization of very feeble impulses or disturbances, such as may be used in conveying signals or producing other desired effects at very great distances. In this case the energy stored in the condenser is passed through the primary of a transformer, the secondary circuit of which contains the receiver, and in order to render the apparatus still more suitable for use in detecting feeble impulses, in addition to the sensitive device which is acted upon by the impulses, another such device is included in the secondary circuit of the transformer. The scheme of connections is in the main that of a Wheatstone bridge, the four branches of which are formed by the sensitive device *a* and resistances L, L′, and L″, all of which should be preferably inductive and also adjustable in a continuous manner, or at least by very small steps. The condenser C′, which is generally made of considerable capacity, is connected to two opposite points of the bridge, while a battery B, in series with a continuously-adjustable non-inductive resistance *r*′, is connected to the other pair of opposite points, as usual. The four resistances included in the branches of the bridge—namely, *a*, L, L′, and L″—are of a suitable size and so proportioned that under normal conditions—that is, when the device *a* is not influenced at all or only slightly by the disturbances—there will be no difference of potential, or, in any case, the minimum of the same at the terminals T and T′ of the condenser. It is assumed in the present instance that the disturbances to be investigated or utilized are such as will produce a difference of electric potential, however small, between two points or regions in the natural media, as the earth, the water,