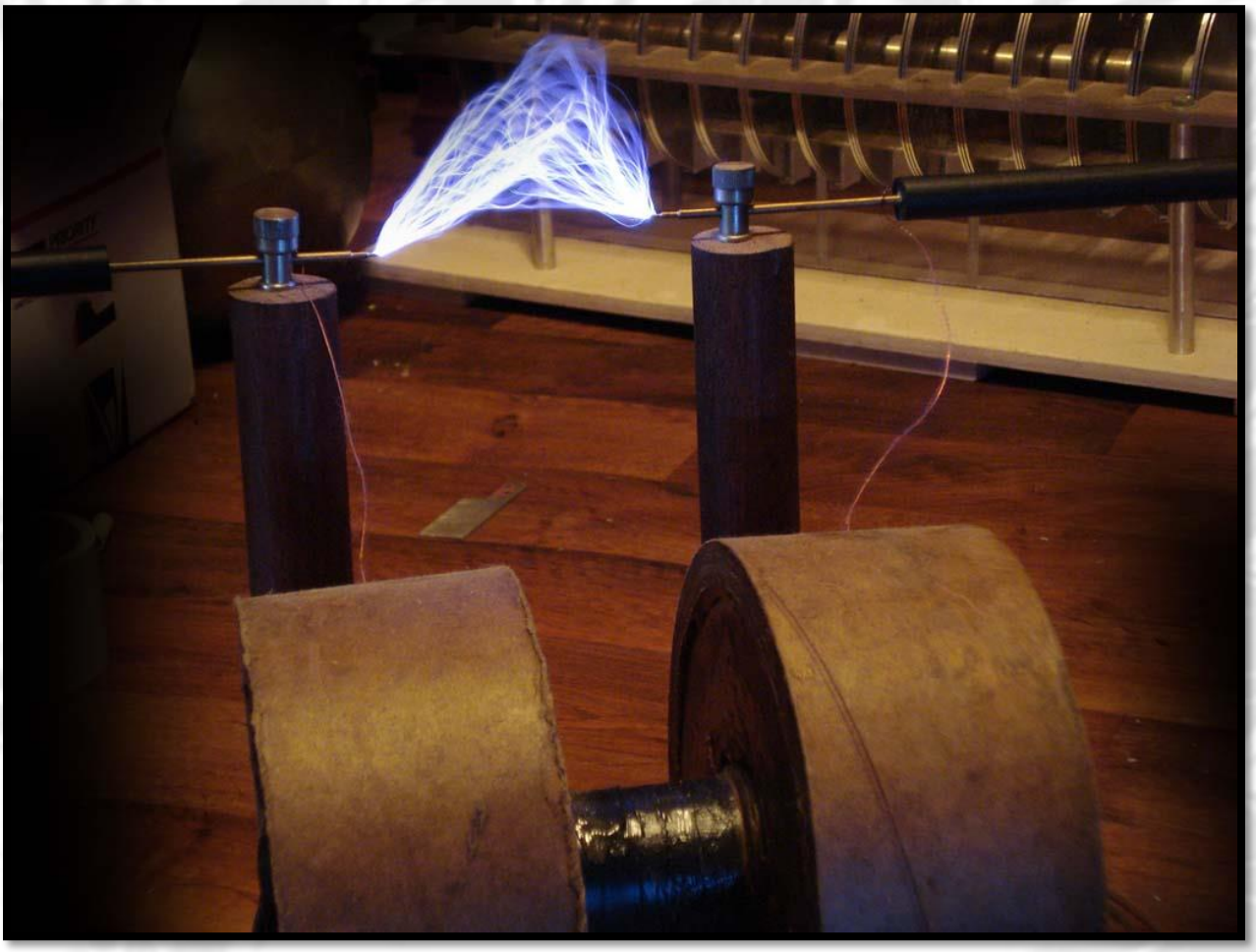


Nikola Tesla:
Electrical Oscillators
November, 1896

Compiled by Jeff Behary of
The Turn Of The Century Electrotherapy Museum
www.electrotherapymuseum.org

29. September 2023

ELECTRICAL OSCILLATORS.

Broadly, this term can be assigned to any appliance capable of producing electrical oscillations. In a more restricted sense I've applied this designation to certain novel induction devices which transform the current or currents obtainable by ordinary methods and apparatus, into electrical oscillations of constant period and generally of a very high frequency, reaching often as much as millions a second.

Electrical vibrations of so high frequencies or rates of vibration are unattainable by purely mechanical means and, to whatever extent such means are employed in the oscillators here considered, they play only a subordinate part, being more or less necessary, but not indispensable adjuncts. This is a feature which distinguishes the oscillators from induction coils or transformers commonly used, in which slow electrical vibrations are obtained by mechanical contrivances and which, on this account, are subject to great limitations, only too well-known to electricians and mechanicians, limitations not only hurtful, but very often fatal to the use of these implements in very many branches of science and industry. In doing away with these restrictions we are opening unsuspected and practically virgin fields for scientific research, and we are affording new and vast opportunities for industrial exploitations. No matter what the future may show, it is certainly being a matter of everyday experience that the above result is completely attained in these new devices. They not only enable us to obtain from ordinary sources of power supply electrical vibrations of practically any frequency desired but, what is most important, the conversion of energy is affected in a highly economical manner.

The fundamental principle, upon which the operation is based, was advanced by me a few years ago and is briefly the following. A condenser is charged from a suitable generator, and the electrical energy stored in it is released more or less suddenly under conditions such that the current impulses are obtained which succeed each other with extreme rapidity. These currents are made the pass through the primary of a transformer, the secondary circuit of which, by inductive action, becomes a source of currents of very high frequency. Generally, the secondary circuit is designed for upward transformation, that is, it contains more turns than the primary, and consequently the currents are of a much higher electromotive force, which can be given almost any value desired. In this respect there seems to be no practical limit and sparks or discharges through the air of many feet in length can be easily obtained with few turns of secondary wire.

To make the method of operation here involved clear to non-technical men it should be stated that a condenser is a device capable of storing electrical energy in a manner similar to a gas

or spring under compression. This stored energy is of a more or less explosive nature and, when suddenly released, manifests itself in the form of electrical vibrations as light, heat and other forms of electrical energy. Although the detonating character of the stored electrical energy and it's mode of discharge or explosion was well known to scientific men it is a fact, that the principal was not made use of in practical converters or induction coils preceding my announcement in 1891. Even Heinrich Hertz, the acknowledged pioneer in electrical vibrations, was entirely unconscious of the enormous advantages which he might have secured in the prosecution of his classical researchers had he, instead of using an ordinary induction coil, veiled himself of the principal involved in the operation of these oscillators. No better illustration of the advances made in these new implements can be given then stating what daily experience has confirmed, that even a comparatively small transformer of this kind, manufactured for less than a few percent of the cost, can, for the majority of uses, outdo the famous induction coil of Spottiswoode. With this fact before us it needs no further argument to convince anyone that the induction coil, as known of old, is soon to become a thing of the past. This is in itself a result of a magnitude such as to enlist the serious attention of all those engaged in electrical research and exploitation.

The evolution of the practical instruments has been a gradual one, involving a number of years of study and experimentation in departments but imperfectly known. During these investigations I discovered, amongst other things, the important part which the presence of gaseous matter plays an induction devices in general, and by a suitable mode of construction I was able to remove this chief cause of inefficiency and trouble. While the fundamental principle has been used in expanded very important departures have been made, particularly in the adaptation of the transformers to ordinary circuits of supply. Great difficulties had to be overcome in the construction of the condensers, inductive circuits and breaks, modes of insulation, regulation in many other features, but the results have been a generous reward for all labors. Practical implements have finally resulted, which are of extremely simple, cheap and compact construction, which are easily taken care of and work with high economy on common, either alternating or direct currents of supply. They can be, however, easily adapted to any other source of electrical energy. In one form of electrical oscillator, eminently suited for physicians applying Roentgen’s discoveries and for experimenters in general, both alternating and direct currents may be used with equally good results, and furthermore by a simple adjustment the transformer may be made to suit any working pressure within very wide limits.

Devices possessing such advantageous features are so much needed and the benefits which will be derived from their use appears so great that I sincerely believe them to constitute a very

valuable contribution to electrical science and industry. A few of the most obvious uses of these transformers may be cited here:

1) Lighting. The currents of extremely high frequency obtained lend themselves admirably to lighting by phosphorescent tubes and bulbs. Whatever the ultimate form of illumination device may be it is very probable that it will be operated by such currents, and that therefore the method and apparatus based on the fundamental principle here used will play an important part in the system. It is a fact, however, that under certain conditions ordinary lamps may be operated more economically with high frequency currents, and it may therefore be quite practicable to convert the ordinary currents in a factory or dwelling for this purpose, as little loss is incurred in the conversion and a certain additional advantages would be gained in doing so. Furthermore, arc-lamps, or lamps of any voltage, high or low, maybe easily operated from such an oscillator.

2) Manufacturer of chemical products. Currents of a high frequency and high potential excite in an extraordinary way chemical activities and, with the experience that I have so far gained, I do not hesitate to say that the time is not far off when we show manufacture nitric acid, ammonia, sulfuric acid, argon and such bodies on a commercial scale by the use of these currents. It is a fact that the nitrogen of the atmosphere enters into combination with the oxygen under certain conditions of high-frequency discharge. The currents seem also capable of producing specific effects in the fusion of bodies, so that there appears to be another Field opening up for research.

3) Production of ozone for sanitary and Industrial uses. For these purposes it appears difficult to offer a more effective and simple machine. The advantages offered are so great that a competition of old apparatus is entirely out of the question. To give a simple illustration, a small oscillator, taking no more than the energy of one lamp, will, by a judicious determination of quantities, cover with active streamers a surface of one square foot. Such a surface would require a very expensive apparatus of ordinary make and, besides, the production of ozone would be less efficient because of the low frequency of the currents.

4) For the professional applications of discoveries of Roentgen by physicians these transformers seem to be ideal instruments. They're extraordinary effectiveness I attribute to the suddenness and enormous electrical pressures which are obtainable, even in a very small apparatus. To again cite an example, I have been able to locate bullets in various parts of the body, even in the most difficult places and embodies of men of more than usual physical development. And this with such an oscillator taking in normal operation no more energy than that needed to light an ordinary incandescent lamp. The photographs taken by means of such

instruments reveal an astonishing amount of detail, and by their employment the value of Roentgen's discoveries will be much enhanced.

5) For the general conversion of electrical energy these transformers are excellently suited. By their help we can convert a direct or alternating current in very many ways and obtain energy for the operation of any kind of devices. With this object in view a special form may be constructed suitable for all kinds of specific uses.

6) For electrotherapeutic treatment and generally medical use it is easy to provide a small oscillator going into a compass of a few cubic inches only and involving but a trifling expense for its manufacturer.

7) Photography. Under certain conditions it is possible to produce with these new appliances light in the vacuum tube of any, up to several hundred candlepower, of intense electrochemical activity, and thus photography may be made independent of sunlight.

8) The transmission of signals can be affected at considerable distances by the use of high frequency currents and in many instances the wires used in the signaling can be done away with. I believe that there are large fields for the use of these appliances open in this and similar directions.

9) For the operation of devices requiring constant movement or generally in apparatus of precision the oscillators will prove valuable, as they furnish currents of rigorously constant period and if any frequency desired.

10) As a laboratory appliance the oscillator affords a much simpler, cheaper and incomparably more efficient and effective apparatus than the old induction coil. It only need to be stated that, owing to the extreme rapidity with which the current succeed each other in the primary, there is no fine wire needed in the secondary circuit. Thus the principal item of cost and cause of inefficiency present in the old apparatus is removed in the new form of coil. To give an idea to a practical man I might state that it is possible, with large facilities, to manufacture a thoroughly finished instrument which will give a spark of one foot in length for probably less than $15. But cheapness alone does not convey an adequate idea of the advantages offered. One will better appreciate these when considering that in most cases where ordinary induction coils are operated from common Supply circuits, owing to the very low frequency obtainable by mechanical means and by the necessity of using few turns, and consequently heavy currents in the primary coil, there is a great power consumption attendant to the operation of such an instrument. Often as much as 5 H.P. have to be expended to secure a stream of sparks 8 to 10 inches. With the improved

induction devices such a result requires an expenditure of energy of certainly no more than that needed for lighting to incandescent lamps.

A special effort has been made to adapt the oscillators to various specific uses. Thus a number of types have resulted which are now ready to be introduced. An important feature is that the facilities for manufacture do not call for great outlay, and that the completion of a great number of transformers would require but little time.

The following types have been fully developed and photographs, working drawings and other particulars of construction can be had at short notice.

1) Smallest size made, capable of being operated both from direct and alternating current circuits, suitable for amateur work, electrotherapeutics and generally such uses where a small amount of energy is required.
2) Small transformer for Roentgen Ray work giving 6-in sparks and enabling location of bullets or foreign substances in any part of the body. The performances of the instrument are much superior to those of even very large coils of ordinary make. The consumption of energy is less than 60 watts, that is considerably less than that taken by two incandescent lamps. The instrument operates on both direct and alternating supply circuits.
3) Small transformer for ozone production and such uses, suitable for both alternating and direct currents. Can also be employed to advantage for many other purposes.
4) An oscillator of larger size, especially constructed to give the greatest suddenness of discharge, which is required in many instances. This will be especially suitable for those who desire the production of powerful effects with Roentgen Rays. Alternating and direct currents can be used in the operation. There is afforded a facility for easy regulation and reversal of currents. The spark length is about 12 in, but can be made much more, if so desired
5) An oscillator design especially for direct circuits with rotating interrupter and facility for varying the speed. This appliance is suitable for general purposes.
6) Oscillator with very rapidly rotating brake, very compact and specially adapted for running lighting devices.
7) A large oscillator with rotating interrupter and condenser in divisions, allowing a number of adjustments to render it suitable for a variety of use.
8) Working drawings of apparatus used in the manufacture of condensers and coils by improved process, found indispensable for satisfactory results, with all the practical details of the procedure.

Some of the results obtained with the perfected oscillator, recently completed, have been shown to a few competent men, and it can be stated without exaggeration that they have been found remarkable.

As to the demands, it is very great, as is evident from a great many letters and inquiries daily received, and there is not the famous doubt that thousands of these instruments can be disposed of at once advantageously in view of the imperfection and inadequacy of the present induction devices.

As to the patents, in the United States the following, relating to the fundamental features of the production and uses of high frequency currents, have been taken out:

No. 462,418, for method and apparatus of electrical conversion and distribution;
No. 454,622, for a system of electrical lighting;
No. 568,176, apparatus for producing electrical currents of high frequency and high potential;
568,177, apparatus for producing ozone and such chemical products;
568, 178, method of regulating apparatus for producing currents of high frequency;
No. 568,178, methods of an apparatus for producing currents of high frequency;
No. 568,180, apparatus for producing electrical currents of high frequency;
No. 567,818, electrical condenser.

Besides these there are a number of applications on more or less important features in the U.S. Patent Office.
As to Germany, the inventions disclosed in the above named patents, except 567,818, have been covered by a patent already issued and by two applications now in the office. The last patent referred to, namely number 567,818, will be applied for.
Practically the same state of things exists in the following countries colon great Britain, France, Belgium and Austria. A patent has also been issued in Italy, and Russia and Spain are under consideration.

(Signed) N. Tesla.

Tesla Laboratory
46 E. Houston Street,
New York.

November, 1896.

(No Model.)

N. TESLA.

METHOD OF AND APPARATUS FOR ELECTRICAL CONVERSION AND DISTRIBUTION.

No. 462,418. Patented Nov. 3, 1891.

Fig. 1

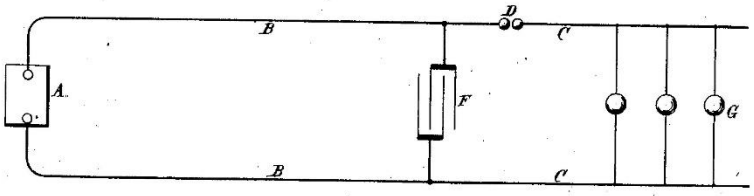
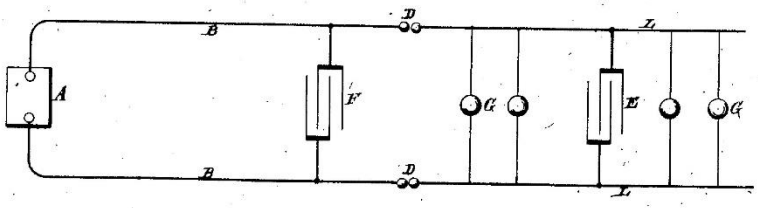


Fig. 2



Witnesses:
Raphael Netter
Frank B. Murphy.

Inventor
Nikola Tesla
by Duncan & Page.
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 formulæ 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 herein described, which consists in charging a con-

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

2. In a system of electrical conversion, the combination of a generator or source of electricity and a line or generating circuit containing a condenser or possessing capacity, 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 adjusted that an intermittent or oscillating disruptive discharge from the generating into the working circuit will be maintained, as set forth.

NIKOLA TESLA.

Witnesses:
ROBT. F. GAYLORD,
PARKER W. PAGE.

(No Model.)

N. TESLA.

SYSTEM OF ELECTRIC LIGHTING.

No. 454,622. Patented June 23, 1891.

Fig. 1

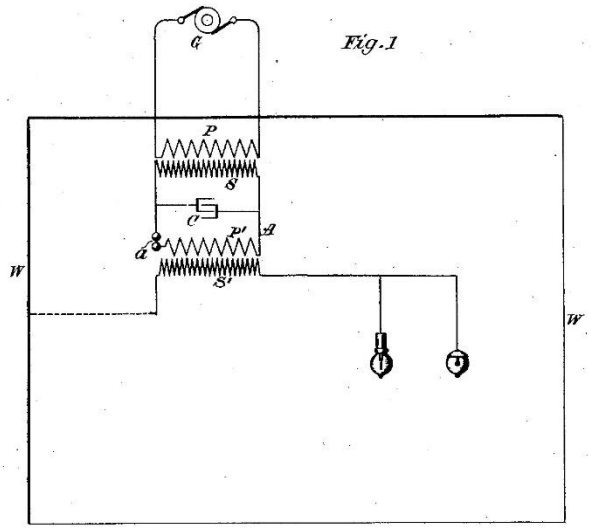


Fig. 2

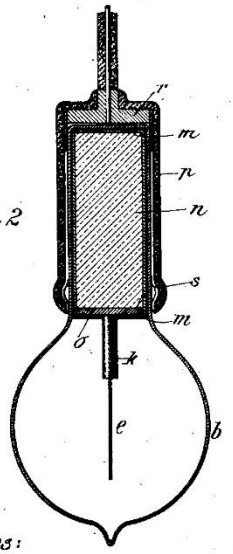
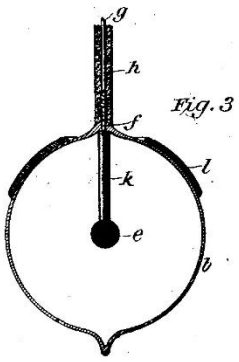


Fig. 3



Witnesses:
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Attorneys.

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 capability 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 *a*, 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 conductors 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.

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Witnesses:
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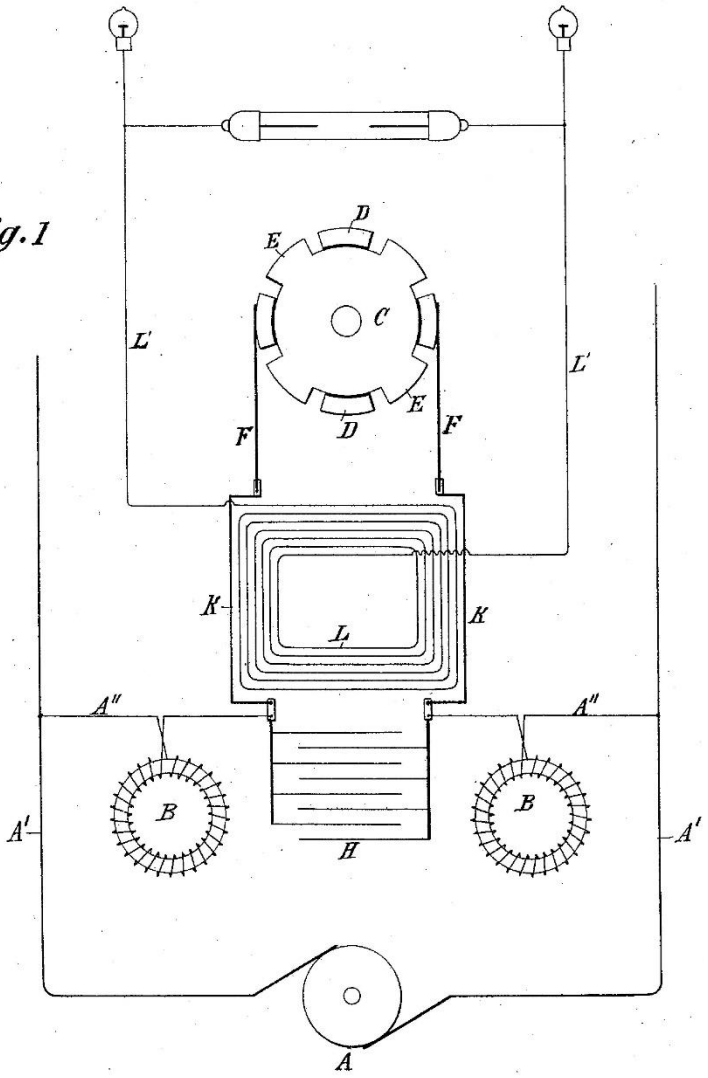
(No Model.) 2 Sheets—Sheet 1.

N. TESLA.

APPARATUS FOR PRODUCING ELECTRIC CURRENTS OF HIGH FREQUENCY AND POTENTIAL.

No. 568,176 Patented Sept. 22, 1896.

Fig. 1



Witnesses:
Raphael Netter
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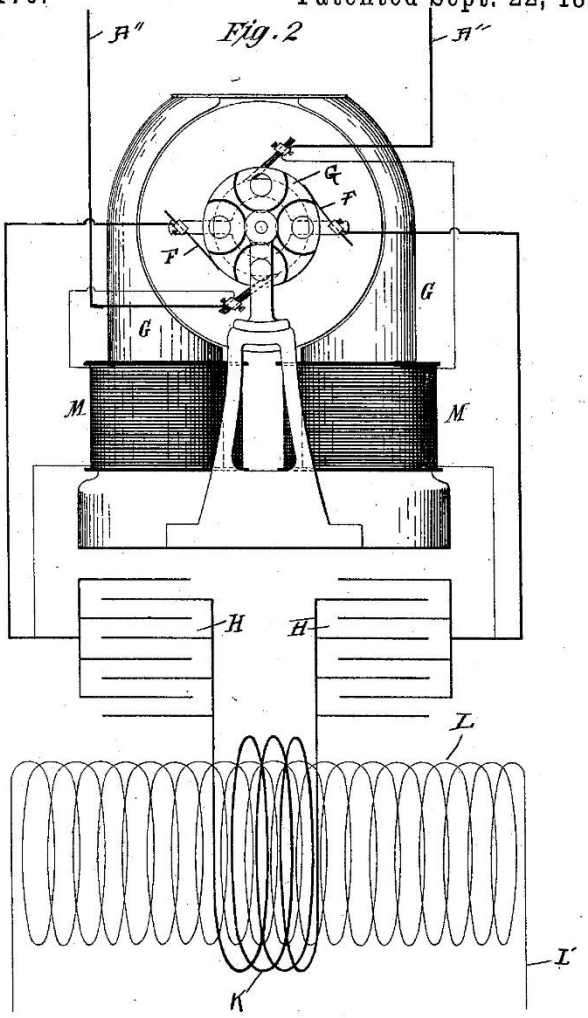
(No Model.) 2 Sheets—Sheet 2.

N. TESLA.

APPARATUS FOR PRODUCING ELECTRIC CURRENTS OF HIGH FREQUENCY AND POTENTIAL.

No. 568,176. Patented Sept. 22, 1896.

Fig. 2



WITNESSES:
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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 interpose 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.

L' 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.

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Witnesses:
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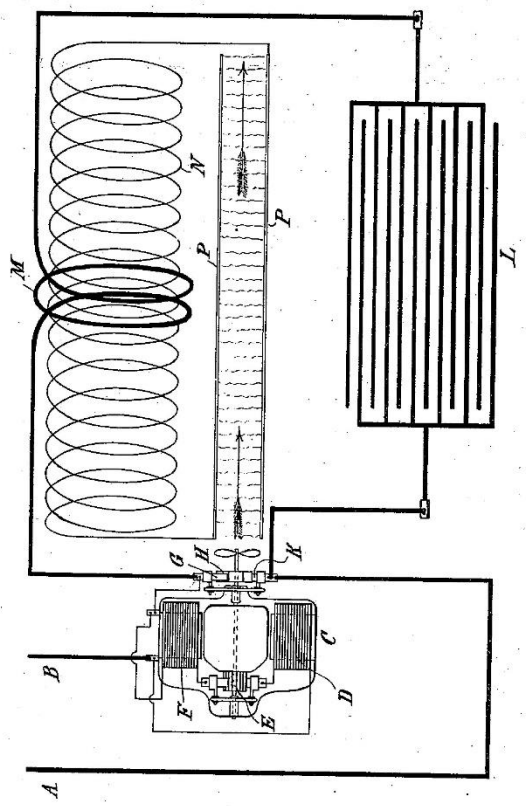
(No Model.) 2 Sheets—Sheet 1.

N. TESLA.

APPARATUS FOR PRODUCING OZONE.

No. 568,177. Patented Sept. 22, 1896.

Fig. 1.



Witnesses:
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Drury W. Cooper

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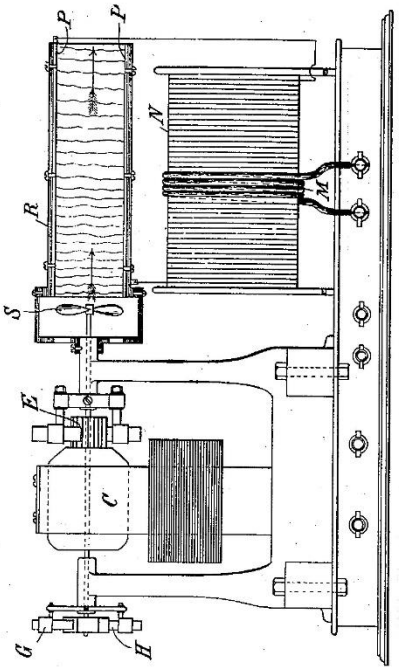
(No Model.) 2 Sheets—Sheet 2.

N. TESLA.

APPARATUS FOR PRODUCING OZONE.

No. 568,177. Patented Sept. 22, 1896.

Fig. 2



Witnesses:
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UNITED STATES PATENT OFFICE.

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APPARATUS FOR PRODUCING OZONE.

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

Application filed June 17, 1896. Serial No. 595,927. (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 effects 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,
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(No Model.) 2 Sheets—Sheet 1.

N. TESLA.

METHOD OF REGULATING APPARATUS FOR PRODUCING CURRENTS OF HIGH FREQUENCY.

No. 568,178. Patented Sept. 22, 1896.

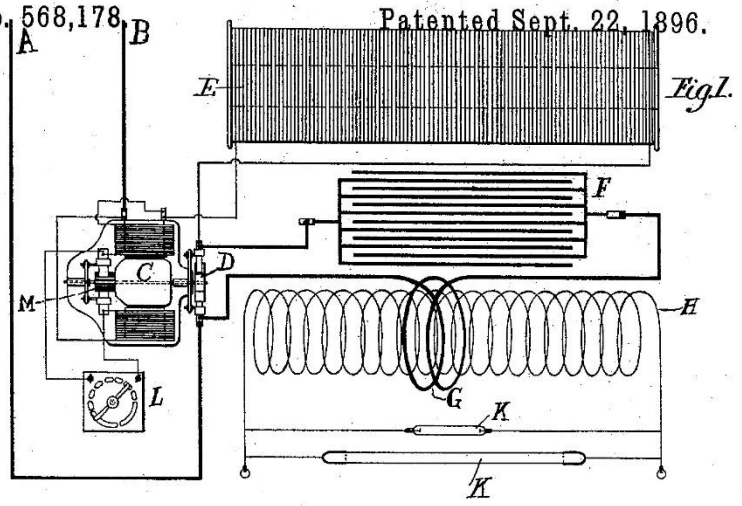
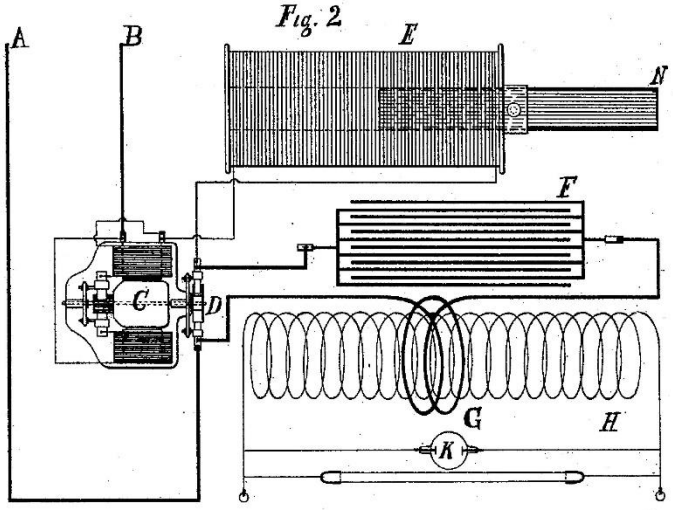


Fig. 1.

Fig. 2



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METHOD OF REGULATING APPARATUS FOR PRODUCING CURRENTS OF HIGH FREQUENCY.

No. 568,178. Patented Sept. 22, 1896.

Fig. 3.

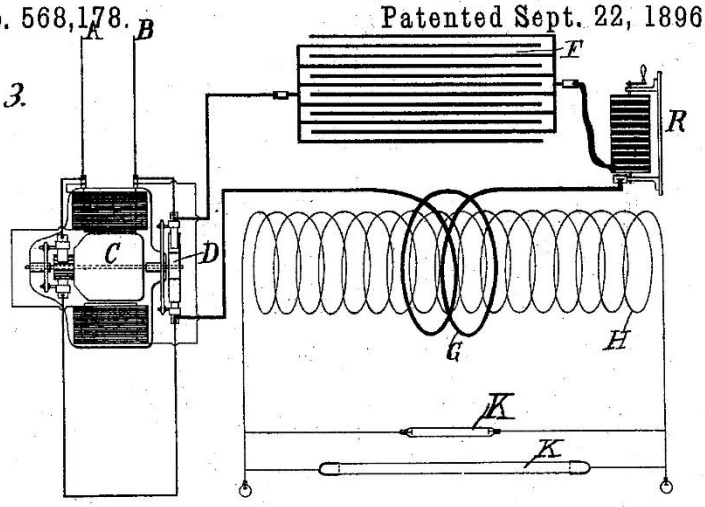
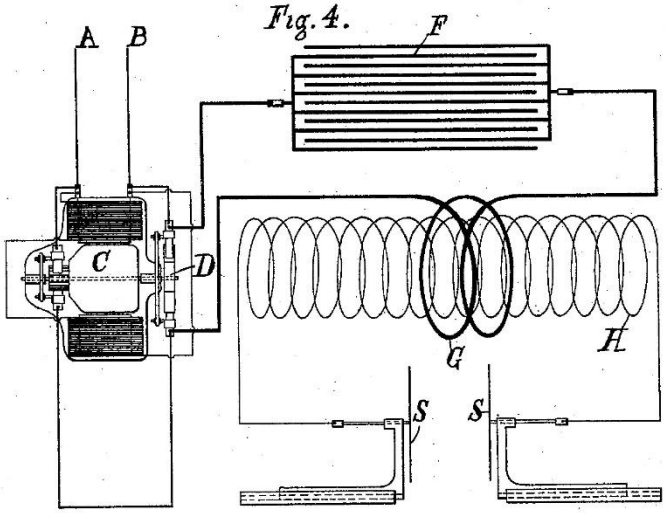


Fig. 4.



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UNITED STATES PATENT OFFICE.

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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. 596,262. (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-controller 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" circuits, 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.

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 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 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 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 impulses in the said circuits, as herein set forth.

NIKOLA TESLA.

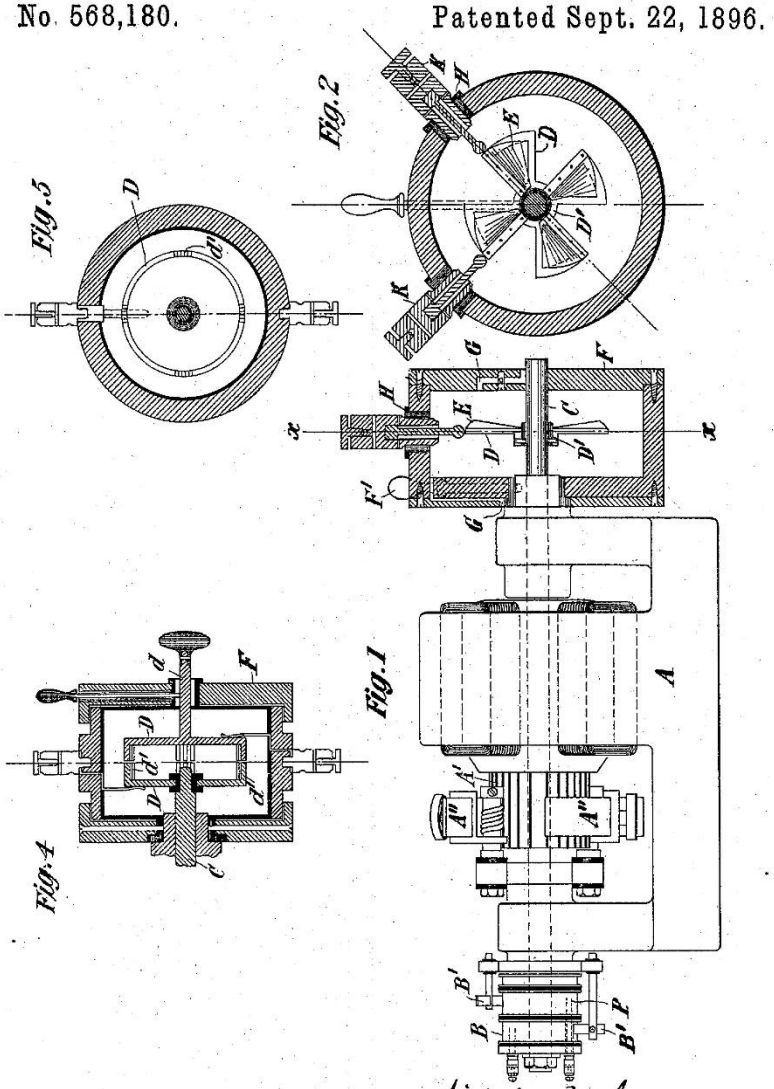
Witnesses:
M. LAWSON DYER,
DRURY W. COOPER.

(No Model.) 2 Sheets—Sheet 1.

N. TESLA.

APPARATUS FOR PRODUCING ELECTRICAL CURRENTS OF HIGH FREQUENCY.

No. 568,180. Patented Sept. 22, 1896.



WITNESSES:

Edwin B. Hopkinson.

Benjamin Burleigh

Nikola Tesla, INVENTOR

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Kerr, Curtis & Page, ATTORNEYS

(No Model.) 2 Sheets—Sheet 2

N. TESLA.

APPARATUS FOR PRODUCING ELECTRICAL CURRENTS OF HIGH FREQUENCY.

No. 568,180. Patented Sept. 22, 1896.

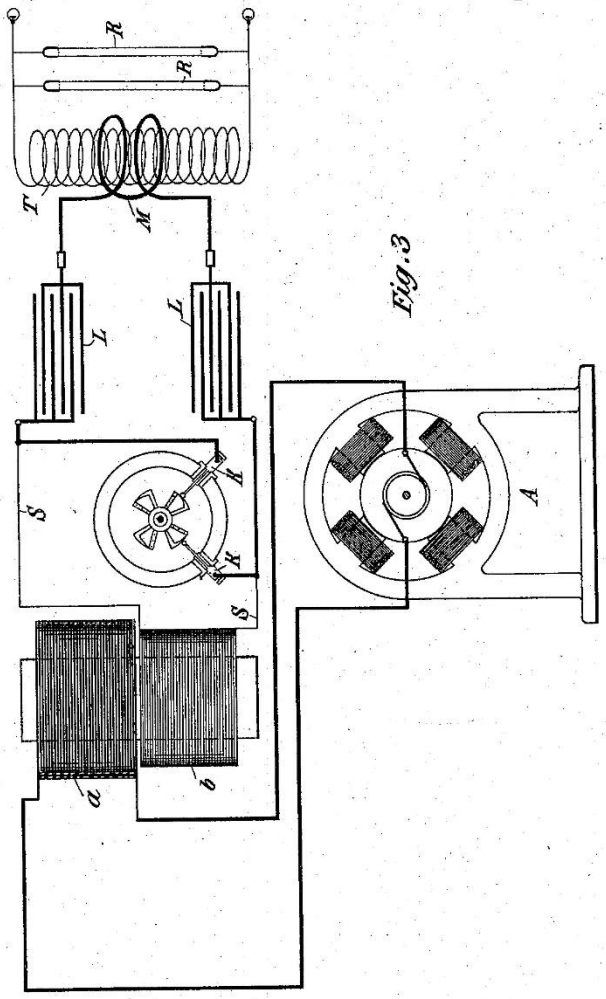

Fig. 3

WITNESSES:

Edwin B. Hopkinson.

Benjamin Barker Jr.

Nikola Tesla INVENTOR

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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

APPARATUS FOR PRODUCING ELECTRICAL CURRENTS OF HIGH FREQUENCY.

SPECIFICATION forming part of Letters Patent No. 568,180, dated September 22, 1896.

Application filed July 9, 1896. Serial No. 598,552. (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 Electrical 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.

This invention is an improvement in apparatus for producing electrical currents of high frequency in accordance with the general plan heretofore invented and practiced by me and based upon the principle of charging a condenser or circuit possessing capacity and discharging the same through a circuit of low self-induction, so that rapid electrical oscillations are obtained. To secure this result, I employ some means for intermittently charging the condenser and for discharging it through the circuit of low self-induction; and among the means which I have heretofore employed for this purpose was a mechanical contact device which controlled both the charging and the discharge circuit in such manner that the condenser was alternately charged by the former and discharged into the latter.

My present improvement consists in an apparatus for effecting the same result by the use of a circuit-controller of special character in which the continuity of the paths for the current is established at intervals by the passage of sparks across a dielectric.

In carrying out my present improvement I employ a circuit-controller containing two terminals or sets of terminals movable with respect to each other into and out of proximity, and I provide means whereby the intervals between the periods of close approximation, during which the spark passes, may be adjusted so that when used in a system supplied by a source of alternating current the periods of make and break may be timed with reference to a phase of the current wave or impulse.

Referring to the drawings, which illustrate in its preferred form the improvement above referred to, Figure 1 is a view, partly in elevation and partly in section, of a generator arranged to give an alternating current with the circuit-controller mounted on its shaft. Fig. 2 is a section of the controller of Fig. 1 on line $x\,x$ of said figure. Fig. 3 is a diagram illustrating the system or apparatus as a whole. Figs. 4 and 5 are sectional views of a modified form of circuit-controller.

A designates in Fig. 1 a generator having a commutator A′ and brushes A″ bearing thereon, and also collecting-rings B B, from which an alternating current is taken by brushes B′ in the well-understood manner.

The circuit-controller is mounted in part on an extension of the shaft C of the generator, and in part on the frame of the same, or on a stationary sleeve surrounding the shaft. Its construction in detail is as follows: D is a metal plate with a central hub D′, which is keyed or clamped to the shaft C. The plate is formed with segmental extensions corresponding in number to the waves of current which the generator delivers. These segments are preferably cut away, leaving only rims or frames, to one of the radial sides of which are secured bent metal plates E, which serve as vanes to maintain a circulation of air when the device is in operation. The segmental disk and vanes are contained within a close insulated box or case F, mounted on the bearing of the generator, or in any other proper way, but so as to be capable of angular adjustment around the shaft. To facilitate such adjustment, a screw-rod F′, provided with a knob or handle, is shown as passing through the wall of the box. The latter may be adjusted by this rod, and when in proper position may be held therein by screwing the rod down into a depression in the sleeve or bearing, as shown in Fig. 1. Air-passages G G are provided at opposite ends of the box, through which air is maintained in circulation by the action of the vanes. Through the sides of the box F and through insulating-gaskets H, when the material of the box is not a sufficiently good insulator, extend metallic terminal plugs K K, with their ends in the plane of the conducting segmental disk D and adjustable radially toward and from the edges of the segments. This or similar devices are employed to carry out the invention above referred to in the manner illustrated in Fig. 3. A in this figure represents any source of alternating current

the potential of which is raised by a transformer, of which *a* is the primary and *b* the secondary. The ends of the secondary circuit S are connected to the terminal plugs K K of an apparatus similar to that of Figs. 1 and 2 and having segments rotating in synchronism with the alternations of the current source, preferably, as above described, by being mounted on the shaft of the generator when the conditions so permit. The plugs K K are then adjusted radially, so as to approach more or less the path of the outer edges of the segmental disk, and so that during the passage of each segment in front of a plug a spark will pass between them, which completes the secondary circuit S. The box or the support for the plugs K is adjusted angularly, so as to bring the plugs and segments into proximity at the desired instants with reference to any phase of the current-wave in the secondary circuit and fixed in position in any proper manner. To the plugs K K are also connected the terminals of a condenser or condensers L, so that at the instant of the rupture of the secondary circuit S by the cessation of the sparks the energy accumulated in such circuit will rush into and charge the condenser. A path of low self-induction and resistance, including a primary M of a few turns, is provided to receive the discharge of the condenser, when the circuit S is again completed by the passage of sparks, the discharge being manifested as a succession of extremely rapid impulses. The potential of these impulses may be raised by a secondary T, which constitutes the source of current for the working circuit or that containing the devices R for utilizing the current.

By means of this apparatus effects of a novel and useful character are obtainable, but to still further increase the efficiency of the discharge or working current I have in some instances provided a means for further breaking up the individual sparks themselves. A device for this purpose is shown in Figs. 4 and 5. The box or case F in these figures is fixedly secured to the frame or bearing of the generator or motor which rotates the circuit-controller in synchronism with the alternating source. Within said box is a disk D, fixed to the shaft C, with projections *d'* extending from its edge parallel with the axis of the shaft. A similar disk D'' on a spindle *d*, in face of the first, is mounted in a bearing in the end of the box F with a capability of rotary adjustment. The ends of the projections *d'* are deeply serrated or several pins or narrow projections placed side by side, as shown in Fig. 4, so that as those of the opposite disks pass each other a rapid succession of sparks will pass from the projections of one disk to those of the other.

What I claim as my invention is—

1. The combination with a source of current, of a condenser adapted to be charged thereby, a circuit into which the condenser discharges in a series of rapid impulses, and a circuit-controller for effecting the charging and discharge of said condenser, composed of conductors movable into and out of proximity with each other, whereby a spark may be maintained between them and the circuit closed thereby during determined intervals, as set forth.

2. The combination with a source of alternating current, of a condenser adapted to be charged thereby, a circuit into which the condenser discharges in a series of rapid impulses, and a circuit-controller for effecting the charging and discharge of said condenser, composed of conductors movable into and out of proximity with each other in synchronism with the alternations of the source, as set forth.

3. A circuit-controller for systems of the kind described, comprising in combination a pair of angularly-adjustable terminals and two or more rotating conductors mounted to pass in proximity to the said terminals, as set forth.

4. A circuit-controller for systems of the kind described, comprising in combination two sets of conductors, one capable of rotation and the other of angular adjustment whereby they may be brought into and out of proximity to each other, at determinate points, and one or both being subdivided so as to present a group of conducting-points, as set forth.

NIKOLA TESLA.

Witnesses:
M. LAWSON DYER,
DRURY W. COOPER.

(No Model.)

N. TESLA.

ELECTRICAL CONDENSER.

No. 567,818. Patented Sept. 15, 1896.

Fig. 2

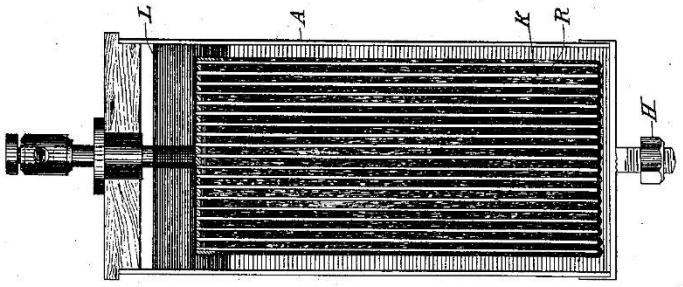
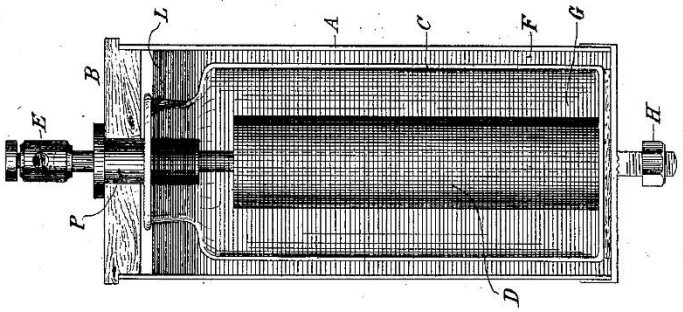


Fig. 1



WITNESSES

Raphael Netter

Harry W. Cupler

INVENTOR

Nikola Tesla

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ATTORNEYS

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

ELECTRICAL CONDENSER.

SPECIFICATION forming part of Letters Patent No. 567,818, dated September 15, 1896.

Application filed June 17, 1896. Serial No. 595,928. (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 Condensers, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

It has heretofore been announced and demonstrated by me that, under ordinary conditions, the efficiency of an electrical condenser is greatly increased by the exclusion of air or gaseous matter in general from the dielectric. In a patent granted to me December 8, 1891, No. 464,667, I have shown and described a convenient and practicable means of accomplishing this result by immersing the conducting-plates or armatures of the condenser in an insulating fluid, such as oil.

My present invention, while based upon this important feature of the practically complete exclusion of air or gas from the dielectric, is an improvement on the forms of condenser heretofore described and used by me.

According to my present invention I employ an electrolyte, or, in general, a conducting liquid in lieu of a solid, as the material for the armatures of the condenser, under conditions more fully hereinafter described, whereby air or gas will be practically prevented from exercising upon the condenser or the more active portions of the same the detrimental effects present in such devices as heretofore made. Such condensers are especially advantageous when used with circuits of great rates of electrical vibration because of the high conducting capacity of such fluids for currents of this character. There is, however, a general advantage derived from the fact that the conducting fluids have a high specific heat, so that the temperature remains constant, a condition in many cases highly advantageous and not met with in condensers of ordinary construction.

In the accompanying drawings, annexed in illustration of the manner in which my improvement is or may be carried into practice, Figure 1 is a view, partly in vertical section, of a condenser constructed in accordance with the invention. Fig. 2 is a part vertical section of a modified form of such condenser.

A designates a jar or receptacle partly or wholly of conducting material and provided with a closely-fitting cap or cover B, preferably of insulating material. Within this receptacle is a smaller jar or vessel C, of insulating material, containing a conducting-electrode D, supported by the cover B, through which passes a suitable terminal E, which may be incased in an insulating-plug P. The spaces within the jars or receptacles are nearly filled with a conducting liquid F G, such as a saline solution, the two bodies of such liquid in the inner and outer receptacles constituting the condenser-armatures. Above the conducting solution in each of the receptacles is poured a layer of oil L or other insulating liquid, which serves to prevent access of air to the highly-charged armatures. The terminals for the two armatures may be provided in various ways, but in such forms of condenser as that illustrated I prefer to utilize the conducting portion of the outer receptacle as one terminal, securing a binding-post to the same, as at H, and to employ an electrode D of suitably-extended surface immersed in the liquid of the inner receptacle and in electrical connection with the binding-post E. It is desirable in some cases to modify the construction of the condenser, as when a larger capacity is required. In such instances, in order to secure the substantial benefits of the improvement above described, I construct the instrument as shown in Fig. 2. In this case I employ a jar or receptacle A which is preferably used also as one terminal and filled with a conducting liquid, as before. Into the latter extends a series of connected conductors K, inclosed and fully insulated from the liquid by a coating of such material as gutta-percha R. These conductors are electrically joined to a terminal E, which extends up through the cover B, and constitute one of the armatures of the condenser. On the surface of the electrolyte or conducting liquid is poured a quantity of oil L, for the purpose above stated. While I have illustrated the invention in its preferred form for general practical purposes, it will be understood that without departure from the invention its construction may be greatly varied and modified.

What I claim is—

1. In an electric condenser constructed or provided with means for the exclusion of air and gas, and an armature composed of a conducting liquid as herein set forth.

2. A condenser comprising as armatures two bodies of conducting liquid electrically insulated and contained in a receptacle from which air and gas are excluded.

3. A condenser comprising two bodies of conducting liquid electrically insulated and contained in a receptacle, and a seal of insulating liquid on the surfaces of the liquid, as set forth.

In testimony whereof I have hereunto set my hand this 15th day of June, 1896.

NIKOLA TESLA.

Witnesses:
DRURY W. COOPER,
M. LAWSON DYER.