

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

SYSTEM OF ELECTRIC LIGHTING.

SPECIFICATION forming part of Letters Patent No. 454,622, dated June 23, 1891.

Application filed April 25, 1891. Serial No. 390,414. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria-Hungary, from Smiljan, Lika, border country of Austria-Hungary, and a resident of New York, in the county and State of New York, have invented certain new and useful Improvements in Methods of and Apparatus for Electric Lighting, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same:

This invention consists in a novel method of and apparatus for producing light by means of electricity.

For a better understanding of the invention it may be stated, first, that heretofore I have produced and employed currents of very high frequency for operating translating devices, such as electric lamps, and, second, that currents of high potential have also been produced and employed for obtaining luminous effects, and this, in a broad sense, may be regarded for purposes of this case as the prior state of the art; but I have discovered that results of the most useful character may be secured under entirely practicable conditions by means of electric currents in which both the above-described conditions of high frequency and great difference of potential are present. In other words, I have made the discovery that an electrical current of an excessively small period and very high potential may be utilized economically and practicably to great advantage for the production of light.

It is difficult for me to define the exact limits of frequency and potential within which my discovery is comprised, for the results obtained are due to both conjointly; but I would make it clear that as to the inferior limits of both, the lowest frequency and potential that I contemplate using are far above what have heretofore been regarded as practicable. As an instance of what I regard as the lowest practicable limits I would state that I have obtained fairly good results by a frequency as low as fifteen thousand to twenty thousand per second and a potential of about twenty thousand volts. Both frequency and potential may be enormously increased above these figures, the practical limits being determined by the character of the apparatus and its ca-

pability of standing the strain. I do not mean by the term "excessively small period" and similar expressions herein to imply that I contemplate any number of pulsations or vibrations per second approximating to the number of light-waves, and this will more fully appear from the description of the nature of invention which is hereinafter contained.

The carrying out of this invention and the full realization of the conditions necessary to the attainment of the desired results involve, first, a novel method of and apparatus for producing the currents or electrical effects of the character described; second, a novel method of utilizing and applying the same for the production of light, and, third, a new form of translating device or light-giving appliance. These I shall now describe.

To produce a current of very high frequency and very high potential, certain well-known devices may be employed. For instance, as the primary source of current or electrical energy a continuous-current generator may be used, the circuit of which may be interrupted with extreme rapidity by mechanical devices, or a magneto-electric machine specially constructed to yield alternating currents of very small period may be used, and in either case, should the potential be too low, an induction-coil may be employed to raise it; or, finally, in order to overcome the mechanical difficulties, which in such cases become practically insuperable before the best results are reached, the principle of the disruptive discharge may be utilized. By means of this latter plan I produce a much greater rate of change in the current than by the other means suggested, and in illustration of my invention I shall confine the description of the means or apparatus for producing the current to this plan, although I would not be understood as limiting myself to its use. The current of high frequency, therefore, that is necessary to the successful working of my invention I produce by the disruptive discharge of the accumulated energy of a condenser maintained by charging said condenser from a suitable source and discharging it into or through a circuit under proper relations of self-induction, capacity, resistance, and period in well-understood ways. Such a discharge is

known to be, under proper conditions, intermittent or oscillating in character, and in this way a current varying in strength at an enormously rapid rate may be produced. Having produced in the above manner a current of excessive frequency, I obtain from it by means of an induction-coil enormously high potentials—that is to say, in the circuit through which or into which the disruptive discharge of the condenser takes place I include the primary of a suitable induction-coil, and by a secondary coil of much longer and finer wire I convert to currents of extremely high potential. The differences in the length of the primary and secondary coils in connection with the enormously rapid rate of change in the primary current yield a secondary of enormous frequency and excessively high potential. Such currents are not, so far as I am aware, available for use in the usual ways; but I have discovered that if I connect to either of the terminals of the secondary coil or source of current of high potential the leading-in wires of such a device, for example, as an ordinary incandescent lamp, the carbon may be brought to and maintained at incandescence, or, in general, that any body capable of conducting the high-tension current described and properly inclosed in a rarefied or exhausted receiver may be rendered luminous or incandescent, either when connected directly with one terminal of the secondary source of energy or placed in the vicinity of such terminals so as to be acted upon inductively.

Without attempting a detailed explanation of the causes to which this phenomenon may be ascribed, I deem it sufficient to state that, assuming the now generally accepted theories of scientists to be correct, the effects thus produced are attributable to molecular bombardment, condenser action, and electric or etheric disturbances. Whatever part each or any of these causes may play in producing the effects noted, it is, however, a fact that a strip of carbon or a mass of any other shape, either of carbon or any more or less conducting substance in a rarefied or exhausted receiver and connected directly or inductively to a source of electrical energy such as I have described, may be maintained at incandescence if the frequency and potential of the current be sufficiently high.

I would here state that by the terms "currents of high frequency and high potential" and similar expressions which I have used in this description I do not mean, necessarily, currents in the usual acceptance of the term, but, generally speaking, electrical disturbances or effects such as would be produced in the secondary source by the action of the primary disturbance or electrical effect.

It is necessary to observe in carrying out this invention that care must be taken to reduce to a minimum the opportunity for the dissipation of the energy from the conductors

intermediate to the source of current and the light-giving body. For this purpose the conductors should be free from projections and points and well covered or coated with a good insulator.

The body to be rendered incandescent should be selected with a view to its capability of withstanding the action to which it is exposed without being rapidly destroyed, for some conductors will be much more speedily consumed than others.

I now refer to the accompanying drawings, in which—

Figure 1 is a diagram of one of the special arrangements that I have employed in carrying out my discovery, and Figs. 2 and 3 are vertical sectional views of modified forms of light-giving devices that I have devised for use with the system.

I would state that as all of the apparatus herein shown, with the exception of certain special forms of lamp invented by me, is or may be of well-known construction and in common use for other purposes, I have indicated such well-known parts therefor by conventional representations.

G is the primary source of current or electrical energy. I have explained above how various forms of generator might be used for this purpose; but in the present illustration I assume that G is an alternating-current generator of comparatively low electro-motive force. Under such circumstances I raise the potential of the current by means of an induction-coil having a primary P and a secondary S. Then by the current developed in this secondary I charge a condenser C, and this condenser I discharge through or into a circuit A, having an air-gap α , or, in general, means for maintaining a disruptive discharge. By the means above described a current of enormous frequency is produced. My object is next to convert this into a working-circuit of very high potential, for which purpose I connect up in the circuit A the primary P' of an induction-coil having a long fine wire secondary S'. The current in the primary P' develops in the secondary S' a current or electrical effect of corresponding frequency, but of enormous difference of potential, and the secondary S' thus becomes the source of the energy to be applied to the purpose of producing light.

The light-giving devices may be connected to either terminal of the secondary S'. If desired, one terminal may be connected to a conducting-wall W of a room or space to be lighted and the other arranged for connection of the lamps therewith. In such case the walls should be coated with some metallic or conducting substance in order that they may have sufficient conductivity.

The lamps or light-giving devices may be an ordinary incandescent lamp; but I prefer to use specially-designed lamps, examples of which I have shown in detail in the draw-

ings. This lamp consists of a rarefied or exhausted bulb or globe which incloses a refractory conducting body, as carbon, of comparatively small bulk and any desired shape. This body is to be connected to the secondary by one or more conductors sealed in the glass, as in ordinary lamps, or is arranged to be inductively connected thereto. For this last-named purpose the body is in electrical contact with a metallic sheet in the interior of the neck of the globe, and on the outside of said neck is a second sheet which is to be connected with the source of current. These two sheets form the armatures of a condenser, and by them the currents or potentials are developed in the light-giving body. As many lamps of this or other kinds may be connected to the terminal of *S'* as the energy supplied is capable of maintaining at incandescence.

In Fig. 3, *b* is a rarefied or exhausted glass globe or receiver, in which is a body of carbon or other suitable conductor *e*. To this body is connected a metallic conductor *f*, which passes through and is sealed in the glass wall of the globe, outside of which it is united to a copper or other wire *g*, by means of which it is to be electrically connected to one pole or terminal of the source of current. Outside of the globe the conducting-wires are protected by a coating of insulation *h*, of any suitable kind, and inside the globe the supporting-wire is inclosed in and insulated by a tube or coating *k* of a refractory insulating substance, such as pipe-clay or the like. A reflecting-plate *l* is shown applied to the outside of the globe *b*. This form of lamp is a type of those designed for direct electrical connection with one terminal of the source of current; but, as above stated, there need not be a direct connection, for the carbon or other illuminating body may be rendered luminous by inductive action of the current thereon, and this may be brought about in several ways. The preferred form of lamp for this purpose, however, is shown in Fig. 2. In this figure the globe *b* is formed with a cylindrical neck, within which is a tube or sheet *m* of conducting material on the side and over the end of a cylinder or plug *n* of any suitable insulating material. The lower edges of this tube are in electrical contact with a metallic plate *o*, secured to the cylinder *n*, all the exposed surfaces of such plate and of the other conductors being carefully coated and protected by insulation. The light-giving body *e*, in this case a straight stem of carbon, is electrically connected with the said plate by a wire or conductor similar to the wire *f*, Fig. 3, which is coated in like manner with a refractory insulating material *k*. The neck of the globe fits into a socket composed of an insulating tube or cylinder *p*, with a more or less complete metallic lining *s*, electrically connected by a metallic head or plate *r* with a conductor *g*, that is to be attached to one

pole of the source of current. The metallic lining *s* and the sheet *m* thus compose the plates or armatures of a condenser.

This invention is not limited to the special means described for producing the results hereinabove set forth, for it will be seen that various plans and means of producing currents of very high frequency are known, and also means for producing very high potentials; but I have only described herein certain ways in which I have practically carried out the invention.

What I claim is—

1. The improvement in the art of electric lighting herein described, which consists in generating or producing for the operation of the lighting devices currents of enormous frequency and excessively high potential, substantially as herein described.

2. The method of producing an electric current for practical application, such as for electric lighting, which consists in generating or producing a current of enormous frequency and inducing by such current in a working circuit, or that to which the lighting devices are connected, a current of corresponding frequency and excessively high potential, as set forth.

3. The method of producing an electric current for practical application, such as for electric lighting, which consists in charging a condenser by a given current, maintaining an intermittent or oscillatory discharge of said condenser through or into a primary circuit, and producing thereby in a secondary working-circuit in inductive relation to the primary very high potentials, as set forth.

4. The method of producing electric light by incandescence by electrically or inductively connecting a conductor inclosed in a rarefied or exhausted receiver to one of the poles or terminals of a source of electric energy or current of a frequency and potential sufficiently high to render said body incandescent, as set forth.

5. A system of electric lighting, consisting in the combination, with a source of electric energy or current of enormous frequency and excessively high potential, of an incandescent lamp or lamps consisting of a conducting body inclosed in a rarefied or exhausted receiver and connected directly or inductively to one pole or terminal of the source of energy, as set forth.

6. In a system of electric lighting, the combination, with a source of currents of enormous frequency and excessively high potential, of incandescent lighting devices, each consisting of a conducting body inclosed in a rarefied or exhausted receiver, said conducting body being connected directly or inductively to one pole or terminal of the source of current, and a conducting body or bodies in the vicinity of said lighting devices connected to the other pole or terminal of said source, as set forth.

7. In a system of electric lighting, the combination, with a source of currents of enormous frequency of excessively high potential, of lighting devices, each consisting of a conducting body inclosed in a rarefied or exhausted receiver and connected by conductors directly or inductively with one of the terminals of said source, all parts of the con-

ductors intermediate to the said source and the light-giving body being insulated and protected to prevent the dissipation of the electric energy, as herein set forth.

NIKOLA TESLA.

Witnesses:

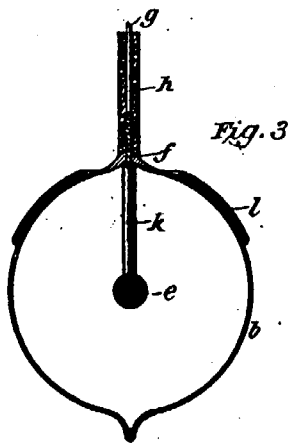
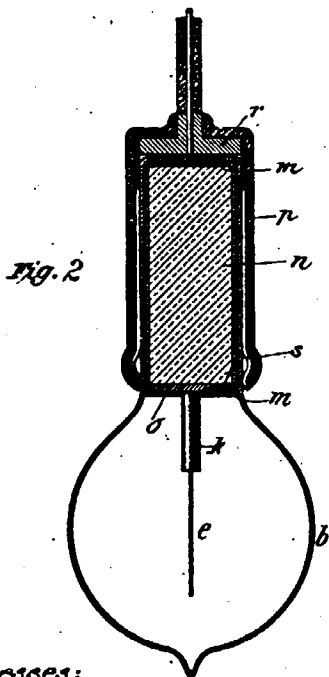
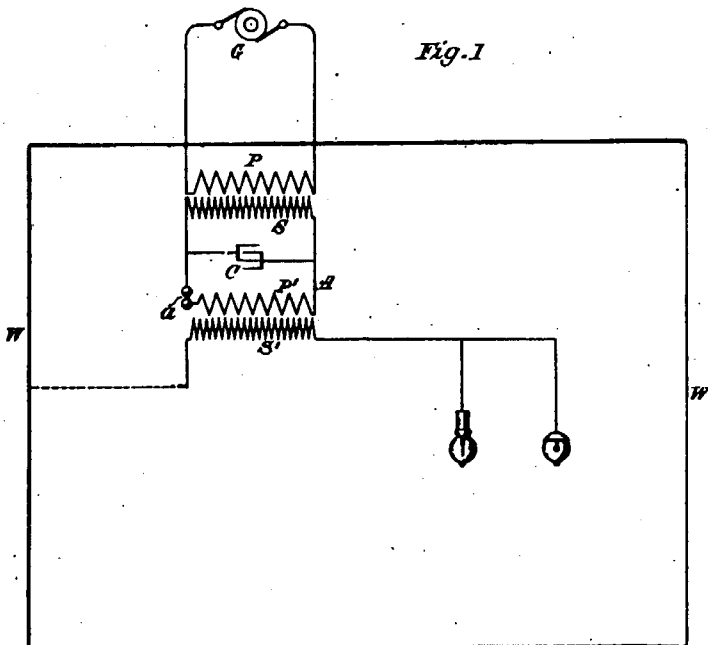
PARKER W. PAGE,
M. G. TRACY.

(No Model.)

N. TESLA.
SYSTEM OF ELECTRIC LIGHTING.

No. 454,622.

Patented June 23, 1891.



Witnesses:

Raphael Netter

Ernest Hopkinson

Inventor

Nikola Tesla

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Attorneys.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

METHOD OF AND APPARATUS FOR ELECTRICAL CONVERSION AND DISTRIBUTION.

SPECIFICATION forming part of Letters Patent No. 462,418, dated November 3, 1891.

Application filed February 4, 1891. Serial No. 380,182. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, 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 Electrical Conversion and Distribution, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

This invention is an improvement in methods of and apparatus for electrical conversion, designed for the better and more economical distribution and application of electrical energy for general useful purposes.

My invention is based on certain electrical phenomena which have been observed by eminent scientists and recognized as due to laws which have been in a measure demonstrated, but which, so far as I am aware, have not hitherto been utilized or applied with any practically useful results. Stated briefly, these phenomena are as follows: First, if a condenser or conductor possessing capacity be charged from a suitable generator and discharged through a circuit, the discharge under certain conditions will be of an intermittent or oscillatory character; second, if two points in an electric circuit through which a current rapidly rising and falling in strength is made to flow be connected with the plates or armatures of a condenser, a variation in the current's strength in the entire circuit or in a portion of the same only may be produced; third, the amount or character of such variation in the current's strength is dependent upon the condenser capacity, the self-induction and resistance of the circuit or its sections, and the period or time rate of change of the current. It may be observed, however, that these several factors—the capacity, the self-induction, resistance, and period—are all related in a manner well understood by electricians; but to render such conversion as may be effected by condensers practically available and useful it is desirable, chiefly on account of the increased output and efficiency and reduced cost of the apparatus, to produce current-impulses succeeding each other with very great rapidity, or, in other words, to render the duration of

each impulse, alternation, or oscillation of the current extremely small. To the many difficulties in the way of effecting this mechanically, as by means of rotating switches or interrupters, is perhaps due the failure to realize practically, at least to any marked degree, the advantages of which such a system is capable. To obviate these difficulties, I have in my present invention taken advantage of the fact above referred to, and which has been long recognized, that if a condenser or a conductor possessing capacity be charged from a suitable source and be discharged through a circuit the discharge under certain conditions, dependent on the capacity of the condenser or conductor, the self-induction and resistance of the discharging circuit, and the rate of supply and decay of the electrical energy, may be effected intermittently or in the form of oscillations of extremely small period.

Briefly stated in general terms, the plan which I pursue in carrying out my invention is as follows:

I employ a generator, preferably, of very high tension and capable of yielding either direct or alternating currents. This generator I connect up with a condenser or conductor of some capacity and discharge the accumulated electrical energy disruptively through an air-space or otherwise into a working circuit containing translating devices and, when required, condensers. These discharges may be of the same direction or alternating and intermittent, succeeding each other more or less rapidly or oscillating to and fro with extreme rapidity. In the working circuit, by reason of the condenser action, the current impulses or discharges of high tension and small volume are converted into currents of lower tension and greater volume. The production and application of a current of such rapid oscillations or alternations (the number may be many millions per second) secures, among others, the following exceptional advantages: First, the capacity of the condensers for a given output is much diminished; second, the efficiency of the condensers is increased and the tendency to become heated reduced, and, third, the range of conversion is enlarged. I have thus succeeded in producing a system or method of conversion

radically different from what has been done heretofore—first, with respect to the number of impulses, alternations, or oscillations of current per unit of time, and, second, with respect to the manner in which the impulses are obtained. To express this result, I define the working current as one of an excessively small period or of an excessively large number of impulses or alternations or oscillations per unit of time, by which I mean not a thousand or even twenty or thirty thousand per second, but many times that number, and one which is made intermittent, alternating, or oscillating of itself without the employment of mechanical devices.

I now proceed to an explanation somewhat more in detail of the nature of my invention, referring to the accompanying drawings.

The two figures are diagrams, each representing a generating-circuit, a working circuit, means for producing an intermittent or oscillating discharge, and condensers arranged or combined as contemplated by my invention.

In Figure 1, A represents a generator of high tension; B B, the conductors which lead out from the same. To these conductors are connected the conductors C of a working circuit containing translating devices, such as incandescent lamps or motors G. In one or both conductors B is a break D, the two ends being separated by an air-space or a film of insulation, through which a disruptive discharge takes place. F is a condenser, the plates of which are connected to the generating-circuit. If this circuit possess itself sufficient capacity, the condenser F may be dispensed with.

In Fig. 2 the generating-circuit B B contains a condenser F and discharges through the air-gaps D into the working circuit C, to any two points of which is connected a condenser E. The condenser E is used to modify the current in any part of the working circuit, such as L.

It may conduce to a better understanding of the invention to consider more in detail the conditions existing in such a system as is illustrated in Fig. 1. Let it be assumed, therefore, that in the system there shown the rate of supply of the electrical energy, the capacity, self-induction, and the resistance of the circuits are so related that a disruptive, intermittent, or oscillating discharge occurs at D. Assume that the first-named takes place. This will evidently occur when the rate of supply from the generator is not adequate to the capacity of the generator, conductors B B, and condenser F. Each time the condenser F is charged to such an extent that the potential or accumulated charge overcomes the dielectric strength of the insulating-space at D the condenser is discharged. It is then recharged from the generator A, and this process is repeated in more or less rapid succession. The discharges will follow each other the more rapidly the more nearly the rate of supply from the generator equals the

rate at which the circuit including the generator is capable of taking up and getting rid of the energy. Since the resistance and self-induction of the working circuit C and the rapidity of the successive discharges may be varied at will, the current strength in the working and generating circuit may bear to one another any desired relation.

To understand the action of the local condenser E in Fig. 2, let a single discharge be first considered. This discharge has two paths offered—one to the condenser E, the other through the part L of the working circuit C. The part L, however, by virtue of its self-induction, offers a strong opposition to such a sudden discharge, while the condenser, on the other hand, offers no such opposition. The result is that practically no current passes at first through the branch L, but presumably opposite electricities rush to the condenser-coatings, this storing for the moment electrical energy in the condenser. Time is gained by this means, and the condenser then discharges through the branch L, this process being repeated for each discharge occurring at D. The amount of electrical energy stored in the condenser at each charge is dependent upon the capacity of the condenser and the potential of its plates. It is evident, therefore, that the quicker the discharges succeed each other the smaller for a given output need be the capacity of the condenser and the greater is also the efficiency of the condenser. This is confirmed by practical results.

The discharges occurring at D, as stated, may be of the same direction or may be alternating, and in the former case the devices contained in the working circuit may be traversed by currents of the same or alternately opposite direction. It may be observed, however, that each intermittent discharge occurring at D may consist of a number of oscillations in the working circuit or branch L.

A periodically-oscillating discharge will occur at D in Fig. 1 when the quantities concerned bear a certain relation expressed in well-known formulae and ascertained by simple experiment. In this case it is demonstrated in theory and practice that the ratio of the strength of the current in the working to that in the generating circuits is the greater the greater the self-induction, and the smaller the resistance of the working circuit the smaller the period of oscillation.

I do not limit myself to the use of any specific forms of the apparatus described in connection with this invention nor to the precise arrangement of the system with respect to its details herein shown. In the drawings return-wires are shown in the circuit; but it will be understood that in any case the ground may be conveniently used in lieu of the return-wire.

What I claim is—

1. The method of electrical conversion here-in described, which consists in charging a con-

denser or conductor possessing capacity and
maintaining a succession of intermittent or
oscillating disruptive discharges of said con-
ductor into a working circuit containing
5 translating devices.

2. In a system of electrical conversion, the
combination of a generator or source of elec-
tricity and a line or generating circuit con-
taining a condenser or possessing capacity,
10 and a working circuit operatively connected
with the generating-circuit through one or

more air-gaps or breaks in the conducting
medium, the electrical conditions being so ad-
justed that an intermittent or oscillating dis-
ruptive discharge from the generating into 15
the working circuit will be maintained, as set
forth.

NIKOLA TESLA.

Witnesses:

ROBT. F. GAYLORD,
PARKER W. PAGE.

(No Model.)

N. TESLA.

METHOD OF AND APPARATUS FOR ELECTRICAL CONVERSION AND DISTRIBUTION.

No. 462,418.

Patented Nov. 3, 1891.

Fig. 1

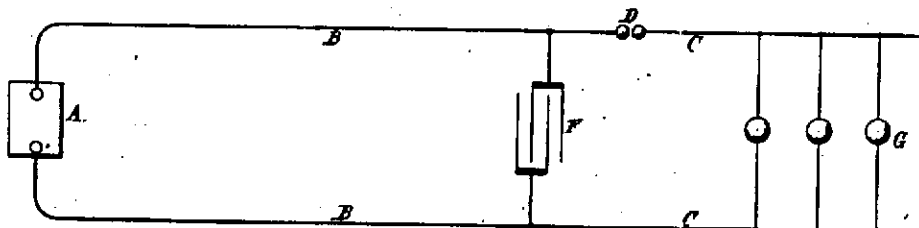
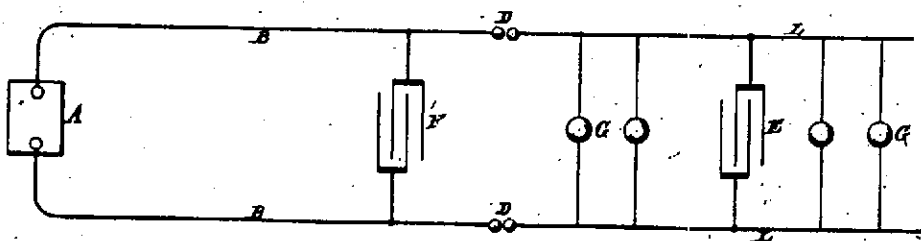


Fig. 2



Witnesses:

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Frank O. Murphy.

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Nikola Tesla
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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

ELECTRO-MAGNETIC MOTOR.

SPECIFICATION forming part of Letters Patent No. 464,666, dated December 8, 1891.

Application filed July 13, 1891. Serial No. 399,312. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electro-Magnetic Motors, of which the following is a specification, reference being had to the drawing accompanying and forming a part of the same.

The general object of my present invention is to secure artificially a difference of a quarter of a phase between the currents in the two energizing-circuits of an alternating-current electro-magnetic motor of that general class invented by me, in which the action or operation is dependent upon the inductive influence upon a rotating armature of independent field magnets or coils exerted successively and not simultaneously.

It is a well-known fact that if the field or energizing circuits of such a motor be both derived from the same source of alternating currents and a condenser of proper capacity be included in one of the same, approximately the desired difference of phase may be obtained between the currents flowing directly from the source and those flowing through the condenser; but the great size and expense of condensers for this purpose that would meet the requirements of the ordinary systems of comparatively low potential are practically prohibitory to their employment.

Another now well-known method or plan of securing a difference of phase between the energizing-currents of motors of this kind is to induce by the currents in one circuit those in the other circuit or circuits; but no means have heretofore been proposed that would secure in this way between the phases of the primary or inducing and the secondary or induced currents that difference—theoretically ninety degrees—that is best adapted for practical and economical working.

I have devised a means which renders practicable both the above-described plans or methods, and by which I am enabled to obtain an economical and efficient alternating-current motor, my invention consisting in placing a condenser in the secondary or induced circuit of the motor above described and raising the potential of the secondary currents to such a

degree that the capacity of the condenser, which is in part dependent on the potential, need be quite small. The value of this condenser will be determined in a well-understood manner with reference to the self-induction and other conditions of the circuit, so as to cause the currents which pass through it to differ from the primary currents by a quarter-phase.

The drawing is a partly-diagrammatic illustration of a motor embodying my invention.

I have illustrated the invention as embodied in a motor in which the inductive relation of the primary and secondary circuits is secured by winding them inside the motor partly upon the same cores; but it will be understood that the invention applies, generally, to other forms of motor in which one of the energizing-currents is induced in any way from the other.

Let A B represent the poles of an alternating-current motor, of which C is the armature wound with coils D, closed upon themselves, as is now the general practice in motors of this kind. The poles A, which alternate with poles B, are wound with coils of ordinary or coarse wire E in such direction as to make them of alternate north and south polarity, as indicated in the diagram by the characters N S. Over these coils or in other inductive relation to the same are wound long fine-wire coils F F and in the same direction throughout as the coils E. These coils are secondaries, in which currents of very high potential are induced. I prefer to connect all the coils E in one series and all the secondaries F in another.

On the intermediate poles B are wound fine-wire energizing-coils G, which are connected in series with one another and also with the series of secondary coils F, the direction of winding being such that a current-impulse induced from the primary coils E imparts the same magnetism to the poles B as that produced in poles A by the primary impulse. This condition is indicated by the characters N' S'.

In the circuit formed by the two sets of coils F and G is introduced a condenser H; otherwise the said circuit is closed upon itself, while the free ends of the circuit of coils E are connected to a source of alternating cur-

rents. As the condenser capacity which is needed in any particular motor of this kind is dependent upon the rate of alternation or the potential, or both, its size or cost, as before explained, may be brought within economical limits for use with the ordinary circuits if the potential of the secondary circuit in the motor be sufficiently high. By giving to the condenser proper values any desired difference of phase between the primary and secondary energizing-circuits may be obtained.

What I claim is—

1. In an alternating-current motor provided with two or more energizing or field circuits, one of which is adapted for connection with a source of currents and the other or others

in inductive relation thereto, the combination, with the secondary or induced circuit or circuits, of a condenser interposed in the same, as set forth. 20

2. In an alternating-current motor, the combination of two energizing-circuits, one connected or adapted for connection with a source of alternating currents, the other constituting a high-potential secondary circuit in inductive relation to the first, and a condenser interposed in said secondary circuit, as set forth. 25

NIKOLA TESLA.

Witnesses:

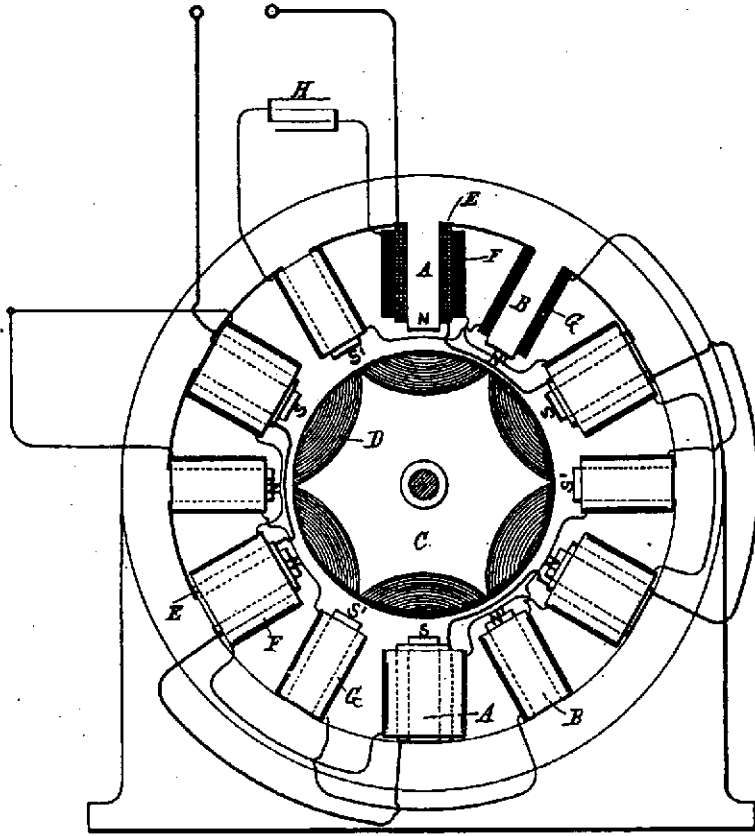
ROBT. F. GAYLORD,
ERNEST HOPKINSON.

(No Model.)

N. TESLA.
ELECTRO MAGNETIC MOTOR.

No. 464,666.

Patented Dec. 8, 1891.



Witnesses:

Raphael Netter
Frank B. Murphy

Inventor

Nikola Tesla
by
Duncan & Page
Attorneys

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

ELECTRIC GENERATOR.

SPECIFICATION forming part of Letters Patent No. 511,916, dated January 2, 1894.

Application filed August 19, 1888. Serial No. 483,562. (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 Generators, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

In an application of even date herewith, Serial No. 483,563, I have shown and described a form of engine invented by me, which, under the influence of an applied force such as the elastic tension of steam or a gas under pressure, yields an oscillation of constant period.

In order that my present invention may be more readily understood I will explain the conditions which are to be observed in order to secure this result.

It is a well known mechanical principle that if a spring possessing a sensible inertia be brought under tension, as by being stretched, and then freed, it will perform vibrations which are isochronous, and as to period, in the main, dependent upon the rigidity of the spring, and its own inertia or that of the system of which it may form an immediate part. This is known to be true in all cases where the force which tends to bring the spring or movable system into a given position is proportionate to the displacement.

In the construction of my engine above referred to I have followed and applied this principle, that is to say, I employ a cylinder and a piston which in any suitable manner I maintain in reciprocation by steam or gas under pressure. To the moving piston or to the cylinder, in case the latter reciprocate and the piston remain stationary, a spring is connected so as to be maintained in vibration thereby, and whatever may be the inertia of the piston or of the moving system and the rigidity of the spring relatively to each other, provided, the practical limits within which the law holds true that the forces which tend to bring the moving system to a given position are proportionate to the displacement, are not exceeded, the impulses of the power impelled piston and the natural vibrations of the spring will always correspond in direction and coincide in time. In the case of the engine referred

to, the ports are so arranged that the movement of the piston within the cylinder in either direction ceases when the force tending to impel it and the momentum which it has acquired are counterbalanced by the increasing pressure of the steam or compressed air in that end of the cylinder toward which it is moving, and as in its movement the piston has shut off at a given point, the pressure that impelled it and established the pressure that tends to return it, it is then impelled in the opposite direction, and this action is continued as long as the requisite pressure is applied. The length of the stroke will vary with the pressure, but the rate or period of reciprocation is no more dependent upon the pressure applied to drive the piston, than would be the period of oscillation of a pendulum permanently maintained in vibration, upon the force which periodically impels it, the effect of variations in such force being merely to produce corresponding variations in the length of stroke or amplitude of vibration respectively.

In practice I have found that the best results are secured by the employment of an air spring, that is, a body of confined air or gas which is compressed and rarefied by the movements of the piston, and in order to secure a spring of constant rigidity I prefer to employ a separate chamber or cylinder containing air at the normal atmospheric pressure, although it might be at any other pressure, and in which works a plunger connected with or carried by the piston rod. The main reason why no engine heretofore has been capable of producing results of this nature is that it has been customary to connect with the reciprocating parts a heavy fly-wheel or some equivalent rotary system of relatively very great inertia, or in other cases where no rotary system was employed, as in certain reciprocating engines or tools, no regard has been paid to the obtainment of the conditions essential to the end which I have in view, nor would the pressure of such conditions in said devices appear to result in any special advantage.

Such an engine as I have described affords a means for accomplishing a result heretofore unattained, the continued production of electric currents of constant period, by imparting the movements of the piston to a core or

coil in a magnetic field. It should be stated however, that in applying the engine for this purpose certain conditions are encountered which should be taken into consideration in order to satisfactorily secure the desired result. When a conductor is moved in a magnetic field and a current caused to circulate therein, the electro-magnetic reaction between it and the field, might disturb the mechanical oscillation to such an extent as to throw it out of isochronism. This, for instance, might occur when the electro-magnetic reaction is very great in comparison to the power of the engine, and there is a retardation of the current so that the electro-magnetic reaction might have an effect similar to that which would result from a variation of the tension of the spring, but if the circuit of the generator be so adjusted that the phases of the electromotive force and current coincide in time, that is to say, when the current is not retarded, then the generator driven by the engine acts merely as a frictional resistance and will not, as a rule, alter the period of the mechanical vibration, although it may vary its amplitude. This condition may be readily secured by properly proportioning the self induction and capacity of the circuit including the generator. I have, however, observed the further fact in connection with the use of such engines as a means for running a generator, that it is advantageous that the period of the engine and the natural period of electrical vibration of the generator should be the same, as in such case the best conditions for electrical resonance are established and the possibility of disturbing the period of mechanical vibrations is reduced to a minimum. I have found that even if the theoretical conditions necessary for maintaining a constant period in the engine itself are not exactly maintained, still the engine and generator combined will vibrate at a constant period. For example, if instead of using in the engine an independent cylinder and plunger, as an air spring of practically constant rigidity, I cause the piston to impinge upon air cushions at the ends of its own cylinder, although the rigidity of such cushions or springs might be considerably affected and varied by the variations of pressure within the cylinder, still by combining with such an engine a generator which has a period of its own approximately that of the engine, constant vibration may be maintained even through a considerable range of varying pressure, owing to the controlling action of the electro-magnetic system. I have even found that under certain conditions the influence of the electro-magnetic system may be made so great as to entirely control the period of the mechanical vibration within wide limits of varying pressure. This is likely to occur in those instances where the power of the engine while fully capable of maintaining a vibration once started, is not sufficient to change its rate. So, for the sake of illustration, if a pendulum is started in vibration,

and a small force applied periodically in the proper direction to maintain it in motion, this force would have no substantial control over the period of the oscillation, unless the inertia of the pendulum be small in comparison to the impelling force, and this would be true no matter through what fraction of the period the force may be applied. In the case under consideration the engine is merely an agent for maintaining the vibration once started, although it will be understood that this does not preclude the performance of useful work which would simply result in a shortening of the stroke. My invention, therefore, involves the combination of a piston free to reciprocate under the influence of steam or a gas under pressure and the movable element of an electric generator which is in direct mechanical connection with the piston, and it is more especially the object of my invention to secure from such combination electric currents of a constant period. In the attainment of this object I have found it preferable to construct the engine so that it of itself controls the period, but as I have stated before, I may so modify the elements of the combination that the electro-magnetic system may exert a partial or even complete control of the period.

In illustration of the manner in which the invention is carried out I now refer to the accompanying drawings.

Figure 1 is a central sectional view of an engine and generator embodying the invention. Fig. 2 is a modification of the same.

Referring to Fig. 1 A is the main cylinder in which works a piston B. Inlet ports C C pass through the sides of the cylinder opening at the middle portion thereof and on opposite sides. Exhaust ports D D extend through the walls of the cylinder and are formed with branches that open into the interior of the cylinder on each side of the inlet ports and on opposite sides of the cylinder. The piston B is formed with two circumferential grooves E F which communicate through openings G in the piston with the cylinder on opposite sides of said piston respectively.

The particular construction of the cylinder, the piston and the ports controlling it may be very much varied, and is not in itself material, except that in the special case now under consideration it is desirable that all the ports, and more especially the exhaust ports should be made very much larger than is usually the case so that no force due to the action of the steam or compressed air will tend to retard or affect the return of the piston in either direction. The piston B is secured to a piston rod H which works in suitable stuffing boxes in the heads of the cylinder A. This rod is prolonged on one side and extends through bearings V in a cylinder I suitably mounted or supported in line with the first, and within which is a disk or plunger J carried by the rod H. The cylinder I is without ports of any kind and is air-tight except as a

small leakage may occur through the bearings V, which experience has shown need not be fitted with any very considerable accuracy. The cylinder I is surrounded by a jacket K which leaves an open space or chamber around it. The bearings V in the cylinder I, extend through the jacket K to the outside air and the chamber between the cylinder and jacket is made steam or air-tight as by a suitable packing. The main supply pipe L for steam or compressed air leads into this chamber, and the two pipes that lead to the cylinder A run from the said chamber, oil cups M being conveniently arranged to deliver oil into the said pipes for lubricating the piston. In the particular form of engine shown, the jacket K which contains the cylinder I is provided with a flange N by which it is screwed to the end of the cylinder A. A small chamber O is thus formed which has air vents P in its sides and drip pipes Q leading out from it through which the oil which collects in it is carried off.

To explain now the operation of the engine described, in the position of the parts shown, or when the piston is at the middle point of its stroke, the plunger J is at the center of the cylinder I and the air on both sides of the same is at the normal pressure of the outside atmosphere. If a source of steam or compressed air be then connected to the inlet ports C C of the cylinder A and a movement be imparted to the piston as by a sudden blow, the latter is caused to reciprocate in a manner well understood. The movements of the piston compress and rarefy the air in the cylinder I at opposite ends of the same alternately. A forward stroke compresses the air ahead of the plunger J which acts as a spring to return it. Similarly on the back stroke the air is compressed on the opposite side of the plunger J and tends to drive it forward. The compressions of the air in the cylinder I and the consequent loss of energy due mainly to the imperfect elasticity of the air, give rise to a very considerable amount of heat. This heat I utilize by conducting the steam or compressed air to the engine cylinder through the chamber formed by the jacket surrounding the air-spring cylinder. The heat thus taken up and used to raise the temperature of the steam or air acting upon the piston is availed of to increase the efficiency of the engine. In any given engine of this kind the normal pressure will produce a stroke of determined length, and this will be increased or diminished according to the increase of pressure above or the reduction of pressure below the normal.

In constructing the apparatus proper allowance is made for a variation in the length of stroke by giving to the confining cylinder I of the air spring properly determined dimensions. The greater the pressure upon the piston, the higher the degree of compression of the air-spring, and the consequent counteracting force upon the plunger. The rate

or period of reciprocation of the piston, however, is mainly determined as described above by the rigidity of the air spring and the inertia of the moving system, and any period of oscillation within very wide limits may be secured by properly portioning these factors, as by varying the dimensions of the air chamber which is equivalent to varying the rigidity of the spring, or by adjusting the weight of the moving parts. These conditions are all readily determinable, and an engine constructed as herein described may be made to follow the principle of operation above stated and maintain a perfectly uniform period through very wide limits of pressure.

The pressure of the air confined in the cylinder when the plunger I is in its central position will always be practically that of the surrounding atmosphere, for while the cylinder is so constructed as not to permit such sudden escape of air as to sensibly impair or modify the action of the air spring there will still be a slow leakage of air into or out of it around the piston rod according to the pressure therein, so that the pressure of the air on opposite sides of the plunger will always tend to remain at that of the outside atmosphere.

To the piston rod H is secured a conductor or coil of wire D' which by the movements of the piston is oscillated in the magnetic field produced by two magnets B' B' which may be permanent magnets or energized by coils C' C' connected with a source of continuous currents E'. The movement of the coil D' across the lines of force established by the magnets gives rise to alternating currents in the coil. These currents, if the period of mechanical oscillation be constant will be of constant period, and may be utilized for any purpose desired.

In the case under consideration it is assumed as a necessary condition that the inertia of the movable element of the generator and the electro-magnetic reaction which it exerts will not be of such character as to materially disturb the action of the engine.

Fig. 2 is an example of a combination in which the engine is not of itself capable of determining entirely the period of oscillation, but in which the generator contributes to this end. In this figure the engine is the same as in Fig. 1. The exterior air spring is however omitted and the air spaces at the ends of the cylinder A relied on for accomplishing the same purpose. As the pressure in these spaces is liable to variations from variations in the steam or gas used in impelling the piston they might affect the period of oscillation, and the conditions are not as stable and certain as in the case of an engine constructed as in Fig. 1. But if the natural period of vibration of the elastic system be made to approximately accord with the average period of the engine such tendencies to variation are very largely overcome and the engine will preserve its period even through a considerable range of variations of pressure. The

generator in this case is composed of a magnetic casing F' in which a laminated core G' secured to the piston rod H is caused to vibrate. Surrounding the plunger are two exciting coils C' C', and one or more induced coils D' D'. The coils C' C' are connected with a generator of continuous currents E' and are wound to produce consequent poles in the core G'. Any movement of the latter will therefore shift the lines of force through coils D' D' and produce currents therein.

In the circuit of coils D' is shown a condenser H'. It need only be said that by the use of a proper condenser the self induction of this circuit may be neutralized. Such a circuit will have a certain natural period of vibration, that is to say that when the electricity therein is disturbed in any way an electrical or electro-magnetic vibration of a certain period takes place, and as this depends upon the capacity and self induction, such period may be varied to approximately accord with the period of the engine.

In case the power of the engine be comparatively small, as when the pressure is applied through a very small fraction of the total stroke, the electrical vibration will tend to control the period, and it is clear that if the character of such vibration be not very widely different from the average period of vibration of the engine under ordinary working conditions such control may be entirely adequate to produce the desired results.

Having now described my invention, what I claim is—

1. The combination with the piston or equivalent element of an engine which is free to reciprocate under the action thereon of steam or a gas under pressure, of the moving conductor or element of an electric generator in direct mechanical connection therewith.

2. The combination with the piston or equivalent element of an engine which is free to reciprocate under the action of steam or a gas

under pressure, of the moving conductor or element of an electric generator in direct mechanical connection therewith, the engine and generator being adapted by their relative adjustment with respect to period to produce currents of constant period, as set forth.

3. The combination with an engine comprising a piston which is free to reciprocate under the action of steam or a gas under pressure, and an electric generator having inducing and induced elements one of which is capable of oscillation in the field of force, the said movable element being carried by the piston rod of the engine, as set forth.

4. The combination with an engine operated by steam or a gas under pressure and having a constant period of reciprocation, of an electric generator, the moving element of which is carried by the reciprocating part of the engine, the generator and its circuit being so related to the engine with respect to the period of electrical vibration as not to disturb the period of the engine, as set forth.

5. The combination with a cylinder and a piston reciprocated by steam or a gas under pressure of a spring maintained in vibration by the movement of the piston, and an electric generator, the movable conductor or element of which is connected with the piston, these elements being constructed and adapted in the manner set forth for producing a current of constant period.

6. The method of producing electric currents of constant period herein described which consists in imparting the oscillations of an engine to the moving element of an electric generator and regulating the period of mechanical oscillation by an adjustment of the reaction of the electric generator, as herein set forth.

NIKOLA TESLA.

Witnesses:

PARKER W. PAGE,
R. F. GAYLORD.

N. TESLA.
ELECTRIC GENERATOR.

No. 511,916.

Patented Jan. 2, 1894.

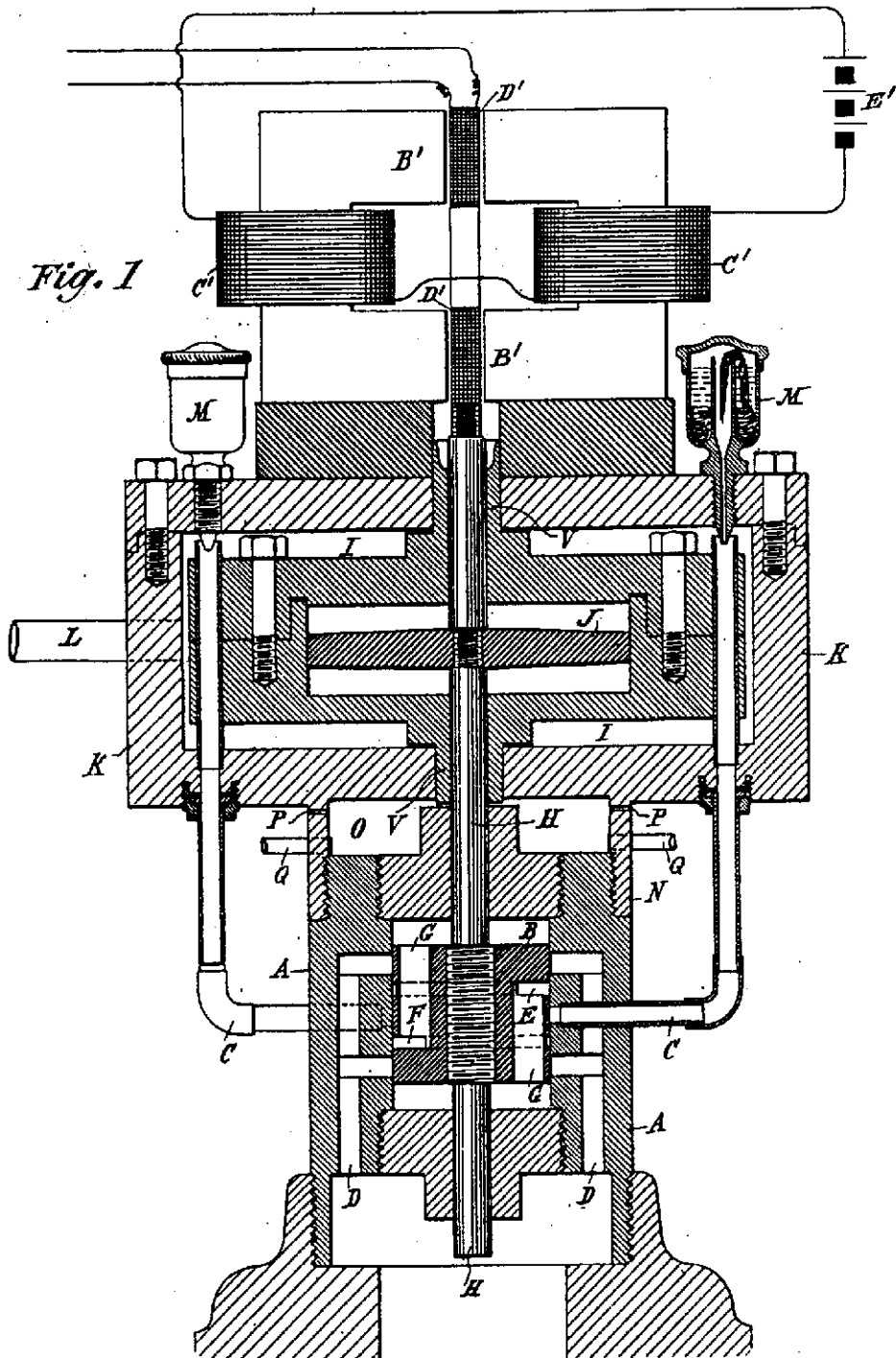


Fig. 1

Witnesses
Raphael Neter
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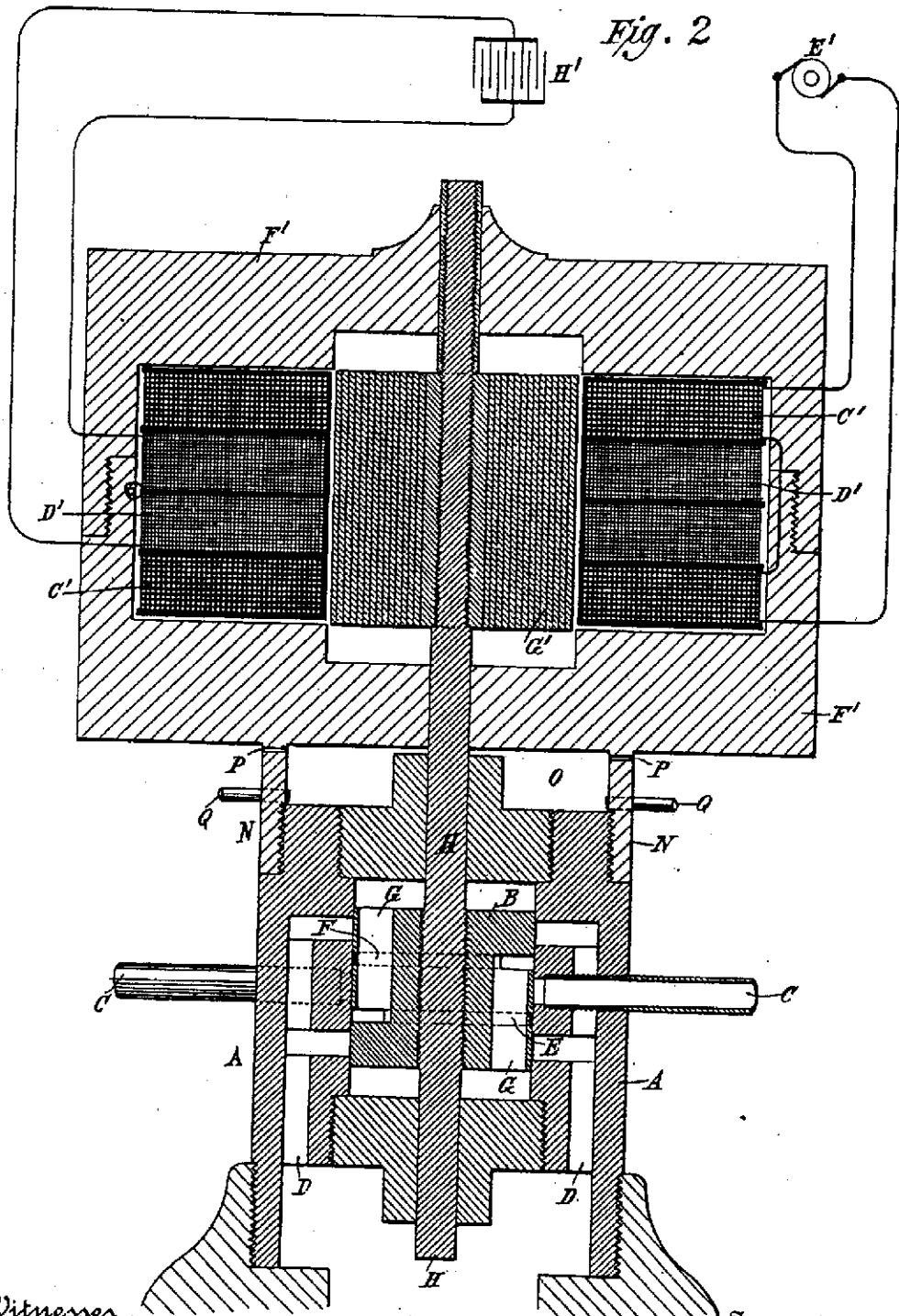
Inventor
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By his Attorneys
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N. TESLA. ELECTRIC GENERATOR.

No. 511,916.

Patented Jan. 2, 1894.

Fig. 2



Witnesses
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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

COIL FOR ELECTRO-MAGNETS.

SPECIFICATION forming part of Letters Patent No. 512,340, dated January 9, 1894.

Application filed July 7, 1893. Serial No. 479,804. (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 Coils for Electro-Magnets and other Apparatus, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

In electric apparatus or systems in which alternating currents are employed the self-induction of the coils or conductors may, and, in fact, in many cases does operate disadvantageously by giving rise to false currents which often reduce what is known as the commercial efficiency of the apparatus composing the system or operate detrimentally in other respects. The effects of self-induction, above referred to, are known to be neutralized by proportioning to a proper degree the capacity of the circuit with relation to the self-induction and frequency of the currents. This has been accomplished heretofore by the use of condensers constructed and applied as separate instruments.

My present invention has for its object to avoid the employment of condensers which are expensive, cumbersome and difficult to maintain in perfect condition, and to so construct the coils themselves as to accomplish the same ultimate object.

I would here state that by the term coils I desire to include generally helices, solenoids, or, in fact, any conductor the different parts of which by the requirements of its application or use are brought into such relations with each other as to materially increase the self-induction.

I have found that in every coil there exists a certain relation between its self-induction and capacity that permits a current of given frequency and potential to pass through it with no other opposition than that of ohmic resistance, or, in other words, as though it possessed no self-induction. This is due to the mutual relations existing between the special character of the current and the self-induction and capacity of the coil, the latter quantity being just capable of neutralizing the self-induction for that frequency. It is well-known that the higher the frequency or potential difference of the current the smaller

the capacity required to counteract the self-induction; hence, in any coil, however small the capacity, it may be sufficient for the purpose stated if the proper conditions in other respects be secured. In the ordinary coils the difference of potential between adjacent turns or spires is very small, so that while they are in a sense condensers, they possess but very small capacity and the relations between the two quantities, self-induction and capacity, are not such as under any ordinary conditions satisfy the requirements herein contemplated, because the capacity relatively to the self-induction is very small.

In order to attain my object and to properly increase the capacity of any given coil, I wind it in such way as to secure a greater difference of potential between its adjacent turns or convolutions, and since the energy stored in the coil—considering the latter as a condenser, is proportionate to the square of the potential difference between its adjacent convolutions, it is evident that I may in this way secure by a proper disposition of these convolutions a greatly increased capacity for a given increase in potential difference between the turns.

I have illustrated diagrammatically in the accompanying drawings the general nature of the plan which I adopt for carrying out this invention.

Figure 1 is a diagram of a coil wound in the ordinary manner. Fig. 2 is a diagram of a winding designed to secure the objects of my invention.

Let A, Fig. 1, designate any given coil the spires or convolutions of which are wound upon and insulated from each other. Let it be assumed that the terminals of this coil show a potential difference of one hundred volts, and that there are one thousand convolutions; then considering any two contiguous points on adjacent convolutions let it be assumed that there will exist between them a potential difference of one-tenth of a volt. If now, as shown in Fig. 2, a conductor B be wound parallel with the conductor A and insulated from it, and the end of A be connected with the starting point of B, the aggregate length of the two conductors being such that the assumed number of convolutions or turns is the same, viz., one thousand, then the po-

tential difference between any two adjacent points in A and B will be fifty volts, and as the capacity effect is proportionate to the square of this difference, the energy stored in the coil as a whole will now be two hundred and fifty thousand as great. Following out this principle, I may wind any given coil either in whole or in part, not only in the specific manuer herein illustrated, but in a great variety of ways, well-known in the art, so as to secure between adjacent convolutions such potential difference as will give the proper capacity to neutralize the self-induction for any given current that may be employed. Capacity secured in this particular way possesses an additional advantage in that it is evenly distributed, a consideration of the greatest importance in many cases, and the results, both as to efficiency and economy, are the more readily and easily obtained as the size of the coils, the potential difference, or frequency of the currents are increased.

Coils composed of independent strands or conductors wound side by side and connected in series are not in themselves new, and I do not regard a more detailed description of the same as necessary. But heretofore, so far as I am aware, the objects in view have been essentially different from mine, and the results

which I obtain even if an incident to such forms of winding have not been appreciated or taken advantage of.

In carrying out my invention it is to be observed that certain facts are well understood by those skilled in the art, viz: the relations of capacity, self-induction, and the frequency and potential difference of the current. What capacity, therefore, in any given case it is desirable to obtain and what special winding will secure it, are readily determinable from the other factors which are known.

What I claim as my invention is—

1. A coil for electric apparatus the adjacent convolutions of which form parts of the circuit between which there exists a potential difference sufficient to secure in the coil a capacity capable of neutralizing its self-induction, as hereinbefore described.

2. A coil composed of contiguous or adjacent insulated conductors electrically connected in series and having a potential difference of such value as to give to the coil as a whole, a capacity sufficient to neutralize its self-induction, as set forth.

NIKOLA TESLA.

Witnesses:

ROBT. F. GAYLORD,
PARKER W. PAGE.

(No Model.)

N. TESLA.
COIL FOR ELECTRO MAGNETS.

Patented Jan. 9, 1894.

No. 512,340.

Fig. 1

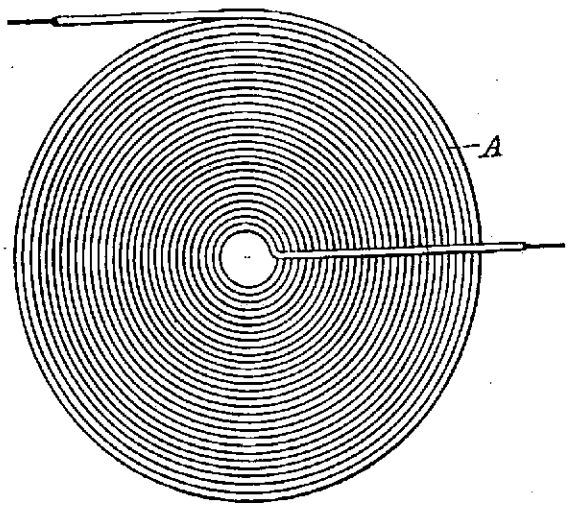
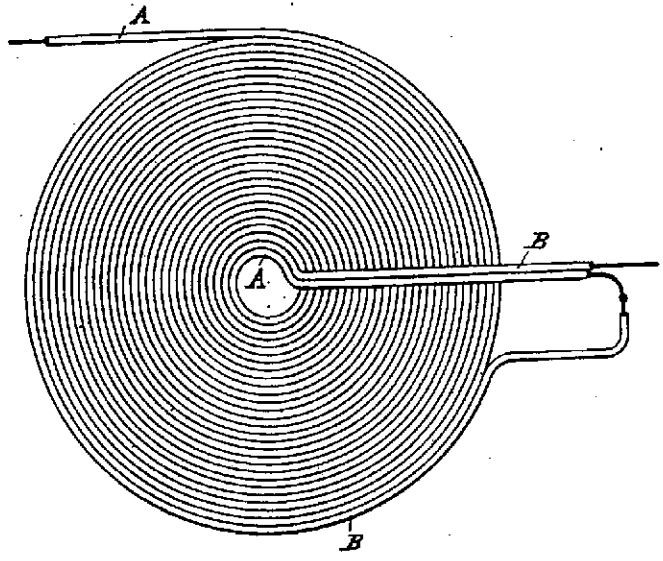


Fig. 2



Witnesses
Raphael Nitter
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By His Attorneys
Duncan & Page

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

APPARATUS FOR PRODUCING ELECTRIC CURRENTS OF HIGH FREQUENCY AND POTENTIAL.

SPECIFICATION forming part of Letters Patent No. 568,176, dated September 22, 1896.

Application filed April 22, 1896. Serial No. 588,534. (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 Apparatus for the Production of Electric Currents of High Frequency and Potential, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

The invention which forms the subject of my present application is embodied in an improvement on an electrical apparatus invented by me and described in prior Letters Patent, notably in United States Patents No. 462,418, dated November 3, 1891, and No. 454,622, dated June 23, 1891. This apparatus was devised for the purpose of converting and supplying electrical energy in a form suited for the production of certain novel electrical phenomena which require currents of higher frequency and potential than can readily or even possibly be developed by generators of the ordinary types or by such mechanical appliances as were theretofore known. The apparatus, as a whole, involves means for utilizing the intermittent or oscillating discharge of the accumulated electrical energy of a condenser or a circuit possessing capacity in what may be designated the "working" circuit, or that which contains the translating devices or those which are operated by such currents.

The object of my present improvements is to provide a simple, compact, and effective apparatus for producing these effects, but adapted more particularly for direct application to and use with existing circuits carrying direct currents, such as the ordinary municipal incandescent-lighting circuits. The way in which I accomplish this, so as to meet the requirements of practical and economical operation under the conditions present, will be understood from a general description of the apparatus which I have devised. In any given circuit, which for present purposes may be considered as conveying direct currents or those of substantially the character of direct or continuous currents and which for general purposes of illustration may be assumed to be a branch or derived circuit across the mains from any ordinary source, I inter-

pose a device or devices in the nature of a choking-coil in order to give to the circuit a high self-induction. I also provide a circuit-controller of any proper character that may be operated to make and break said circuit. Around the break or point of interruption I place a condenser or condensers to store the energy of the discharge-current, and in a local circuit and in series with such condenser I place the primary of a transformer, the secondary of which then becomes the source of the currents of high frequency. It will be apparent from a consideration of the conditions involved that were the condenser to be directly charged by the current from the source and then discharged into the working circuit a very large capacity would ordinarily be required, but by the above arrangement the current of high electromotive force which is induced at each break of the main circuit furnishes the proper current for charging the condenser, which may therefore be small and inexpensive. Moreover, it will be observed that since the self-induction of the circuit through which the condenser discharges, as well as the capacity of the condenser itself, may be given practically any desired value, the frequency of the discharge-current may be adjusted at will.

The object sought in this invention may be realized by specifically different arrangements of apparatus, but in the drawings hereto annexed I have illustrated forms which are typical of the best and most practicable means for carrying out the invention of which I am at present aware.

Figure 1 is a diagrammatic illustration of the apparatus, and Fig. 2 a modification of the same.

Referring to Fig. 1, A designates any source of direct current. In any branch of the circuit from said source, such, for example, as would be formed by the conductors A' A' from the mains A' and the conductors K K, are placed self-induction or choking coils B B and a circuit-controller C. This latter may be an ordinary metallic disk or cylinder with teeth or separated segments D D E E, of which one or more pairs, as E E, diametrically opposite, are integral or in electrical contact with the body of the cylinder, so that when the controller is in the position in which the

two brushes F F bear upon two of said segments E E the circuit through the choking-coils B will be closed. The segments D D are insulated, and while shown in the drawings as of substantially the same length of arc as the segments E E this latter relation may be varied at will to regulate the periods of charging and discharging.

The controller C is designed to be rotated by any proper device, such, for example, as an electromagnetic motor, as shown in Fig. 2, receiving current either from the main source or elsewhere. Around the controller C, or in general in parallel therewith, is a condenser H, and in series with the latter the primary K of a transformer, the secondary L of which constitutes the source of the currents of high frequency which may be applied to many useful purposes, as for electric illumination, the operation of Crooke's tubes, or the production of high vacua.

I' indicates the circuit from the secondary, which may be regarded as the working circuit.

A more convenient and simplified arrangement of the apparatus is shown in Fig. 2. In this case the small motor G, which drives the controller, has its field-coils in derivation to the main circuit, and the controller C and condenser H are in parallel in the field-circuit between the two coils. In such case the field-coils M take the place of the choking-coils B. In this arrangement, and in fact generally, it is preferable to use two condensers or a condenser in two parts and to arrange the primary coil of the transformer between them. The interruptions of the field-circuit of the motor should be so rapid as to permit only a partial demagnetization of the cores. These latter, however, should in this specific arrangement be laminated.

The apparatus, as will now be seen, comprises, as essential elements, choking-coils, a circuit-controller, means for rotating the same, a condenser, and a transformer. These elements may be mechanically associated in any convenient and compact form, but so far as their general arrangement and relations are concerned I prefer the relative disposition illustrated, mainly because, by reason of their symmetrical arrangement in the circuit, the liability of injury to the insulation of any of the devices is reduced to a minimum.

I do not mean to imply by the terms employed in describing my improvements that I limit myself to the use of the precise devices commonly designated by such terms.

For instance, the choking-coil as a distinctive device may be wholly dispensed with, provided the circuit in which it must otherwise be placed have a sufficiently high self-induction produced in other ways. So, too, the necessity of a condenser, strictly speaking, is avoided when the circuit itself possesses sufficient capacity to accomplish the desired result.

Having now described my invention and the manner in which the same is or may be carried into practical effect, what I claim is—

1. The apparatus herein described for converting direct currents into currents of high frequency, comprising in combination a circuit of high self-induction, a circuit-controller adapted to make and break such circuit, a condenser into which the said circuit discharges when interrupted, and a transformer through the primary of which the condenser discharges as set forth.

2. The combination of a source of direct current and a circuit therefrom, choking-coils in said circuit, means for making and breaking the circuit through said coils, a condenser around the point of interruption in the said circuit and a transformer having its primary in circuit with the condenser as set forth.

3. The combination with a circuit of high self-induction and means for making and breaking the same, of a condenser around the point of interruption in the said circuit, and a transformer the primary of which is in the condenser-circuit as described.

4. The combination with a circuit of direct current and having a high self-induction, of a circuit-controller for making and breaking said circuit, a motor for driving the controller, a condenser in a circuit connected with the first around the point of interruption therein, and a transformer the primary of which is in circuit with the condenser as set forth.

5. The combination with a circuit of direct current, a controller for making and breaking the same, a motor having its field-magnets in said circuit and driving the said controller, a condenser connected with the circuit around the point of interruption therein and a transformer the primary of which is in circuit with the condenser as set forth.

NIKOLA TESLA.

Witnesses:

EDWIN B. HOPKINSON,
M. LAWSON DYER.

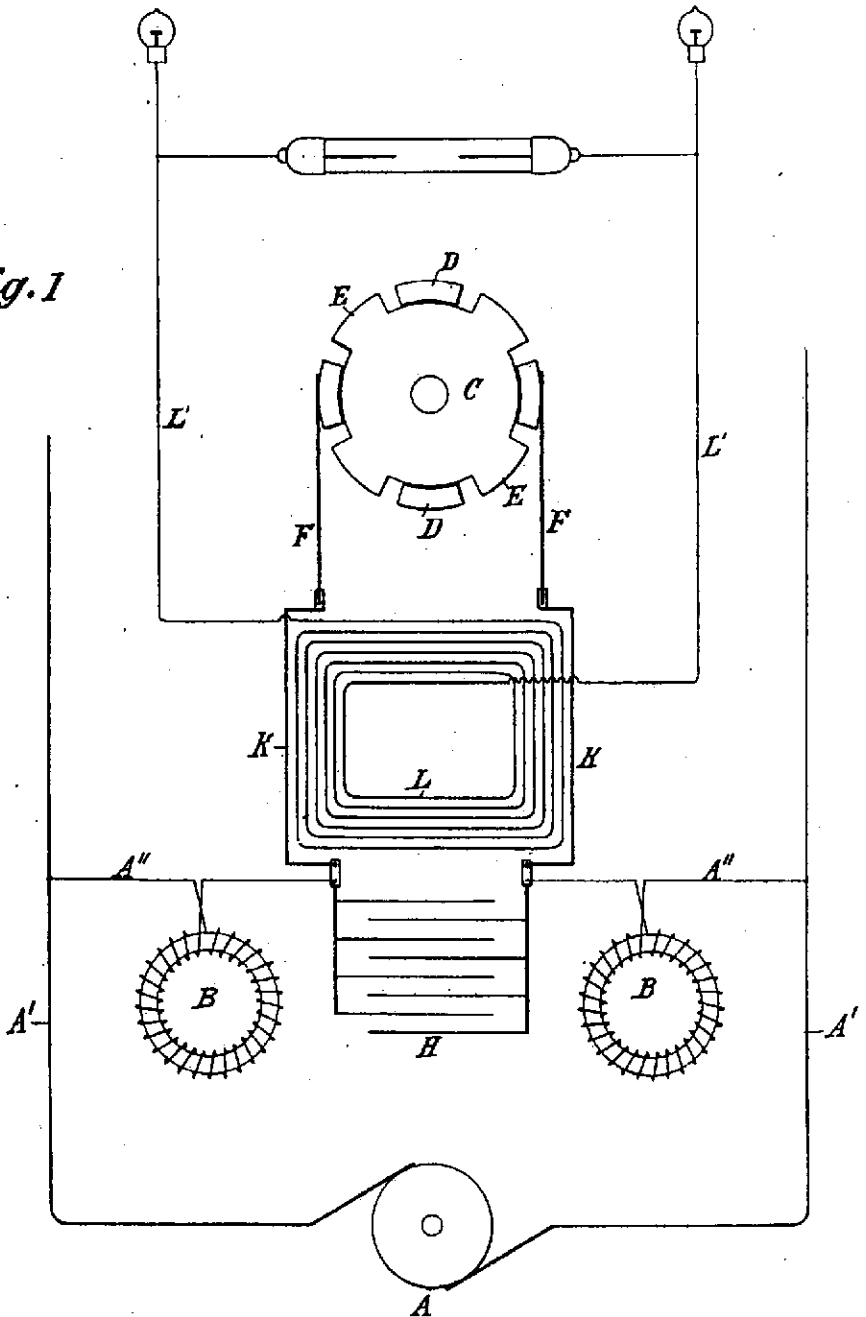
N. TESLA.

APPARATUS FOR PRODUCING ELECTRIC CURRENTS OF HIGH FREQUENCY AND POTENTIAL.

No. 568,176

Patented Sept. 22, 1896.

Fig. 1



Witnesses:
Raphael Ketter
Henry W. Cropper

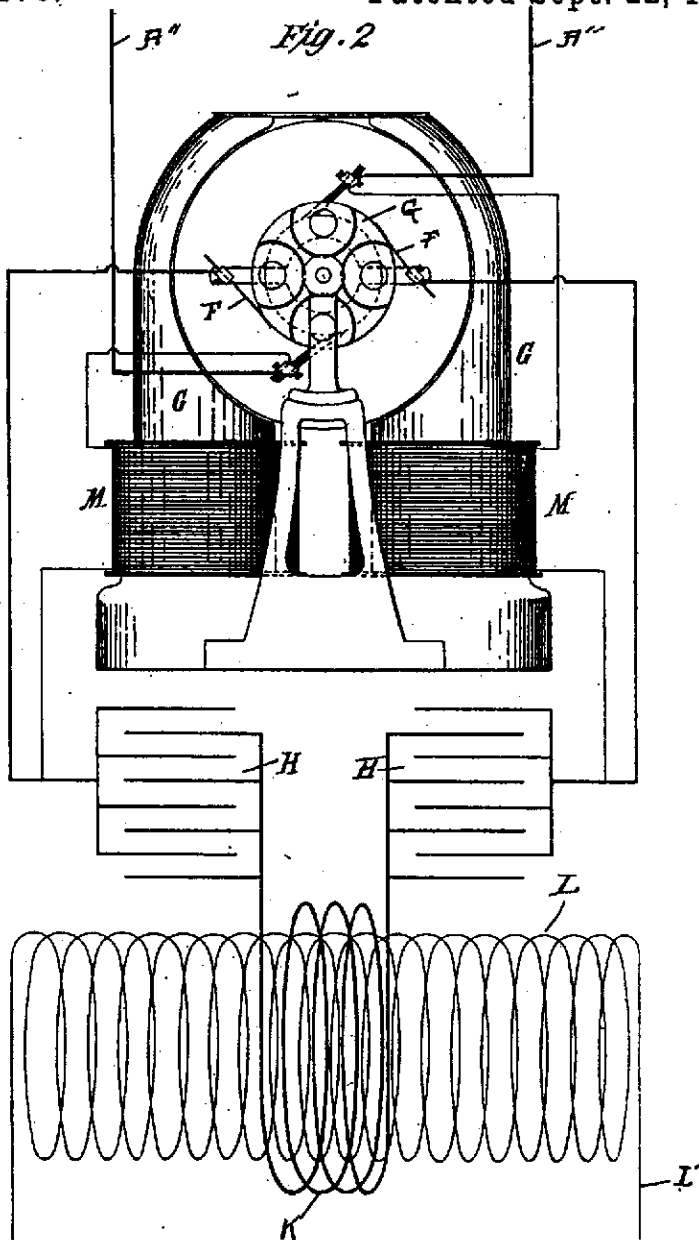
Nikola Tesla, Inventor
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Atty

N. TESLA.

APPARATUS FOR PRODUCING ELECTRIC CURRENTS OF HIGH FREQUENCY AND POTENTIAL.

No. 568,176.

Patented Sept. 22, 1896.



WITNESSES:

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Edwin B. Hopkinson

Nikola Tesla INVENTOR

BY
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ATTORNEYS

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

APPARATUS FOR PRODUCING OZONE.

SPECIFICATION forming part of Letters Patent No. 568,177, dated September 22, 1896.

Application filed June 17, 1896. Serial No. 695,927. (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 Apparatus for Producing Ozone, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

The invention subject of my present application has primarily as its object to provide a simple, cheap, and effective apparatus for the production of ozone or such gases as are obtained by the action of high-tension electrical discharges, although in the application to such purposes of the apparatus heretofore invented by me and designed for the production of electric currents of high frequency and potential I have made certain improvements in such apparatus itself which are novel and useful in other and more general applications of the same. I have heretofore shown and described, notably in Patents No. 462,418, dated November 3, 1891, and No. 454,622, dated June 23, 1891, an apparatus devised for the purpose of converting and supplying electrical energy in a form suited for the production of certain novel electrical phenomena which require currents of higher frequency and potential than can readily or even possibly be developed by generators of the ordinary types or by such mechanical appliances as were theretofore known. This apparatus involved means for utilizing the intermittent or oscillating discharge of the accumulated electrical energy of a condenser or a circuit possessing capacity in what may be designated the "working" circuit or that which contains the translating devices or means for utilizing such currents. In my present improvement I have utilized appliances of this general character under conditions and in combination with certain instrumentalities, hereinafter described, which enable me to produce, without difficulty and at very slight expense, ozone in any desired quantities. I would state the apparatus which I have devised for this purpose is capable of other and highly important uses of a similar nature, but for purposes of the present case I deem it sufficient to describe its operation and ef-

facts when used for the purpose of generating ozone.

In the accompanying drawings, illustrative of the principle of construction and mode of operation of my improvement, Figure 1 is a diagrammatic illustration of the invention; and Fig. 2, a view, partly in side elevation and partly in section, of the apparatus as I construct it for practical use.

The device hereinafter described is especially designed for direct application to and use with existing circuits carrying direct currents, such as the ordinary municipal incandescent-lighting circuits.

Let A B designate the terminals from any given circuit of this character. In such circuit I connect up an electromagnetic motor C in any of the usual ways. That is to say, the coils of the field and armature may be in series or derivation or wholly independent, and either or both are connected up in the circuit. In the present instance one terminal, as B, is connected to one of the binding-posts, from which the circuit is led through one field-coil, D, the brushes and commutator E, the other field-coil, F, and thence to a brush G, which rests upon a circuit-controller H, consisting in general of a conducting disk or cylinder with insulating-sections in its periphery. The other terminal, as A, connects with a second brush K, bearing on the controller, so that the current which passes through and operates the motor is periodically interrupted. For this reason the iron cores of the motor should be laminated. Around the controller is formed a circuit of low self-induction, which includes a condenser L and the primary M of a transformer. The circuit, including the motor is of relatively high self-induction, and this property is imparted to it by the coils of the motor, or, when these are not sufficient, by the addition of suitable choking-coils, so that at each break of the motor-circuit a current of high electromotive force will be developed for charging the condenser, which may therefore be small and inexpensive. The condenser discharges through the circuit which is completed through the brushes G K and the controller H, and since the self-induction of this circuit, as well as the capacity of the con-

denser itself, may be given practically any desired value the frequency of the discharge-current may be adjusted at will. The potential of the high-frequency discharge-current is raised by a secondary coil N in inductive relation to the primary M. The conductors of such secondary circuit are connected to two insulated conducting-plates P, P, and when the apparatus is in operation a discharge in the form of streams will be maintained between such plates, as indicated by the wavy lines in the figures. If air be forced between the plates P during this discharge, the effectiveness of the apparatus is increased and ozone is generated in large quantities. In order to secure this result, I inclose the said plates P P in a casing R of any proper description, through which a current of air is maintained by a fan S, mounted on the shaft of the motor.

This apparatus may be constructed and combined in very compact form and small compass. Its operation involves but a small expenditure of energy, while it requires practically no care or attention for the continued production of ozone in unlimited amount.

What I claim as my invention is—

1. The combination with a circuit of direct currents, of a controller for making and breaking the same, a motor included in or connected with said circuit so as to increase its self-induction, and driving the said controller, a condenser in a circuit around the controller, and a transformer through the primary of which the condenser discharges, as set forth.

2. The combination with a circuit of direct currents, of a controller for making and breaking the same, a series-wound motor having its coils included in said circuit and driving the said controller, a condenser connected with the circuit around the point of interruption therein, and a transformer, the primary of which is in the discharge-circuit of the condenser, as set forth.

3. A device for producing ozone comprising in combination, surfaces between which an

electrical discharge takes place, a transformer for producing the potential necessary for such discharge, a condenser in the primary circuit of the transformer, a charging-circuit, means for charging the condenser by such circuit and discharging it through the primary of the transformer, and a device for maintaining a current of air between the discharge-surfaces, as set forth.

4. A device for producing ozone comprising in combination, surfaces between which an electrical discharge takes place, a transformer for producing the potential necessary for such discharge, a condenser in the primary circuit of the transformer, a charging-circuit, means for charging the condenser by such circuit and discharging it through the primary of the transformer, a motor operated by the charging-circuit, and a device operated thereby for maintaining a current of air between the discharge-surfaces, as set forth.

5. A device for producing ozone comprising in combination, surfaces between which an electrical discharge takes place, a transformer for producing the potential necessary for such discharge, a condenser in the primary circuit of the transformer, a charging-circuit, a circuit-controller effecting the charging and discharging of the condenser, and a fan-motor connected with the charging-circuit and operating the circuit-controller and adapted to maintain a current of air between the discharge-surfaces, as set forth.

6. A device for producing ozone comprising in combination, means for charging a condenser, a circuit of low self-induction and resistance into which the condenser discharges, a coil for raising the potential of such discharge, and means for passing a current of air through the high-potential discharge, as set forth.

NIKOLA TESLA.

Witnesses:

DRURY W. COOPER,
M. LAWSON DYER.

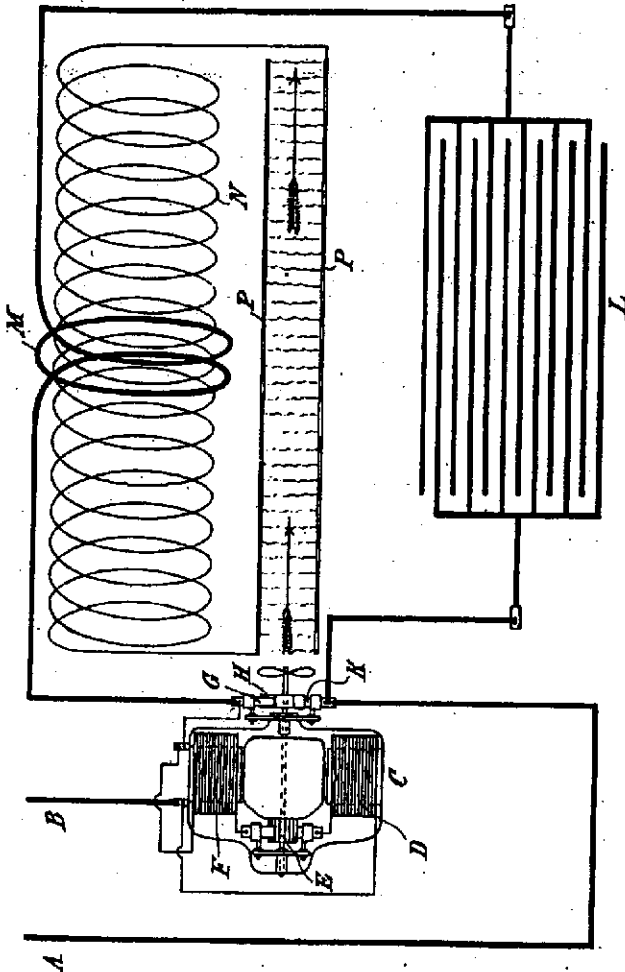
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APPARATUS FOR PRODUCING OZONE.

No. 568,177.

Patented Sept. 22, 1896.

Fig. 1



Witnesses:

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Dury W. Conner

Nikola Tesla, Inventor

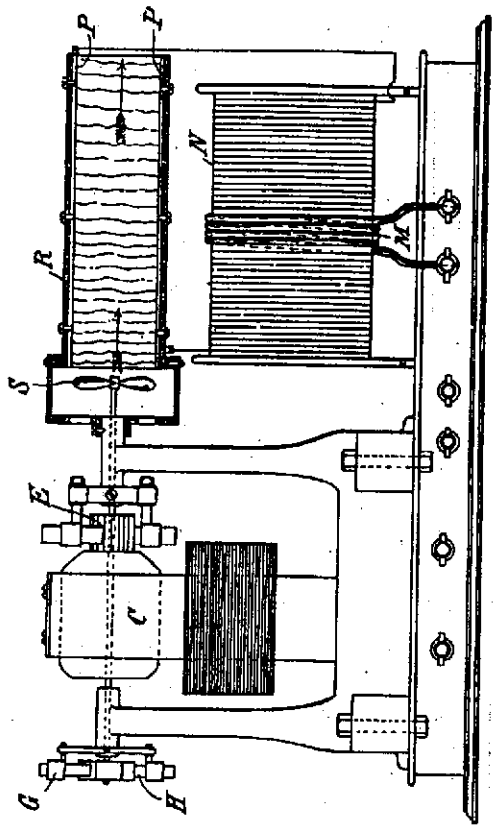
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APPARATUS FOR PRODUCING OZONE.

No. 568,177.

Patented Sept. 22, 1896.

Fig. 2



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64

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

METHOD OF REGULATING APPARATUS FOR PRODUCING CURRENTS OF HIGH FREQUENCY.

SPECIFICATION forming part of Letters Patent No. 568,178, dated September 22, 1896.

Application filed June 20, 1896. Serial No. 596,282. (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 Regulating Apparatus for Producing Currents of High Frequency, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

In previous patents and applications I have shown and described a method of and apparatus for generating electric currents of high frequency suitable for the production of various novel phenomena, such as illumination by means of vacuum-tubes, the production of ozone, Roentgen shadows, and other purposes. The special apparatus of this character which I have devised for use with circuits carrying currents in the nature of those classed as direct, or such as are generally obtainable from the ordinary circuits used in municipal systems of incandescent lighting, is based upon the following principles:

The energy of the direct-current supply is periodically directed into and stored in a circuit of relatively high self-induction, and in such form is employed to charge a condenser or circuit of capacity, which, in turn, is caused to discharge through a circuit of low self-induction containing means whereby the intermittent current of discharge is raised to the potential necessary for producing any desired effect.

Considering the conditions necessary for the attainment of these results, there will be found, as the essential elements of the system, the supply-circuit, from which the periodic impulses are obtained, and what may be regarded as the local circuits, comprising the circuit of high self-induction for charging the condenser and the circuit of low self-induction into which the condenser discharges and which itself may constitute the working circuit, or that containing the devices for utilizing the current, or may be inductively related to a secondary circuit which constitutes the working circuit proper. These several circuits, it will be understood, may be more or less interconnected; but for purposes of illustration they may be regarded as practically distinct, with a circuit-con-

troller for alternately connecting the condenser with the circuit by which it is charged and with that into which it discharges, and with a primary of a transformer in the latter circuit having its secondary in that which contains the devices operated by the current.

To this system or combination the invention, subject of my present application, pertains, and has for its object to provide a proper and economical means of regulation therefor.

It is well known that every electric circuit, provided its ohmic resistance does not exceed certain definite limits, has a period of vibration of its own analogous to the period of vibration of a weighted spring. In order to alternately charge a given circuit of this character by periodic impulses impressed upon it and to discharge it most effectively, the frequency of the impressed impulses should bear a definite relation to the frequency of vibration possessed by the circuit itself. Moreover, for like reasons the period or vibration of the discharge-circuit should bear a similar relation to the impressed impulses or the period of the charging-circuit. When the conditions are such that the general law of harmonic vibrations is followed, the circuits are said to be in resonance or in electromagnetic synchronism, and this condition I have found in my system to be highly advantageous. Hence in practice I adjust the electrical constants of the circuits so that in normal operation this condition of resonance is approximately attained. To accomplish this, the number of impulses of current directed into the charging-circuit per unit time is made equal to the period of the charging-circuit itself, or, generally, to a harmonic thereof, and the same relations are maintained between the charging and discharge circuit. Any departure from this condition will result in a decreased output, and this fact I take advantage of in regulating such output by varying the frequencies of the impulses or vibrations in the several circuits.

Inasmuch as the period of any given circuit depends upon the relations of its resistance, self-induction, and capacity, a variation of any one or more of these may result in a variation in its period. There are therefore various ways in which the frequencies of

vibration of the several circuits in the system referred to may be varied, but the most practicable and efficient ways of accomplishing the desired result are the following: (a) varying the rate of the impressed impulses of current, or those which are directed from the source of supply into the charging-circuit, as by varying the speed of the commutator or other circuit-controller; (b) varying the self-induction of the charging-circuit; (c) varying the self-induction or capacity of the discharge-circuit.

To regulate the output of a single circuit which has no vibration of its own by merely varying its period would evidently require, for any extended range of regulation, a very wide range of variation of period; but in the system described a very wide range of regulation of the output may be obtained by a very slight change of the frequency of one of the circuits when the above-mentioned rules are observed.

In illustration of my invention I have shown by diagrams in the accompanying drawings some of the more practicable means for carrying out the same. The figures, as stated, are diagrammatic illustrations of the system in its typical form provided with regulating devices of different specific character. These diagrams will be described in detail in their order.

In each of the figures, A B designate the conductors of a supply-circuit of continuous current; C, a motor connected therewith in any of the usual ways and driving a current-controller D, which serves to alternately close the supply-circuit through the motor or through a self-induction coil E and to connect such motor-circuit with a condenser F, the circuit of which contains a primary coil G, in proximity to which is a secondary coil H, serving as the source of supply to the working circuit, or that in which are connected up the devices K K for utilizing the current.

The circuit-controller, it may be stated, is any device which will permit of a periodic charging of the condenser F by the energy of the supply-circuit and its discharging into a circuit of low self-induction supplying directly or indirectly the translating devices. Inasmuch as the source of supply is generally of low potential, it is undesirable to charge the condenser directly therefrom, as a condenser of large capacity will in such cases be required. I therefore employ a motor of high self-induction, or in place of or in addition to such motor a choking or self-induction coil E, to store up the energy of the supply-current directed into it and to deliver it in the form of a high-potential discharge when its circuit is interrupted and connected to the terminals of the condenser.

In order to secure the greatest efficiency in a system of this kind, it is essential, as I have before stated, that the circuits, which, mainly as a matter of convenience, I have designated as the "charging" and the "discharge" cir-

uits, should be approximately in resonance or electromagnetic synchronism. Moreover, in order to obtain the greatest output from a given apparatus of this kind, it is desirable to maintain as high a frequency as possible.

The electrical conditions, which are now well understood, having been adjusted to secure, as far as practical considerations will permit, these results, I effect the regulation of the system by adjusting its elements so as to depart in a greater or less degree from the above conditions with a corresponding variation of output. For example, as in Figure 1, I may vary the speed of the motor, and consequently of the controller, in any suitable manner, as by means of a rheostat L in a shunt to such motor or by shifting the position of the brushes on the main commutator M of the motor or otherwise. A very slight variation in this respect, by disturbing the relations between the rate of impressed impulses and the vibration of the circuit of high self-induction into which they are directed, causes a marked departure from the condition of resonance and a corresponding reduction in the amount of energy delivered by the impressed impulses to the apparatus.

A similar result may be secured by modifying any of the constants of the local circuits, as above indicated. For example, in Fig. 2 the choking-coil E is shown as provided with an adjustable core N, by the movement of which into and out of the coil the self-induction, and consequently the period of the circuit containing such coil, may be varied.

As an example of the way in which the discharge-circuit, or that into which the condenser discharges, may be modified to produce the same result I have shown in Fig. 3 an adjustable self-induction coil R in the circuit with the condenser, by the adjustment of which the period of vibration of such circuit may be changed.

The same result would be secured by varying the capacity of the condenser; but if the condenser were of relatively large capacity this might be an objectionable plan, and a more practicable method is to employ a variable condenser in the secondary or working circuit, as shown in Fig. 4. As the potential in this circuit is raised to a high degree, a condenser of very small capacity may be employed, and if the two circuits, primary and secondary, are very intimately and closely connected the variation of capacity in the secondary is similar in its effects to the variation of the capacity of the condenser in the primary. I have illustrated as a means well adapted for this purpose two metallic plates S S, adjustable to and from each other and constituting the two armatures of the condenser.

I have confined the description herein to a source of supply of direct current, as to such the invention more particularly applies, but it will be understood that if the system be supplied by periodic impulses from any

source which will effect the same results the regulation of the system may be effected by the method herein described, and this my claims are intended to include.

5 What I claim is—

1. The method of regulating the energy delivered by a system for the production of high-frequency currents and comprising a supply-circuit, a condenser, a circuit through which
10 the same discharges and means for controlling the charging of the condenser by the supply-circuit and the discharging of the same, the said method consisting in varying the relations of the frequencies of the impulses in
15 the circuits comprising the system, as set forth.

2. The method of regulating the energy delivered by a system for the production of high-frequency currents comprising a supply-circuit of direct currents, a condenser adapted
20 to be charged by the supply-circuit and to

discharge through another circuit, the said method consisting in varying the frequency of the impulses of current from the supply-circuit, as set forth.

3. The method of producing and regulating electric currents of high frequency which consists in directing impulses from a supply-circuit into a charging-circuit of high self-induction, charging a condenser by the accumulated energy of such charging-circuit, discharging the condenser through a circuit of low self-induction, raising the potential of the condenser discharge and varying the relations of the frequencies of the electrical
35 impulses in the said circuits, as herein set forth.

NIKOLA TESLA.

Witnesses:

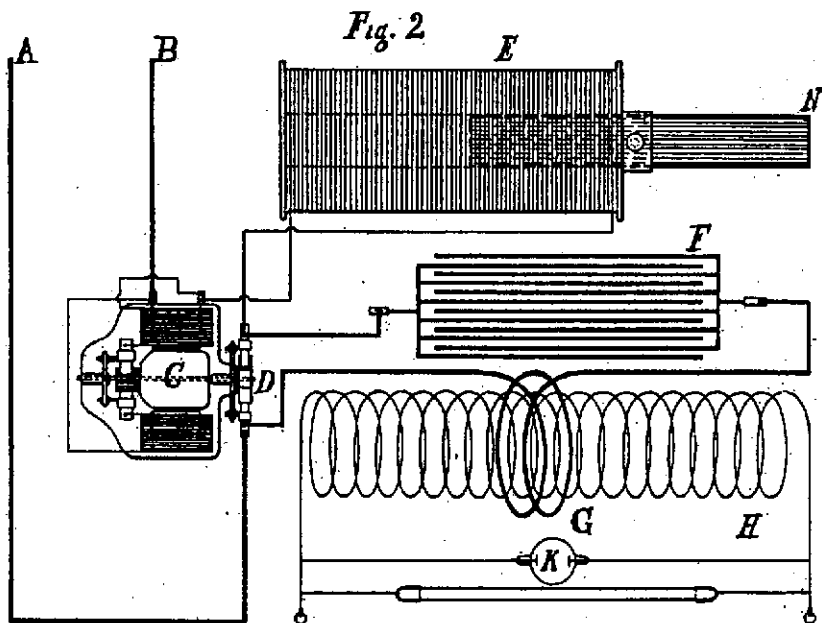
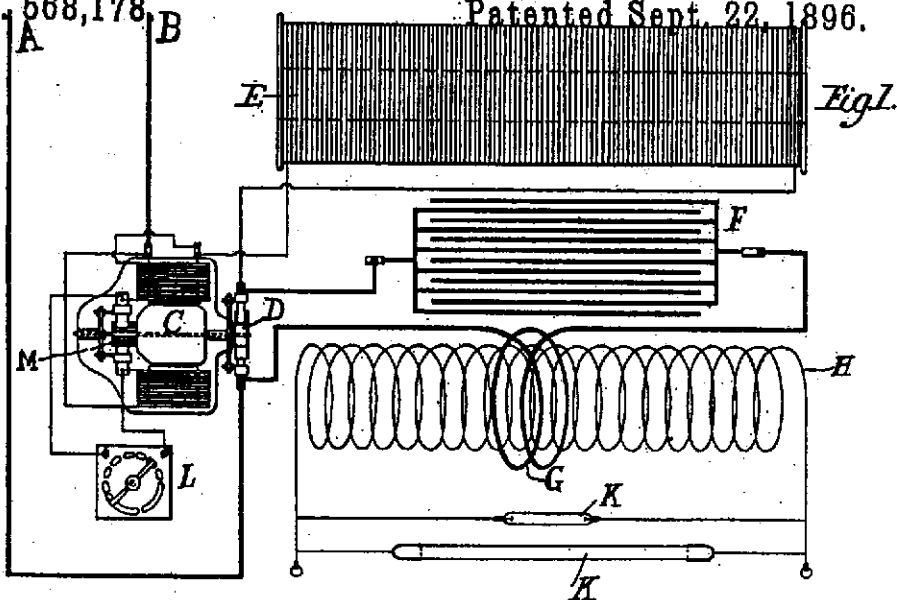
M. LAWSON DYER,
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METHOD OF REGULATING APPARATUS FOR PRODUCING CURRENTS OF HIGH FREQUENCY.

No. 568,178, B

Patented Sept. 22, 1896.



WITNESSES

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METHOD OF REGULATING APPARATUS FOR PRODUCING CURRENTS OF HIGH FREQUENCY.

No. 568,178. B

Patented Sept. 22, 1896.

Fig. 3.

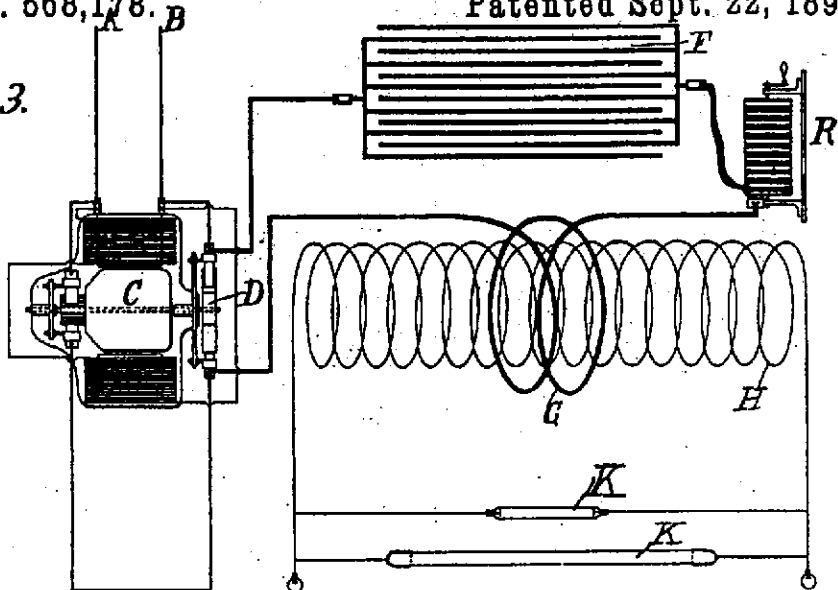
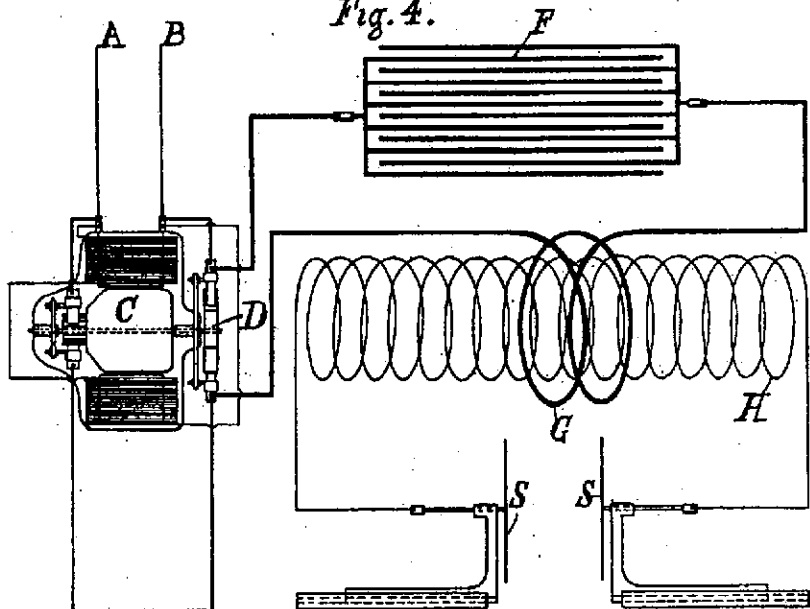


Fig. 4.



WITNESSES

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NIKOLA TESLA, OF NEW YORK, N. Y.

METHOD OF AND APPARATUS FOR PRODUCING CURRENTS OF HIGH FREQUENCY.

SPECIFICATION forming part of Letters Patent No. 568,179, dated September 22, 1896.

Application filed July 6, 1896. Serial No. 598,130. (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 Producing Currents of High Frequency, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

The apparatus for producing electrical currents of very high frequency in which is embodied the invention of my present application involves as its chief element means for the periodic charging of a condenser or circuit possessing capacity by the energy of a given source and the discharge of the same through a circuit of low self-induction, whereby the rapid succession of impulses characteristic of a condenser discharge under such circumstances is made available for many practical and useful purposes.

The general arrangement of circuits and apparatus which I prefer for ordinary applications of this invention I have shown and described in an application filed by me April 22, 1896, Serial No. 588,534, as comprising a local circuit of high self-induction connected with a source of supply, a condenser, a discharge-circuit of low self-induction, and a circuit-controller operating to alternately effect the charging of the condenser by the energy stored in the circuit of high self-induction and its discharge through that of low self-induction. I have shown, however, in the application referred to as the source of supply a continuous-current generator, or in general a source of direct currents, and while the principle of operation and the general character of the apparatus remain the same whether the current of the source be direct or alternating, yet the economical utilization of the latter involves certain special principles and appliances which it is my present object to illustrate as the basis for the claims of invention made herein.

When the potential of the source periodically rises and falls, whether with reversals or not is immaterial, it is essential to economical operation that the intervals of interruption of the charging-current should bear a definite time relation to the period of the

current, in order that the effective potential of the impulses charging the condenser may be as high as possible. I therefore provide, in case an alternating or equivalent electromotive force be employed as the source of supply, a circuit-controller which will interrupt the charging-circuit at instants predetermined with reference to the variations of potential therein. The most practicable means for accomplishing this of which I am aware is to employ a synchronous motor connected with the source of supply and operating a circuit-controller which interrupts the charging-current at or about the instant of highest potential of each wave and permits the condenser to discharge the energy stored in it through its appropriate circuit. This apparatus, which may be considered as typical of the means employed for carrying out the invention, I have illustrated in the accompanying drawings.

The figures are diagrammatic illustrations of the system in slightly-modified forms, and will be described in detail in their order.

Referring to Figure 1, A designates any source of alternating or equivalent current, from which lead off mains A' A'. At any point where it is desired to produce the high-frequency currents a branch circuit B is taken off from the mains, and in order to raise the potential of the current a transformer is employed, represented by the primary C and secondary D. The circuit of the secondary includes the energizing-coils of a synchronous motor E and a circuit-controller, which, in the present instance, in Fig. 1 is shown as composed of a metal disk F with insulated segments F' in its periphery and fixed to the shaft of the motor. An insulating-arm G, stationary with respect to the motor-shaft and adjustable with reference to the poles of the fixed magnets, carries two brushes H H, which bear upon the periphery of the disk. With the parts thus arranged the secondary circuit is completed through the coils of the motor whenever the two brushes rest upon the uninsulated segments of the disk and interrupted through the motor at other times. Such a motor, if properly constructed, in well-understood ways, maintains very exact synchronism with the alterations of the source, and the arm G may therefore be adjusted to

interrupt the current at any determined point in its waves. It will be understood that by the proper relations of insulated and conducting segments and the motor-poles the current may be interrupted twice in each complete wave at or about the points of highest potential. The self-induction of the circuit containing the motor and controller should be high, and the motor itself will usually be constructed in such manner that no other self-induction device will be needed. The energy stored in this circuit is utilized at each break therein to charge a condenser K. With this object the terminals of the condenser are connected to the two brushes H H or to points of the circuit adjacent thereto, so that when the circuit through the motor is interrupted the terminals of the motor-circuit will be connected with the condenser, whereby the latter will receive the high-potential inductive discharge from the motor or secondary circuit.

The condenser discharges into a circuit of low self-induction, one terminal of which is connected directly to a condenser-terminal and the other to the brush H opposite to that connected with the other condenser-terminal, so that the discharge-circuit of the condenser will be completed simultaneously with the motor-circuit and interrupted while the motor-circuit is broken and the condenser being charged.

The discharge-circuit contains a primary M of a few turns, and this induces in a secondary N impulses of high potential, which by reason of their great frequency are available for the operation of vacuum-tubes P, single terminal-lamps R, and other novel and useful purposes.

It is obvious that the supply-current need not be alternating, provided it be converted or transformed into an alternating current before reaching the controller. For example, the present improvements are applicable to various forms of rotary transformers, as is illustrated in Figs. 2 and 3.

E' designates a continuous-current motor, here represented as having four field-poles wound with coils E'' in shunt to the armature. The line-wires B B connect with the brushes b b, bearing on the usual commutator.

On an extension of the motor-shaft is a circuit-controller composed of a cylinder the surface of which is divided into four conducting-segments c and four insulating-segments d, the former being diametrically connected in pairs, as shown in Fig. 3.

Through the shaft run two insulated conductors e e from any two commutator-segments ninety degrees apart, and these connect with the two pairs of segments c, respectively. With such arrangement it is evident that any two adjacent segments c c become the terminals of an alternating-current source, so that if two brushes H H be applied to the periphery of the cylinder they will take off current dur-

ing such portion of the wave as the width of segment and position of the brushes may determine. By adjusting the position of the brushes relatively to the cylinder, therefore, the alternating current delivered to the segments c c may be interrupted at any point in its waves.

While the brushes H H are on the conducting-segments the current which they collect stores energy in a circuit of high self-induction formed by the wires f f, self-induction coils S S, the conductors B B, the brushes, and commutator. When this circuit is interrupted by the brushes H H passing onto the insulating-segments of the controller, the high-potential discharge of this circuit charges the condensers K K, which then discharge through the circuit of low self-induction containing the primary M. The secondary circuit N contains any devices, as P R, for utilizing the current.

The mechanical construction of the circuit-controller may be greatly varied, and in other respects the details shown and described are merely given as typical illustrations of the nature and purpose of the invention.

What I claim is—

1. The method herein described of producing electric currents of high frequency, which consists in generating an alternating current, charging a condenser thereby during determinate intervals of each wave of said current, and discharging the condenser through a circuit of low self-induction, as herein set forth.

2. The combination with a source of alternating current, a condenser, a circuit-controller adapted to direct the current during determinate intervals of each wave into the condenser for charging the same, and a circuit of low self-induction into which the condenser discharges, as set forth.

3. The combination with a source of alternating current, a synchronous motor operated thereby, a circuit-controller operated by the motor and adapted to interrupt the circuit through the motor at determinate points in each wave, a condenser connected with the motor-circuit and adapted on the interruption of the same to receive the energy stored therein, and a circuit into which the condenser discharges, as set forth.

4. The combination with a source of alternating current, a charging-circuit in which the energy of said current is stored, a circuit-controller adapted to interrupt the charging-circuit at determinate points in each wave, a condenser for receiving, on the interruption of the charging-circuit, the energy accumulated therein, and a circuit into which the condenser discharges when connected therewith by the circuit-controller, as set forth.

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Witnesses:

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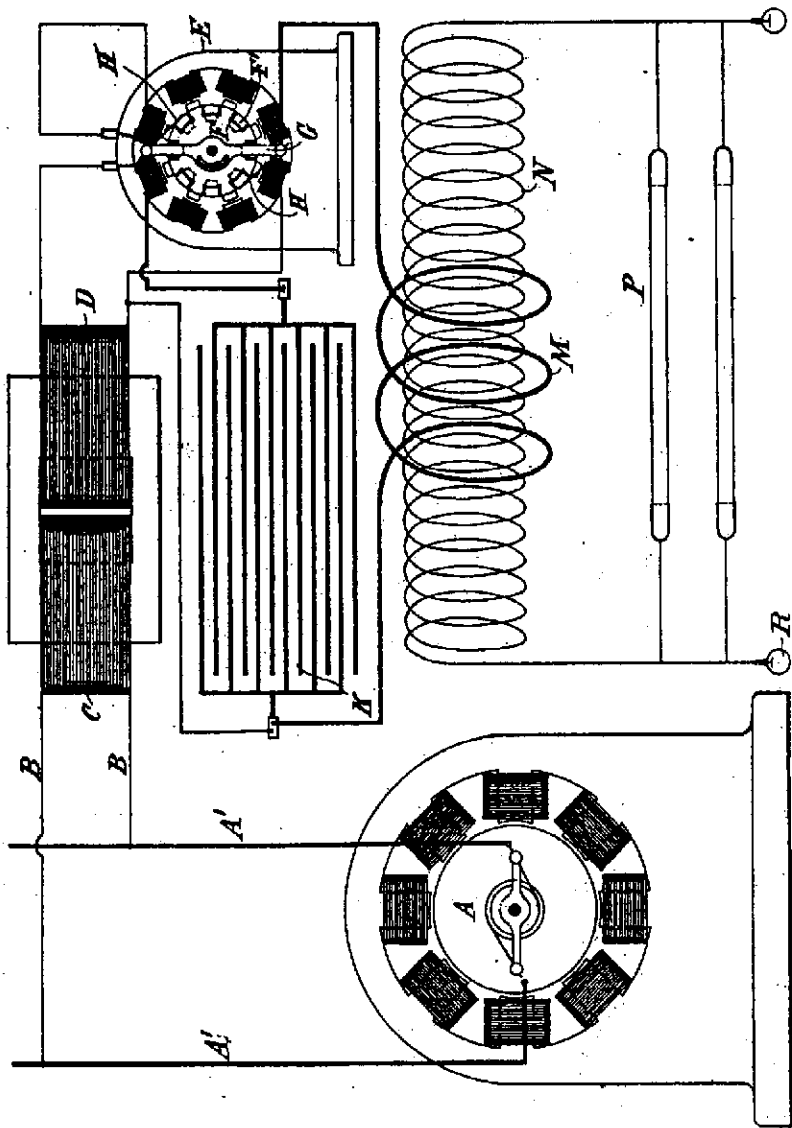
N. TESLA.

METHOD OF AND APPARATUS FOR PRODUCING CURRENTS OF HIGH FREQUENCY.

No. 568,179.

Patented Sept. 22, 1896.

FIG. 1



WITNESSES

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METHOD OF AND APPARATUS FOR PRODUCING CURRENTS OF HIGH FREQUENCY.

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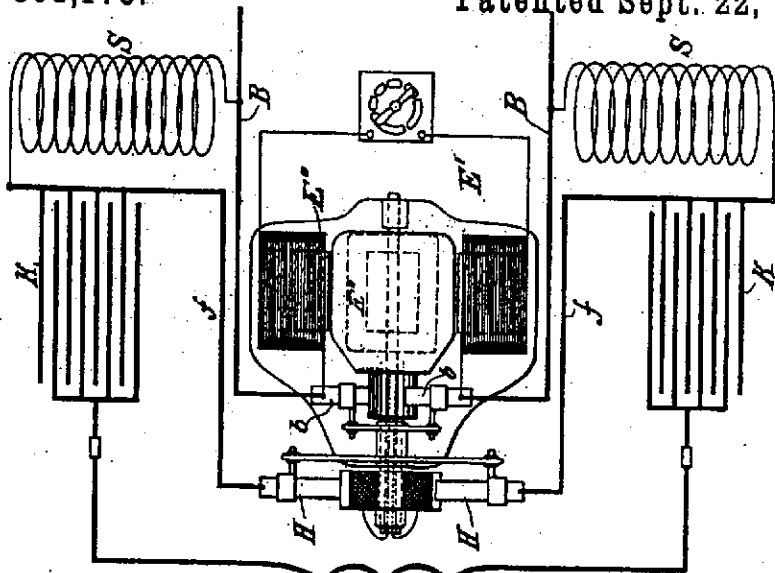
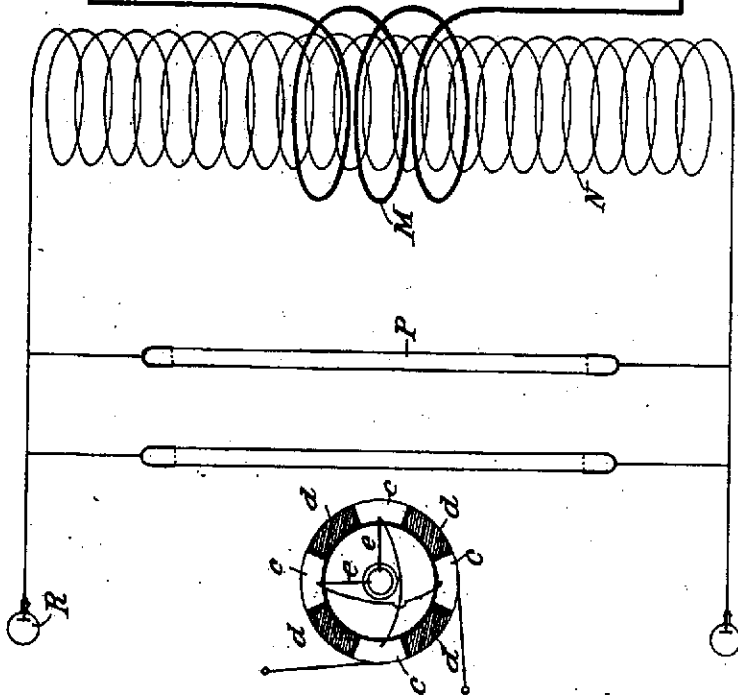


FIG. 2



WITNESSES

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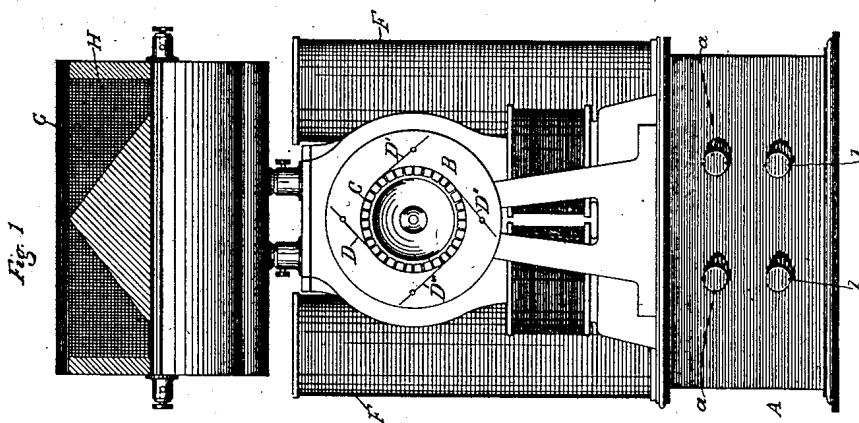
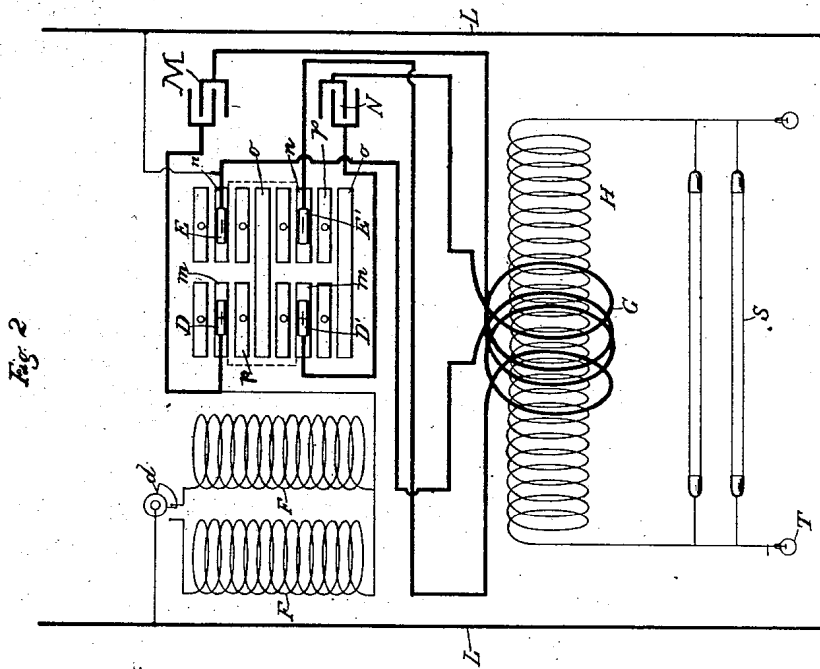
(No Model.)

N. TESLA.

APPARATUS FOR PRODUCING CURRENTS OF HIGH FREQUENCY.

No. 583,953.

Patented June 8, 1897.



WITNESSES

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APPARATUS FOR PRODUCING CURRENTS OF HIGH FREQUENCY.

SPECIFICATION forming part of Letters Patent No. 583,953, dated June 8, 1897.

Application filed October 19, 1896. Serial No. 609,292. (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 Apparatus for Producing Currents of High Frequency; of which the following is specification, reference being had to the drawings accompanying and forming a part of the same.

The invention upon which my present application is based is an improvement in apparatus for the conversion of electrical currents of ordinary character—such, for instance, as are obtainable from the mains of municipal electric light and power systems and either continuous or alternating—into currents of very high frequency and potential.

The improvement is applicable generally to apparatus of the kind heretofore invented by me and more particularly described in United States Letters Patent granted to me on September 22, 1896, No. 568,176; but in the description of the invention which follows the illustration is confined to a form of apparatus designed for converting a continuous or direct current into one of high frequency. In the several forms of apparatus for this purpose which I have devised and heretofore described I have employed a circuit of high self-induction connected with the mains from a suitable source of current and containing some form of circuit-controller for periodically interrupting it. Around the break or point of interruption I have arranged a condenser, into which the circuit discharges when interrupted, and this condenser is in turn made to discharge through a circuit containing the primary of a transformer, and of such character that the condenser-discharge will be in the form of an extremely rapid succession of impulses.

Now in order to secure in an apparatus of this kind as high frequency as possible and the advantages resulting therefrom I subdivide the condenser necessary for storing the energy required into integral parts or provide independent condensers, and employ means for charging said condensers in multiple and discharging them in series through the primary of the transformer. To secure this result without unduly complicating the appa-

ratus is a matter of very considerable difficulty, but I have accomplished it by means of the apparatus which I shall now proceed to describe by reference to the drawings.

Figure 1 is a side elevation of the apparatus which I employ; and Fig. 2 is a diagram of the circuit connections.

Referring to Fig. 1, A is a box or case containing the condensers, of which the terminals are *a a b b*, respectively. On this case is mounted a small electromagnetic motor B, by the shaft of which is operated the circuit-controller C. Upon the said controller bear brushes, as shown at *D D' D'' D'''*.

F F are self-induction coils placed beside the motor. Above these is the transformer, composed, essentially, of a primary *G* and a secondary *H*. These devices are intended to be enclosed in a suitable box or case, and may be very greatly modified in construction and relative arrangement. The circuit-controller, however, should conform in general principle of construction to that hereinafter described in so far as may be necessary to secure the operation pointed out.

Referring now to Fig. 2, *L L* designate the mains from a suitable source of supply, between which a circuit is formed, including the self-induction coils *F F* and the circuit-controller C. A switch *d* may be employed to bring either or both of the coils *F F* into this circuit, as may be desired.

The circuit-controller is built up of insulated plates or segments, upon which the positive and negative brushes bear, and these plates may be considered as belonging to three sets or classes, first, the plates *m* for what may be considered as the positive brushes *D D'* in one row, electrically connected together, and the corresponding plates *n* for what may similarly be considered as the negative brushes *E E'* in the other row; second, the plates *o*, which lie in both rows, and hence are conveniently made in single pieces extending across the controller, and, third, the idle or spacing plates *p*, which are interposed in each row between the other two sets. The angle between adjacent plates of the same set is equal to the angle of displacement between adjacent brushes of the same sign, and obviously there may be two or more of each. The brush *D* of one set is connected with one

main through the coils F, and each one of the brushes of the same set is connected to one of the terminals of the condensers M N, respectively. Similarly the brush E of the other set of brushes is connected to the opposite main and each of the brushes of said set to the opposite condenser terminals through the primary or strands of a primary G. In the diagram, Fig. 2, I have shown but two brushes in each set and two condensers, but more than this number may be used, the same plan of connections shown and described being followed out.

In the position of the parts shown in Fig. 2, in which two positive and two negative brushes are shown, the brushes are bearing on plates *m m* and *n n*. Consequently the circuit through the coils F F is through the condensers in multiple, and, assuming that energy has been stored in said coils, the condensers will thus be charged. If now by the movement of the controller plates or brushes the latter are shifted across the idle or spacing plates *p* onto the long or cross-connected plates *o* two results follow: The mains are short-circuited through the coils F F, which therefore store energy, while the condensers are connected in series through the primary coil or coils G. These actions are repeated by the further movement of the controller, the condensers being charged in parallel when the brushes are on plates *m n* and discharged in series when the brushes pass onto plates *o*. The motor may be run by an independent source or by current derived from the mains, and the apparatus may be employed to supply current for any suitable devices S T, connected with the secondary coil H.

As stated above, the specific construction of the circuit-controller may be very greatly varied without departure from the invention. In the drawings the plates are assumed to be associated in the form of a cylinder which revolves with respect to brushes bearing on its periphery; but it will be understood that this is merely a typical illustration of any form of terminals or contacts and conductors, whether rotary or reciprocating, which constitute a circuit-controller capable of effecting the same result.

The advantages resulting from the subdivision of the condenser or the employment of a plurality of condensers are mainly that a high frequency is obtainable in apparatus of any size; that the current of discharge through the sliding contacts is greatly reduced and injury to such contacts thereby avoided and a great saving in wire in the secondary effected.

What I claim is—

1. In an apparatus of the kind described, the combination with a set of contacts, one of which is adapted for connection with one of the mains from a source of current, and each of which is connected to one of the terminals of a series of condensers, and a second set of contacts similarly connected to the opposite main and condenser terminals, respectively, of electrically-connected plates or segments upon which the contacts of the first set bear, similarly-connected plates upon which the contacts of the second set bear, and isolated plates common to the two sets of contacts, the said plates being arranged in the manner described, whereby the condensers will be alternately charged in multiple and discharged in series, as set forth.

2. In an apparatus of the kind described, the combination with a set of positive brushes, one of which is adapted for connection with one of the mains from a source of current, and each of which is connected to one of the terminals of a series of condensers, and negative brushes similarly connected to the opposite main and condenser terminals, respectively, of a cylinder composed of electrically-connected segments upon which the positive brushes only bear, similarly-connected segments upon which the negative brushes only bear, and isolated plates upon which both sets of brushes simultaneously bear, the said plates being arranged in the manner described, whereby the condensers will be alternately charged in multiple and discharged in series, as set forth.

NIKOLA TESLA.

Witnesses:

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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 ap-

proximately 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

5 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.

10 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.

20 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

35 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

40 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.

45 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

50 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:

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N. TESLA. ELECTRICAL TRANSFORMER.

No. 593,138.

Patented Nov. 2, 1897.

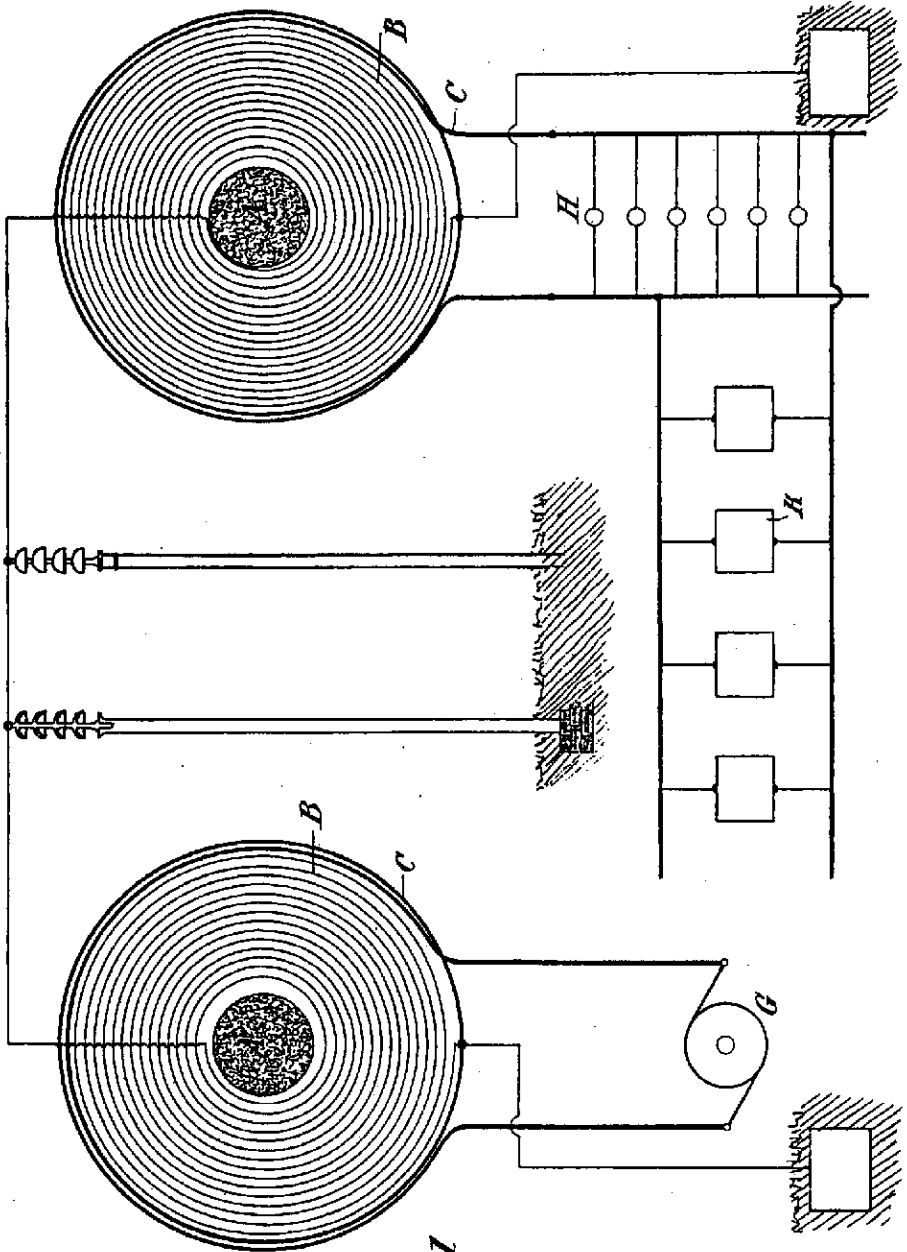


Fig. 1

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Fig. 3

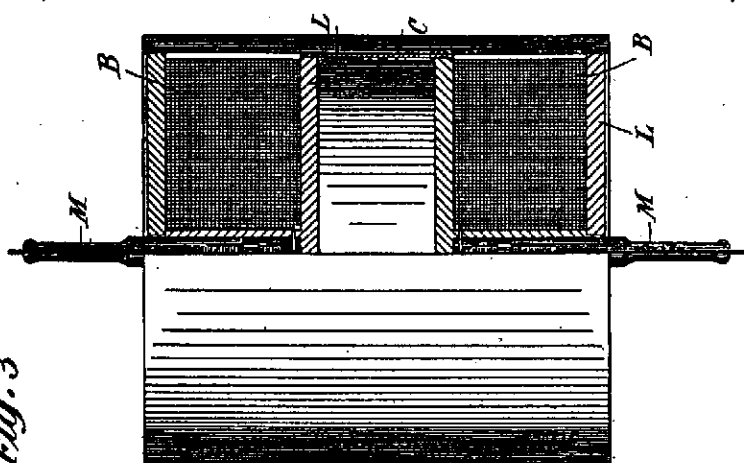
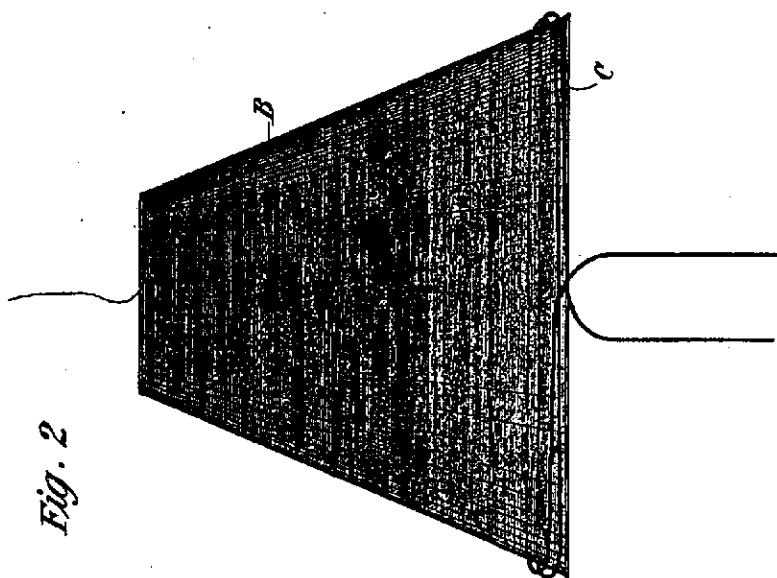


Fig. 2



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UNITED STATES PATENT OFFICE.

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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 im-

provement 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:

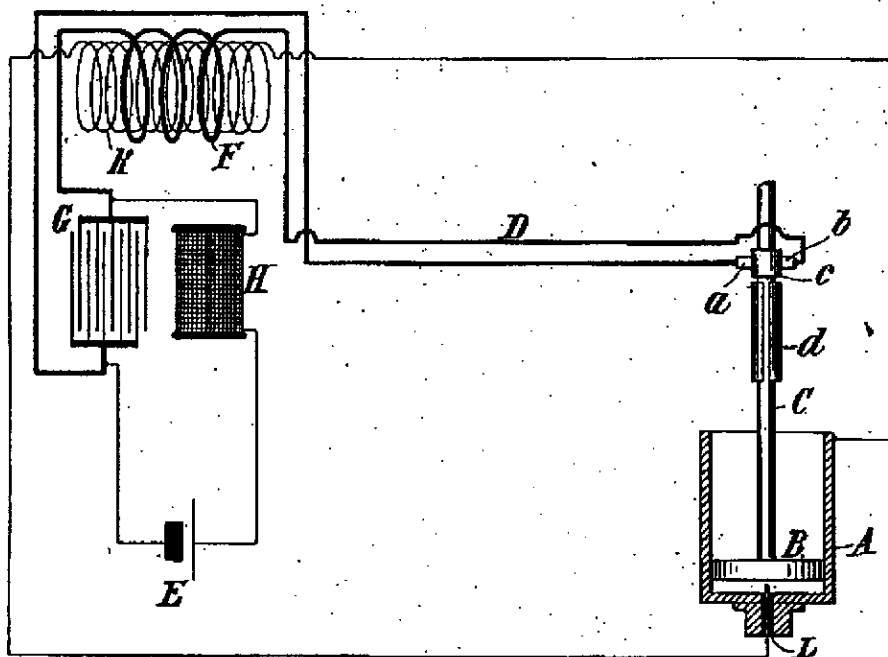
M. LAWSON DYER,
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ELECTRICAL IGNITER FOR GAS ENGINES.

(Application filed Feb. 17, 1907. Renewed June 18, 1908.)

(No Model.)



Witnesses:

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Nikola Tesla, Inventor

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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

APPARATUS FOR THE UTILIZATION OF RADIANT ENERGY.

SPECIFICATION forming part of Letters Patent No. 685,957, dated November 5, 1901.

Application filed March 21, 1901. Serial No. 52,153. (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 the Utilization of Radiant Energy, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

It is well known that certain radiations—such as those of ultra-violet light, cathodic, Roentgen rays, or the like—possess the property of charging and discharging conductors of electricity, the discharge being particularly noticeable when the conductor upon which the rays impinge is negatively electrified. These radiations are generally considered to be ether vibrations of extremely small wave lengths, and in explanation of the phenomena noted it has been assumed by some authorities that they ionize or render conducting the atmosphere through which they are propagated. My own experiments and observations, however, lead me to conclusions more in accord with the theory heretofore advanced by me that sources of such radiant energy throw off with great velocity minute particles of matter which are strongly electrified, and therefore capable of charging an electrical conductor, or, even if not so, may at any rate discharge an electrified conductor either by carrying off bodily its charge or otherwise.

My present application is based upon a discovery which I have made that when rays or radiations of the above kind are permitted to fall upon an insulated conducting-body connected to one of the terminals of a condenser while the other terminal of the same is made by independent means to receive or to carry away electricity a current flows into the condenser so long as the insulated body is exposed to the rays, and under the conditions hereinafter specified an indefinite accumulation of electrical energy in the condenser takes place. This energy after a suitable time interval, during which the rays are allowed to act, may manifest itself in a powerful discharge, which may be utilized for the

operation or control of mechanical or electrical devices or rendered useful in many other ways.

In applying my discovery I provide a condenser, preferably of considerable electrostatic capacity, and connect one of its terminals to an insulated metal plate or other conducting-body exposed to the rays or streams of radiant matter. It is very important, particularly in view of the fact that electrical energy is generally supplied at a very slow rate to the condenser, to construct the same with the greatest care. I use, by preference, the best quality of mica as dielectric, taking every possible precaution in insulating the armatures, so that the instrument may withstand great electrical pressures without leaking and may leave no perceptible electrification when discharging instantaneously. In practice I have found that the best results are obtained with condensers treated in the manner described in a patent granted to me February 23, 1897, No. 577,671. Obviously the above precautions should be the more rigorously observed the slower the rate of charging and the smaller the time interval during which the energy is allowed to accumulate in the condenser. The insulated plate or conducting-body should present as large a surface as practicable to the rays or streams of matter, I having ascertained that the amount of energy conveyed to it per unit of time is under otherwise identical conditions proportionate to the area exposed, or nearly so. Furthermore, the surface should be clean and preferably highly polished or amalgamated. The second terminal or armature of the condenser may be connected to one of the poles of a battery or other source of electricity or to any conducting body or object whatever of such properties or so conditioned that by its means electricity of the required sign will be supplied to the terminal. A simple way of supplying positive or negative electricity to the terminal is to connect the same either to an insulated conductor supported at some height in the atmosphere or to a grounded conductor, the former, as is well known, furnishing positive and the latter negative electricity. As the rays or supposed streams of mat-

ter generally convey a positive charge to the first condenser-terminal, which is connected to the plate or conductor above mentioned, I usually connect the second terminal of the condenser to the ground, this being the most convenient way of obtaining negative electricity, dispensing with the necessity of providing an artificial source. In order to utilize for any useful purpose the energy accumulated in the condenser, I furthermore connect to the terminals of the same a circuit including an instrument or apparatus which it is desired to operate and another instrument or device for alternately closing and opening the circuit. This latter may be any form of circuit-controller, with fixed or movable parts or electrodes, which may be actuated either by the stored energy or by independent means.

My discovery will be more fully understood from the following description and annexed drawings, to which reference is now made, and in which—

Figure 1 is a diagram showing the general arrangement of apparatus as usually employed. Fig. 2 is a similar diagram illustrating more in detail typical forms of the devices or elements used in practice, and Figs. 3 and 4 are diagrammatical representations of modified arrangements suitable for special purposes.

As illustrative of the manner in which the several parts or elements of the apparatus in one of its simplest forms are to be arranged and connected for useful operation, reference is made to Fig. 1, in which C is the condenser, P the insulated plate or conducting-body which is exposed to the rays, and P' another plate or conductor which is grounded, all being joined in series, as shown. The terminals T T' of the condenser are also connected to a circuit which includes a device R to be operated and a circuit-controlling device *d* of the character above referred to.

The apparatus being arranged as shown, it will be found that when the radiations of the sun or of any other source capable of producing the effects before described fall upon the plate P an accumulation of electrical energy in the condenser C will result. This phenomenon, I believe, is best explained as follows: The sun, as well as other sources of radiant energy, throws off minute particles of matter positively electrified, which, impinging upon the plate P, communicate continuously an electrical charge to the same. The opposite terminal of the condenser being connected to the ground, which may be considered as a vast reservoir of negative electricity, a feeble current flows continuously into the condenser, and inasmuch as these supposed particles are of an inconceivably small radius or curvature, and consequently charged to a relatively very high potential, this charging of the condenser may continue, as I have actually observed, almost indefinitely, even to the point of rupturing the dielectric. If the

device *d* be of such character that it will operate to close the circuit in which it is included when the potential in the condenser has reached a certain magnitude, the accumulated charge will pass through the circuit, which also includes the receiver R, and operate the latter.

In illustration of a particular form of apparatus which may be used in carrying out my discovery I now refer to Fig. 2. In this figure, which in the general arrangement of the elements is identical to Fig. 1, the device *d* is shown as composed of two very thin conducting-plates *t t'*, placed in close proximity and very mobile, either by reason of extreme flexibility or owing to the character of their support. To improve their action, they should be inclosed in a receptacle, from which the air may be exhausted. The plates *t t'* are connected in series with a working circuit, including a suitable receiver, which in this case is shown as consisting of an electromagnet M, a movable armature *a*, a retractile spring *b*, and a ratchet-wheel *w*, provided with a spring-pawl *r*, which is pivoted to armature *a*, as illustrated. When the radiations of the sun or other radiant source fall upon plate P, a current flows into the condenser, as above explained, until the potential therein rises sufficiently to attract and bring into contact the two plates *t t'*, and thereby close the circuit connected to the two condenser-terminals. This permits a flow of current which energizes the magnet M, causing it to draw down the armature *a* and impart a partial rotation to the ratchet-wheel *w*. As the current ceases the armature is retracted by the spring *b*, without, however, moving the wheel *w*. With the stoppage of the current the plates *t t'* cease to be attracted and separate, thus restoring the circuit to its original condition.

Fig. 3 shows a modified form of apparatus used in connection with an artificial source of radiant energy, which in this instance may be an arc emitting copiously ultra-violet rays. A suitable reflector may be provided for concentrating and directing the radiations. A magnet R and circuit-controller *d* are arranged as in the previous figures; but in the present case the former instead of performing itself the whole work only serves the purpose of alternately opening and closing a local circuit, containing a source of current B and a receiving or translating device D. The controller *d*, if desired, may consist of two fixed electrodes separated by a minute air-gap or weak dielectric film, which breaks down more or less suddenly when a definite difference of potential is reached at the terminals of the condenser and returns to its original state upon the passage of the discharge.

Still another modification is shown in Fig. 4, in which the source S of radiant energy is a special form of Roentgen tube devised by

me, having but one terminal k , generally of aluminium, in the form of half a sphere, with a plain polished surface on the front side, from which the streams are thrown off. It may be excited by attaching it to one of the terminals of any generator of sufficiently high electromotive force; but whatever apparatus be used it is important that the tube be exhausted to a high degree, as otherwise it might prove entirely ineffective. The working or discharge circuit connected to the terminals T T' of the condenser includes in this case the primary p of a transformer and a circuit-controller comprising a fixed terminal or brush t and a movable terminal t' in the shape of a wheel, with conducting and insulating segments, which may be rotated at an arbitrary speed by any suitable means. In inductive relation to the primary wire or coil p is a secondary s , usually of a much greater number of turns, to the ends of which is connected a receiver R . The terminals of the condenser being connected, as indicated, one to an insulated plate P and the other to a grounded plate P' , when the tube S is excited rays or streams of matter are emitted from the same, which convey a positive charge to the plate P and condenser-terminal T , while terminal T' is continuously receiving negative electricity from the plate P' . This, as before explained, results in an accumulation of electrical energy in the condenser, which goes on as long as the circuit including the primary p is interrupted. Whenever the circuit is closed owing to the rotation of the terminal t' , the stored energy is discharged through the primary p , this giving rise in the secondary s to induced currents, which operate the receiver R .

It is clear from what has been stated above that if the terminal T is connected to a plate supplying positive instead of negative electricity the rays should convey negative electricity to plate P . The source S may be any form of Roentgen or Lenard tube; but it is obvious from the theory of action that in order to be very effective the electrical impulses exciting it should be wholly or at least preponderatingly of one sign. If ordinary symmetrical alternating currents are employed, provision should be made for allowing the rays to fall upon the plate P only during those periods when they are productive of the desired result. Evidently if the radiations of the source be stopped or intercepted or their intensity varied in any manner, as by periodically interrupting or rhythmically varying the current exciting the source, there will be corresponding changes in the action upon the receiver R , and thus signals may be transmitted and many other useful effects produced. Furthermore, it will be understood that any form of circuit-closer which will respond to or be set in operation when a predetermined amount of energy is stored in the condenser may be used in lieu of the device

specifically described with reference to Fig. 2 and also that the special details of construction and arrangement of the several parts of the apparatus may be very greatly varied without departure from the invention.

Having described my invention, what I claim is—

1. An apparatus for utilizing radiant energy, comprising in combination a condenser, one armature of which is subjected to the action of rays or radiations, independent means for charging the other armature, a circuit and apparatus therein adapted to be operated or controlled by the discharge of the condenser, as set forth. 75
2. An apparatus for utilizing radiant energy, comprising in combination, a condenser, one armature of which is subjected to the action of rays or radiations, independent means for charging the other armature, a local circuit connected with the condenser-terminals, a circuit-controller therein and means adapted to be operated or controlled by the discharge of the condenser when the local circuit is closed, as set forth. 85
3. An apparatus for utilizing radiant energy, comprising in combination, a condenser, one terminal of which is subjected to the action of rays or radiations, independent means for charging the other armature, a local circuit connected with the condenser-terminals, a circuit-controller therein dependent for operation on a given rise of potential in the condenser, and devices operated by the discharge of the condenser when the local circuit is closed, as set forth. 95
4. An apparatus for utilizing radiant energy, comprising in combination, a condenser, one terminal of which is subjected to the action of rays or radiations, and the other of which is connected with the ground, a circuit and apparatus therein adapted to be operated by the discharge of the accumulated energy in the condenser, as set forth. 105
5. An apparatus for utilizing radiant energy, comprising in combination, a condenser, one terminal of which is subjected to the action of rays or radiations and the other of which is connected with the ground, a local circuit connected with the condenser-terminals, a circuit-controller therein and means adapted to be operated by the discharge of the condenser when the local circuit is closed, as set forth. 110
6. An apparatus for utilizing radiant energy, comprising in combination, a condenser, one terminal of which is subjected to the action of rays or radiations and the other of which is connected with the ground, a local circuit connected with the condenser-terminals, a circuit-controller therein adapted to be operated by a given rise of potential in the condenser, and devices operated by the discharge of the condenser when the local circuit is closed, as set forth. 115
7. An apparatus for utilizing radiant en- 120

ergy, comprising a condenser, having one terminal connected to earth and the other to an elevated conducting-plate, which is adapted to receive the rays from a distant source of
5 radiant energy, a local circuit connected with the condenser-terminals, a receiver therein, and a circuit-controller therefor which is

adapted to be operated by a given rise of potential in the condenser, as set forth.

NIKOLA TESLA.

Witnesses:

M. LAWSON DYER,
RICHARD DONOVAN.

N. TESLA.

APPARATUS FOR THE UTILIZATION OF RADIANT ENERGY.

(Application filed Mar. 21, 1901.)

(No Model.)

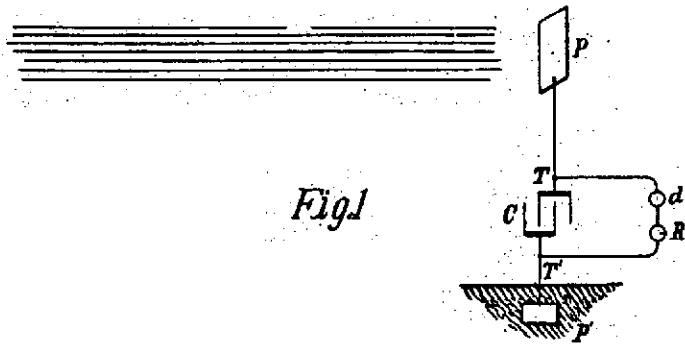


Fig. 1

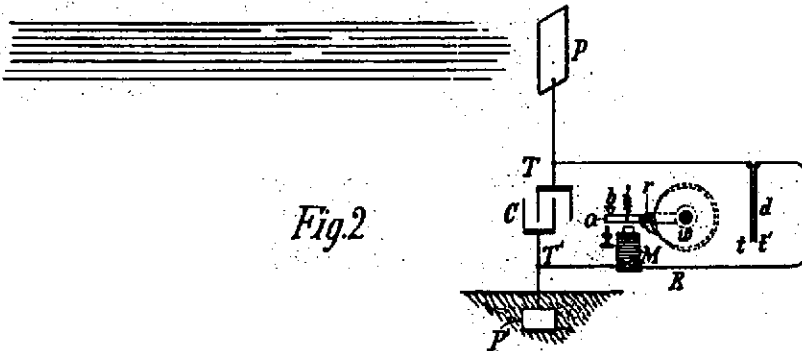


Fig. 2

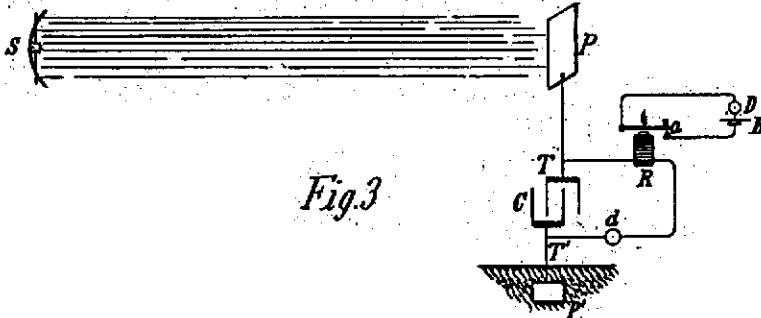


Fig. 3

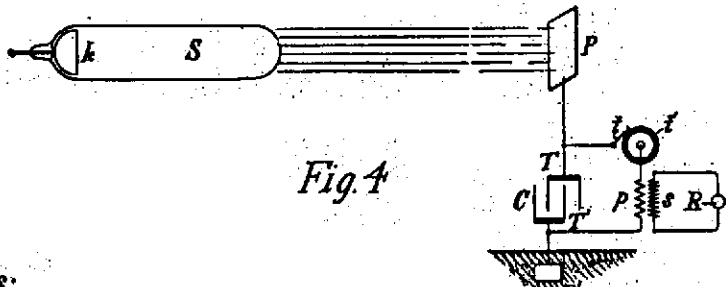


Fig. 4

Witnesses:
Rudolf Ketter
Dr. Lammie Dyer.

Inventor
Nikola Tesla
 by *Ken. Page & Cooper* Attys

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

METHOD OF UTILIZING RADIANT ENERGY.

SPECIFICATION forming part of Letters Patent No. 685,958, dated November 5, 1901.

Application filed March 21, 1901. Serial No. 52,154. (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 Methods of Utilizing Radiant Energy, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

It is well known that certain radiations—such as those of ultra-violet light, cathodic, Roentgen rays, or the like—possess the property of charging and discharging conductors of electricity, the discharge being particularly noticeable when the conductor upon which the rays impinge is negatively electrified. These radiations are generally considered to be ether vibrations of extremely small wave lengths, and in explanation of the phenomena noted it has been assumed by some authorities that they ionize or render conducting the atmosphere through which they are propagated. My own experiments and observations, however, lead me to conclusions more in accord with the theory heretofore advanced by me that sources of such radiant energy throw off with great velocity minute particles of matter which are strongly electrified, and therefore capable of charging an electrical conductor, or even if not so may at any rate discharge an electrified conductor either by carrying off bodily its charge or otherwise.

My present application is based upon a discovery which I have made that when rays or radiations of the above kind are permitted to fall upon an insulated conducting body connected to one of the terminals of a condenser, while the other terminal of the same is made by independent means to receive or to carry away electricity, a current flows into the condenser so long as the insulated body is exposed to the rays, and under the conditions hereinafter specified an indefinite accumulation of electrical energy in the condenser takes place. This energy after a suitable time interval, during which the rays are allowed to act, may manifest itself in a powerful discharge, which may be utilized for the operation or control of mechanical or elec-

trical devices or rendered useful in many other ways.

In applying my discovery I provide a condenser, preferably of considerable electrostatic capacity, and connect one of its terminals to an insulated metal plate or other conducting body exposed to the rays or streams of radiant matter. It is very important, particularly in view of the fact that electrical energy is generally supplied at a very slow rate to the condenser, to construct the same with the greatest care. I use by preference the best quality of mica as dielectric, taking every possible precaution in insulating the armatures, so that the instrument may withstand great electrical pressures without leaking and may leave no perceptible electrification when discharging instantaneously. In practice I have found that the best results are obtained with condensers treated in the manner described in a patent granted to me February 23, 1897, No. 577,671. Obviously the above precautions should be the more rigorously observed the slower the rate of charging and the smaller the time interval during which the energy is allowed to accumulate in the condenser. The insulated plate or conducting body should present as large a surface as practicable to the rays or streams of matter, I having ascertained that the amount of energy conveyed to it per unit of time is under otherwise identical conditions proportionate to the area exposed, or nearly so. Furthermore, the surface should be clean and preferably highly polished or amalgamated. The second terminal or armature of the condenser may be connected to one of the poles of a battery or other source of electricity or to any conducting body or object whatever of such properties or so conditioned that by its means electricity of the required sign will be supplied to the terminal. A simple way of supplying positive or negative electricity to the terminal is to connect the same either to an insulated conductor, supported at some height in the atmosphere, or to a grounded conductor, the former, as is well known, furnishing positive and the latter negative electricity. As the rays or supposed streams of matter generally convey a positive charge to the first condenser-terminal, which is connect-

ed to the plate or conductor above mentioned, I usually connect the second terminal of the condenser to the ground, this being the most convenient way of obtaining negative electric-
 5 ity, dispensing with the necessity of providing an artificial source. In order to utilize for any useful purpose the energy accumulated in the condenser, I furthermore connect to the terminals of the same a circuit includ-
 10 ing an instrument or apparatus which it is desired to operate and another instrument or device for alternately closing and opening the circuit. This latter may be any form of circuit-controller, with fixed or movable parts
 15 or electrodes, which may be actuated either by the stored energy or by independent means.

The rays or radiations which are to be utilized for the operation of the apparatus above described in general terms may be derived
 20 from a natural source, as the sun, or may be artificially produced by such means, for example, as an arc-lamp, a Roentgen tube, and the like, and they may be employed for a great variety of useful purposes.

25 My discovery will be more fully understood from the following detailed description and annexed drawings, to which reference is now made, and in which—

Figure 1 is a diagram showing typical forms
 30 of the devices or elements as arranged and connected in applying the method for the operation of a mechanical contrivance or instrument solely by the energy stored; and Fig. 2 is a diagrammatical representation of a modified
 35 arrangement suitable for special purposes, with a circuit-controller actuated by independent means.

Referring to Fig. 1, C is the condenser, P the insulated plate or conducting body, which
 40 is exposed to the rays, and P' another plate or conductor, all being joined in series, as shown. The terminals T T' of the condenser are also connected to a circuit including a receiver R,
 45 which is to be operated, and a circuit-controlling device *d*, which in this case is composed of two very thin conducting-plates *t t'*, placed in close proximity and very mobile, either by reason of extreme flexibility or owing to the
 50 character of their support. To improve their action, they should be inclosed in a receptacle from which the air may be exhausted. The receiver R is shown as consisting of an electro-
 magnet M, a movable armature *a*, a retractile spring *b*, and a ratchet-wheel *w*, provided with a spring-pawl *r*, which is pivoted
 55 to armature *a*, as illustrated. The apparatus being arranged as shown, it will be found that when the radiations of the sun or of any other source capable of producing the effects before
 60 described fall upon the plate P an accumulation of electrical energy in the condenser C will result. This phenomenon, I believe, is best explained as follows: The sun as well as other sources of radiant energy throw off minute particles of matter positively electrified,
 65 which, impinging upon the plate P, communicate an electrical charge to the same. The

opposite terminal of the condenser being connected to the ground, which may be considered as a vast reservoir of negative electricity,
 70 a feeble current flows continuously into the condenser, and inasmuch as these supposed particles are of an inconceivably small radius or curvature, and consequently charged to a
 75 relatively very high potential, this charging of the condenser may continue, as I have found in practice, almost indefinitely, even to the point of rupturing the dielectric. Obviously whatever circuit-controller be employed
 80 it should operate to close the circuit in which it is included when the potential in the condenser has reached the desired magnitude. Thus in Fig. 2 when the electrical pressure at the terminals T T' rises to a certain
 85 predetermined value the plates *t t'*, attracting each other, close the circuit connected to the terminals. This permits a flow of current which energizes the magnet M, causing it to
 90 draw down the armature *a* and impart a partial rotation to the ratchet-wheel *w*. As the current ceases the armature is retracted by the spring *b* without, however, moving the wheel *w*. With the stoppage of the current the plates *t t'* cease to be attracted and separate,
 95 thus restoring the circuit to its original condition.

Many useful applications of this method of utilizing the radiations emanating from the sun or other source and many ways of carrying
 100 out the same will at once suggest themselves from the above description. By way of illustration a modified arrangement is shown in Fig. 2, in which the source S of radiant energy is a special form of Roentgen
 105 tube devised by me having but one terminal *k*, generally of aluminium, in the form of half a sphere with a plain polished surface on the front side, from which the streams are
 110 thrown off. It may be excited by attaching it to one of the terminals of any generator of sufficiently-high electromotive force; but whatever apparatus be used it is important
 115 that the tube be exhausted to a high degree, as otherwise it might prove entirely ineffective. The working or discharge circuit connected to the terminals T T' of the condenser
 120 includes in this case the primary *p* of a transformer and a circuit-controller comprising a fixed terminal or brush *t* and a movable terminal *t'* in the shape of a wheel with conducting and insulating segments which may be
 125 rotated at an arbitrary speed by any suitable means. In inductive relation to the primary wire or coil *p* is a secondary *s*, usually of a much greater number of turns, to the ends of which is connected a receiver R. The terminals of the condenser being connected as
 130 indicated, one to an insulated plate P and the other to a grounded plate P', when the tube S is excited rays or streams of matter are emitted from the same, which convey a positive charge to the plate P and condenser-terminal T, while terminal T' is continuously receiving negative electricity from the plate

P'. This, as before explained, results in an accumulation of electrical energy in the condenser, which goes on as long as the circuit including the primary p is interrupted.

5 Whenever the circuit is closed, owing to the rotation of the terminal t' , the stored energy is discharged through the primary p , this giving rise in the secondary s to induced currents which operate the receiver R.

10 It is clear from what has been stated above that if the terminal T' is connected to a plate supplying positive instead of negative electricity the rays should convey negative electricity to plate P. The source S may be any

15 form of Roentgen or Lenard tube; but it is obvious from the theory of action that in order to be very effective the electrical impulses exciting it should be wholly or at least preponderatingly of one sign. If ordinary

20 symmetrical alternating currents are employed, provision should be made for allowing the rays to fall upon the plate P only during those periods when they are productive of the desired result. Evidently if the

25 radiations of the source be stopped or intercepted or their intensity varied in any manner, as by periodically interrupting or rhythmically varying the current exciting the source, there will be corresponding changes

30 in the action upon the receiver R, and thus signals may be transmitted and many other useful effects produced. Furthermore, it will be understood that any form of circuit-closer which will respond to or be set in operation

35 when a predetermined amount of energy is stored in the condenser may be used in lieu of the device specifically described with reference to Fig. 1, and also that the special details of construction and arrangement of

40 the several parts of the apparatus may be very greatly varied without departure from the invention.

Having described my invention, what I claim is—

45 1. The method of utilizing radiant energy,

which consists in charging one of the armatures of a condenser by rays or radiations, and the other armature by independent means, and discharging the condenser through a suitable receiver, as set forth.

2. The method of utilizing radiant energy, which consists in simultaneously charging a condenser by means of rays or radiations and an independent source of electrical energy, and discharging the condenser through a suitable receiver, as set forth.

3. The method of utilizing radiant energy, which consists in charging one of the armatures of a condenser by rays or radiations, and the other by independent means, controlling the action or effect of said rays or radiations and discharging the condenser through a suitable receiver, as set forth.

4. The method of utilizing radiant energy, which consists in charging one of the armatures of a condenser by rays or radiations and the other by independent means, varying the intensity of the said rays or radiations and periodically discharging the condenser through a suitable receiver, as set forth.

5. The method of utilizing radiant energy, which consists in directing upon an elevated conductor, connected to one of the armatures of a condenser, rays or radiations capable of positively electrifying the same, carrying off electricity from the other armature by connecting the same with the ground, and discharging the accumulated energy through a suitable receiver, as set forth.

6. The method of utilizing radiant energy, which consists in charging one of the armatures of a condenser by rays or radiations, and the other by independent means, and effecting by the automatic discharge of the accumulated energy the operation or control of a suitable receiver, as set forth.

NIKOLA TESLA.

Witnesses:

M. LAWSON DYER,
RICHARD DONOVAN.

N. TESLA.
METHOD OF UTILIZING RADIANT ENERGY.

(Application filed Mar. 21, 1901.)

(No Model.)

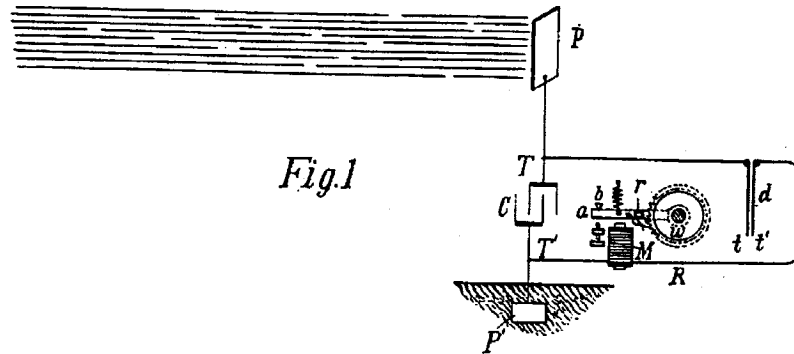


Fig. 1

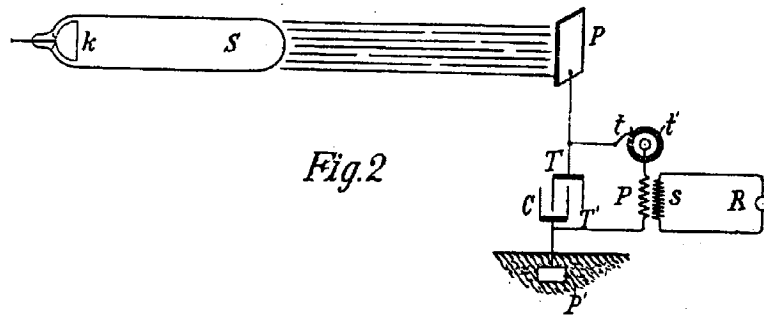


Fig. 2

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Nikola Tesla, Inventor

by *Wm. Page & Cooper* Attys