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METHOD AND APPARATUS FOR PRODUCING HIGH TENSION UNIDIRECTIONAL DISCHARGE.

APPLICATION FILED FEB. 23, 1917.

1,281,673. Patented Oct. 15, 1918.

3 SHEETS—SHEET 1.

Fig. 1.

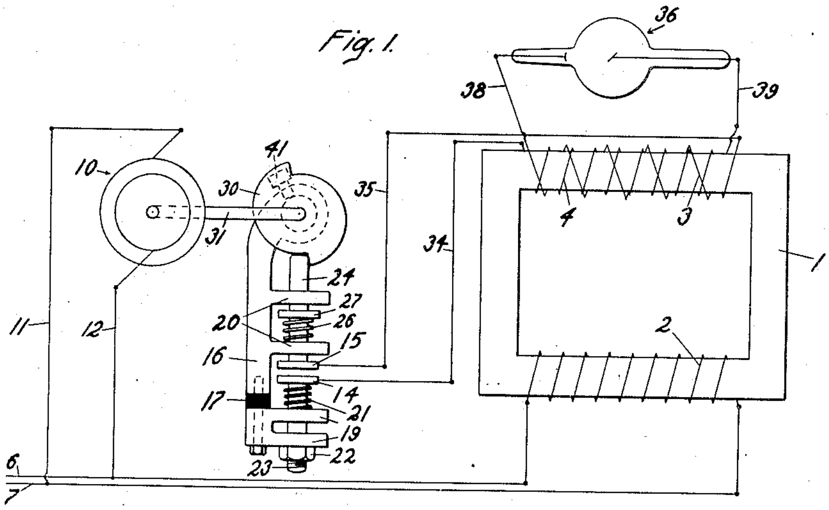


Fig. 2.

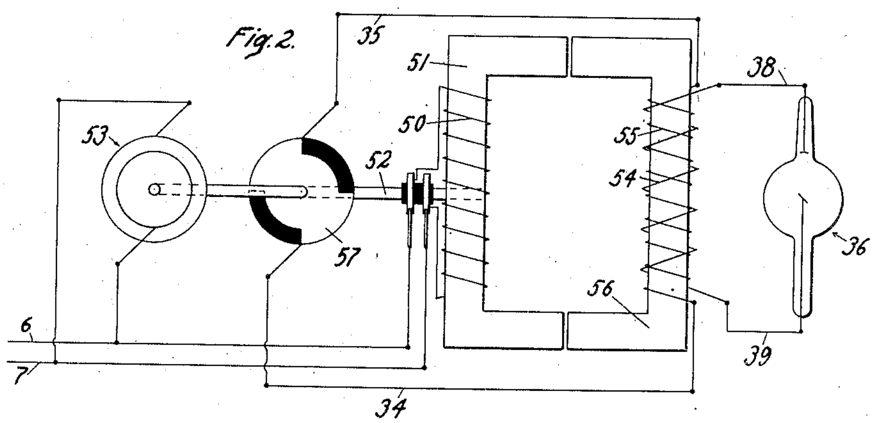
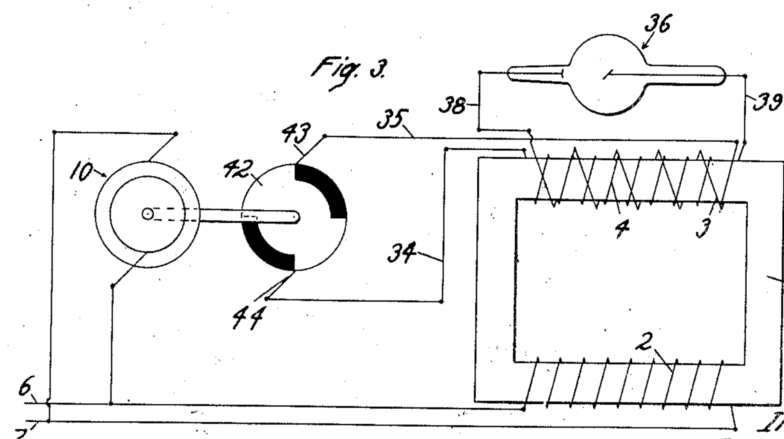


Fig. 3.



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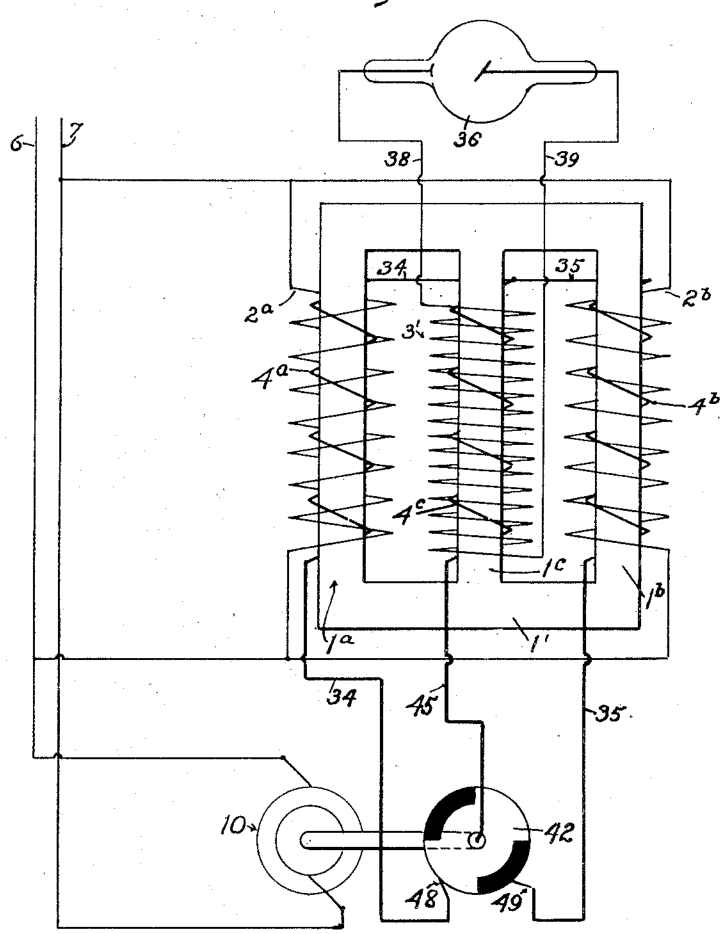
3 SHEETS—SHEET 2.

Fig. 4.



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3 SHEETS—SHEET 3.

Fig. 5

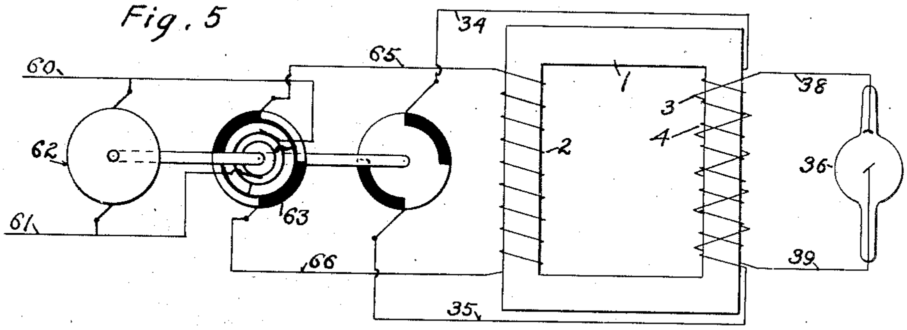


Fig 6.

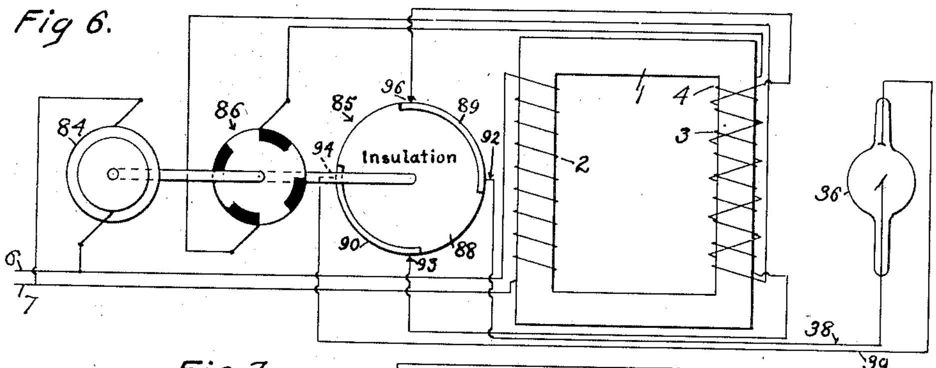


Fig. 7.

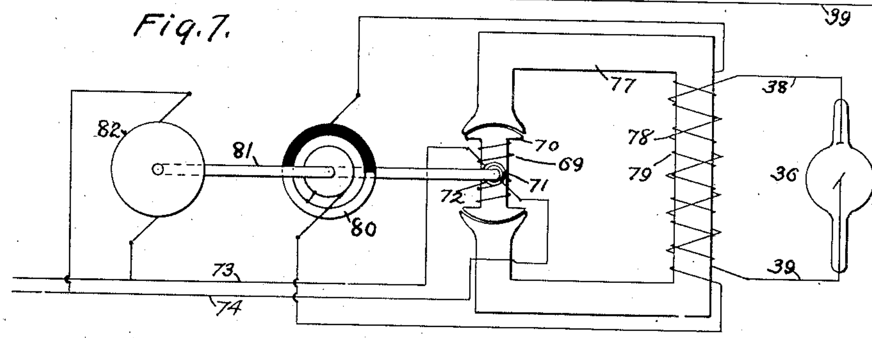
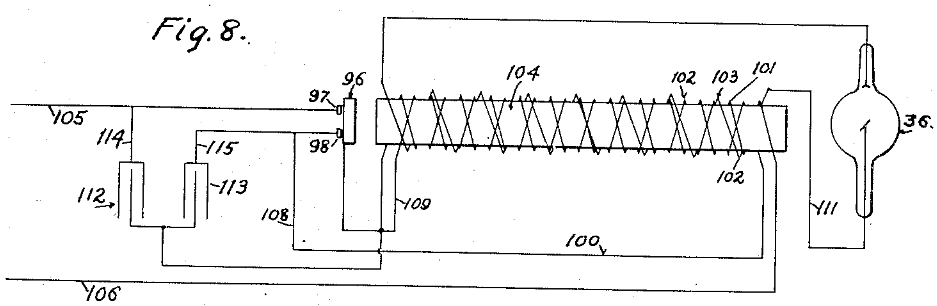


Fig. 8.



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UNITED STATES PATENT OFFICE.

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METHOD AND APPARATUS FOR PRODUCING HIGH-TENSION UNIDIRECTIONAL DISCHARGE.

1,281,673. Specification of Letters Patent. Patented Oct. 15, 1918.

Application filed February 23, 1917. Serial No. 150,305.

To all whom it may concern:

Be it known that I, JAMES E. SEELEY, a citizen of the United States, residing at Los Angeles, in the county of Los Angeles, State of California, have invented a new and useful Method and Apparatus for Producing High-Tension Unidirectional Discharge, of which the following is a specification.

This invention relates to means for production of a high tension unidirectional discharge electric current for production of X rays, or for other purposes. It is recognized that X rays or Röntgen rays may be most effectively produced by the use of unidirectional currents of approximately 200,000 volts, such, for example, as may be obtained by rectifying high tension alternating current supplied from a high tension transformer. In order to produce such rectified high tension current, apparatus may be used such as set forth in the patents of Lemp, No. 774,090 and 774,138, Nov. 1, 1904, in which the attempt is made to take only the peaks of waves of the same sign. It has been found however that in the practical operation of apparatus of this character, an arc is always formed at the time of break, with the result that the circuit connection is maintained through the arc in such manner as to allow the current to flow until the potential difference has fallen to a relatively low value. The resulting current of low potential difference supplied to the X ray apparatus not only represents a waste of energy, but on account of its heating effect, it shortens the life of the tube.

An important object of my invention in this connection is to provide for production of high tension unidirectional impulses substantially free from such low tension current.

A further object of the invention is to provide means for applying high tension unidirectional current to an X ray or other circuit without the use of rectifying devices in the high tension connections.

Another object of the invention is to provide for regulation or variation of the high tension current throughout a considerable range.

I have found that unidirectional high tension current impulses, substantially free from undesirable low tension current, may be produced by providing a controlling secondary winding on a step up transformer in addition to the secondary winding connected to the load circuit, and making and breaking the circuit of this controlling winding in synchronism with the magnetic flux in the transformer, the operation of such controlling winding being so timed that the current impulses of one sign induced in the load circuit are increased in tension and the current impulses of opposite sign are eliminated or decreased.

I have also found that by varying the time of control of the controlling circuit, the character of the high tension current, as to tension and intensity, may be varied within a wide range.

The accompanying drawings illustrate embodiments of my invention and referring thereto:

Figure 1. is a diagram showing an apparatus adapted to produce unidirectional high tension current impulses for each alternate half cycle in the alternating current supply circuit.

Fig. 2. is a diagram showing a construction of the apparatus adapted to produce a high tension unidirectional current impulse at each half cycle of the alternating current supply circuit.

Fig. 3. is a diagram showing a modification of the form shown in Fig. 1.

Fig. 4. is a diagram of another form of the invention adapted to produce a unidirectional current impulse at each half wave.

Fig. 5. is a diagram showing a construction of the apparatus adapted for energizing by direct current.

Fig. 6. is a diagram of an apparatus in which the high tension unidirectional discharge is produced at each half cycle, rectification being obtained by commutator means in the high tension circuit, such commutator means being however not intended to break the connection, but only to reverse it.

Fig. 7. is a diagram showing an apparatus in which the variation of magnetic flux required for inducing the high tension current is obtained by rotating a part of the magnetic circuit.

Fig. 8 is a diagram showing an apparatus in which a vibrating interrupter is used for control of the energization and controlling or energy absorbing circuits.

The form of my invention shown in Fig. 1 comprises a transformer having an iron core 1, which is shown as forming a closed iron circuit, said core being for example formed of laminated iron and of any suitable size and shape. On this core are wound a primary winding 2 connected to an energizing circuit, a secondary winding 3 connected to a load circuit and a controlling or energy absorbing winding 4 connected to an energy absorbing circuit. I have obtained the best results by winding the secondary windings on a different part of the core from the primary winding and by making the core such as to provide rather high reluctance. The primary winding 2 may be energized by connection from an alternating current supply circuit indicated at 6 and 7, and said circuit is also connected to operating means for a circuit controlling device for controlling a circuit of the controlling or energy absorbing coil 4, said circuit controlling device being operated in synchronism in the current in the alternating supply circuit 6 and 7. For this purpose a synchronous motor, indicated at 10, may be connected by branch wires 11 and 12 to the alternating current supply 6, 7, said synchronous motor being mechanically connected to the circuit controlling device hereinafter described. The circuit controlling device shown in Fig. 1 comprises a stationary contact 14 and a contact 15, mounted respectively in guide means 19 and 20, insulated from one another as indicated at 17 and carried by an arm 16 which may be rotated around the axis of rotation of the shaft 31 of motor 10, and may be provided with fastening means 41. The contact device 14 is held in normal position by spring 21, the operation of said contact device by said spring being adjustably limited by a nut 22 screwing on the stem 23 of said contact device. Contact device 15 is provided with a stem 24 sliding in the guide means 20 and a spring 26 engages a collar 27 on said stem, so as to tend to move said contact device 15 to position for opening the circuit. Said contact device is moved to position to close the circuit by means of a cam 30 mounted on a shaft 31 which is operated by the synchronous motor 10 aforesaid. Contacts 14 and 15 are connected to winding 4 of the transformer by wires 34 and 35. The load circuit connected to winding 3 includes a load device 36, such as an X-ray tube, adapted to utilize high tension unidirectional current, and connected by wires 38 and 39 to said winding 3.

The operation is as follows: Alternating current is supplied to the primary winding of the transformer from the circuit 6, 7 and the controlling circuit is controlled by operation of the circuit controller by synchronous motor 10, in synchronism with the alternating current, in such manner that said circuit is maintained closed except during a part of each alternate half wave. When the time and duration of interruption are properly determined, there is produced during such interruption, a high tension current in the secondary load circuit, including the load device 36, said high tension current being unidirectional, and the electromotive force thereof exceeding that of the primary circuit by a far greater ratio than the ordinary ratio of transformation corresponding to the winding ratio of the primary and secondary windings of the transformer. The necessary adjustment to produce maximum tension or any desired tension within the limits of the apparatus, may be obtained by adjusting the nut 22, to change the amount of inward movement of the contact means 14, and thereby change the duration of contact therewith of the movable contact means 15; and by turning the support 16 for said contacts around the axis of rotation to shift the time of break. Or if desired, suitable means may be provided for shifting the cam device around the shaft as in well known devices used in magnetos for the purpose of advancing the spark.

In explanation of the operation of this apparatus it may be stated that alternating current from the circuit 6, 7 produces an alternating magnetic flux in the core, and if the controlling circuit including winding 4 were always open, there would be induced in the secondary winding 3 an alternating current through the load device, the electromotive force in this secondary circuit as compared with that in the energizing circuit, being determined by the winding ratio of the primary and secondary coils. If the controlling circuit of low impedance were kept continually closed, the discharge in the secondary load circuit would be practically eliminated. In the operation of the circuit controlling means 14, 15 by the synchronous motor, the controlling circuit 34, 35 is periodically closed momentarily during each alternate half wave, so that the impulse which would otherwise be produced during such wave, in the high tension circuit, is eliminated. Moreover, when the closure and interruption are properly timed with reference to the phase of the energizing current, the electromotive force produced in the high tension load circuit is many times that which would be produced by direct induction without the action of the controlling winding, and is moreover not determined solely by the winding ratio of the primary and secondary windings, but is out of all proportion to such ratio. The electromotive force produced in the load circuit, under these conditions, is in fact due mainly to the rapid change in magnetic flux in the iron core, by reason of the rapid change in the resistance and current in the controlling circuit. The flux in the magnetic circuit is due to the resultant of the magnetomotive forces produced by the primary and secondary currents, and any sudden change in any of these currents will produce a corresponding change in the magnetic flux. On account of the low resistance and impedance of the short circuited secondary or controlling circuit, the interruption thereof at the circuit controller produces a comparatively rapid change in the current strength in such circuit, with a correspondingly rapid change in the magnetic flux and thereby induces in the high tension secondary circuit a current of high electromotive force.

Any other form of circuit controlling means may be used for interrupting the controlling circuit. Thus, as shown in Fig. 3, a rotating commutator 42 with brushes 43 and 44 may be interposed in this circuit and operated by the synchronous motor 10.

The circuit controlling means shown in Figs. 1 and 3 are adapted to make two contacts for each revolution, and with such a construction the motor 10 will be adapted to rotate at one-half synchronous speed, so that the times of circuit control are synchronized with the alternating current and take place at each alternate half wave. In case of a motor running at synchronous speed, there will be one contact on the commutator, or one circuit controlling operation effected for each rotation of the circuit controller.

I may provide for utilizing every alternation or half wave of the current in the production of a unidirectional impulse, by suitably constructing the transformer, so that the direction of the magnetic flux, induced by the primary winding, is presented oppositely with reference to the secondary windings, at each alternate half wave, for example, by mechanical rotation of a part of the transformer, the effect of a decreasing positive magnetic flux at any half wave being, with such reversal, equivalent to the effect of a decreasing negative magnetic flux during the next half wave, and the effect on the load circuit is therefore the same in either case. Such a transformer is shown in Fig. 2, wherein the primary or low tension winding 50 is wound on a core or armature member 51 carried by a shaft 52 rotated in synchronism with the alternating current by a synchronous motor 53, the secondary windings 54 and 55 for the load and controlling circuits, respectively, being wound on the stationary core member 56. The circuit controller 57 is also operated by the shaft 52 in synchronism with the alternating current, and the operation is as above described, except that a unidirectional impulse is produced in the load circuit at each alternation of the current.

A unidirectional current impulse may also be produced at each alternation of the energizing current, without the use of relatively moving transformer or generator core parts, by providing for alternate supply to the load circuit, of impulses derived from reversely wound coils brought alternately into operative relation with the load circuit. Thus, as shown in Fig. 4, the energizing circuit 6, 7 may be connected to windings 2^a and 2^b, which are wound oppositely on the two legs 1^a and 1^b of the transformer core 1′. The controlling circuit, in this case, has two branches 34 and 35 including respective coils 4^a and 4^b and connected respectively to brushes 48 and 49 adapted to make contact alternately with contact means 42, operated in synchronism with the alternating supply current by synchronous motor 10. Said branch circuit connections 34 and 35 are both connected to the contact means 42 through a connection 45 which includes a winding 4^c in inductive relation to a secondary winding 3′ which is included in the load circuit 38, 39. For the sake of convenience, economy, and more effective operation, these windings 4^c and 3′ are preferably wound on a third leg or branch 1^c of the transformer core 1. In the operation of this form of my invention, the alternating current from circuit 6, 7, energizes windings 2^a and 2^b in such manner as to produce an alternating magnetic flux in the cores 1^a and 1^b, the windings being adapted to act in the same direction with respect to the magnetic circuit, so their inductive actions are cumulative in the core parts 1^a and 1^b but neutralize each other in the core part 1^c. There is therefore no direct inductive effect from the energizing windings, on the secondary winding 3′ connected to the load circuit. During certain alternate half cycles, the controlling circuit 34 including winding 4^a is closed at contacts 48, 42, and is interrupted at such time as to produce a sudden change of magnetic flux in the transformer core, with the result that a self inductive current is generated in the controlling winding 4^a and this current, passing in the winding 4^c on the third branch 1^c of the transformer core, induces a high tension impulse in the secondary winding 3′ connected to the load circuit. In the next succeeding half wave, the controlling circuit through winding 4^b on the other core portion 1^b is closed and opened in such manner as to produce another impulse in the secondary load circuit, and the windings are so arranged that these impulses produced during alternate half waves are in the same direction in the winding 4^c, and therefore in the same direction in the secondary winding 3′ and in the load circuit connected thereto.

In case it is desired to produce the unidirectional high tension discharge by electric current from a low tension direct current supply circuit, indicated at 60, 61 in Fig. 5, the said circuit may be connected to a direct current motor 62 and through a rotary contact maker 63 operated by said motor, with the wires 65, 66 leading to the primary winding 2 of the transformer in such manner as to supply intermittent energizing impulses for said transformer. In this case the alternating current required for energization of the transformer is obtained by commutation of the primary current, but the operation is otherwise as above described. Or, as shown in Fig. 7, the transformer may be of the motor generator type, the primary winding 69 being mounted on a rotating armature or core 70 and connected by slip rings 71, 72 to the direct current energizing circuit 73, 74, so as to produce alternating magnetic flux in the stationary core 77 on which are wound the secondary windings 78 and 79, connected respectively to the load circuit and to the controlling circuit, the latter circuit including the make and break device 80, which is mounted on the shaft 81 that carries the armature or core 70 and is driven by the direct current motor 82 energized from aforesaid circuit 73, 74. The armature 70 in this case acts in the same maner as a rotating permanent magnet, and may be replaced by such a magnet.

The advantages of my invention, are; first, that a wave or impulse of proper character for the operation of X-ray tubes and the like, may be generated without any accompanying undesirable waves or impulses; second, that the character of the wave, as to tension and current intensity, may be changed throughout a great range, by changing the time of the break and its relative position with respect to the phase of the energizing current or magnetic flux which change may be effected while the machine is in operation; third, that a current of low tension, say from two to six volts, such as is produced in the controlling coil of few turns, is more easily controlled by make and break than a discharge current of high tension, say upward of 100,000 volts such as is desired in the load circuit; fourth, that on account of the low resistance of the controlling circuit, the effect of the sudden increase of resistance at the break or air gap of the circuit controller is much more effective in controlling the rate of change of magnetic flux than would be the case with a similar break in the high tension circuit, and is correspondingly effective in increasing the tension in the high tension circuit; fifth, that the high tension secondary winding requires less than fifty per cent. of the number of turns usually employed in such devices, for the generation of currents suitable for the production of X-rays, inasmuch as the voltage produced exceeds that due to the ratio of turns of the energizing and load windings; sixth, that the construction may be made much lighter and more compact, and better insulation may be secured, and apparatus may be made at much less cost than apparatus heretofore used for the stated purpose, thereby rendering the X-ray available for use where it has heretofore been prohibited on account of the high cost of the current generating means.

As shown in Fig. 6 a high tension rectifier or commutator 85 may be included in the high tension secondary or load circuit. In this case the motor may operate the circuit controller 86 at full speed of synchronism and said circuit controller may be provided with contact means for closing and opening connection once during each alternation, so that two impulses of high tension current of opposite sign are produced at each cycle, these impulses being rectified by the high tension rectifier 85. Said rectifier may be of any suitable construction for high tension current rectification, comprising, for example an insulating disk 88, carrying contact segments 89, 90 and adapted to connect alternately, in pairs, stationary contacts 91, 92, 93, 94 which are connected in the load circuit as shown.

In place of a rotative circuit controller operated by a synchronous motor, I may especially in case of energization by direct current use a vibratory circuit controller operated by the magnetic core of the transformer, as shown in Fig. 8, wherein 96 indicates an armature normally held by suitable spring means, against back contacts 97, 98 which are included in the circuits 105, 108 of both the primary winding 101 and the controlling secondary winding 102, said windings together with the secondary winding 103 being wound on a common core 104 adapted to attract said armature when energized. On energization of the said core, said armature is caused to break both the primary circuit 105 106 and the secondary controlling circuit 108, 109 of low impedance, with the result that a high tension impulse is produced in the load circuit, 110, 111. By making the armature 96 polarized, it may be caused to operate only during alternate half waves, with the result that only unidirectional impulses are produced in the load circuit. If desired, the contact means described may be constructed to provide for non-simultaneous control of the energizing circuit through winding 101, and the controlling circuit through winding 103, so as to increase or decrease the effect of the controlling winding, as may be desired.

Condensers 112 and 113 may be provided in connections 114 and 115 across the breaks made at contacts 97 and 98, respectively, to reduce the sparking at such breaks, in the usual manner of such devices.

What I claim is:

1. The method of producing unidirectional high tension current in a load circuit, which consists in inducing alternating magnetic flux in a magnetic circuit by the action of an inducing circuit, in inductive relation to the load circuit and controlling the magnetic flux by the action of an electric conducting circuit in inductive relation to said magnetic circuit, said controlling circuit being closed and opened at such times as to increase the tension of the current impulses of one sign induced in the load circuit and to decrease the intensity of the impulses of opposite sign.

2. The method of producing unidirectional current in a load circuit, which consists in producing alternating current in an energizing circuit, in inductive relation to said load circuit, and controlling the inducing action on said load circuit by closing and opening a controlling circuit, of low impedance relatively to said load circuit and in inductive relation to said load circuit and said energizing circuit, at times synchronized with the inductive action on said load circuit, so as to increase the tension of the inducted current of one sign in said load circuit and to decrease the tension of the current of opposite sign in said circuit.

3. An apparatus for production of high tension unidirectional current comprising a transformer having a low tension primary winding with supply connections for receiving alternating current, and a high tension secondary winding with load connections, a controlling circuit including another secondary winding on said transformer and also including circuit controlling means and means for closing and opening said circuit controlling means in synchronism with the alternating magnetic flux induced in the transformer by the alternating current in the primary winding, in such manner as to increase the tension of the induced impulses of one sign in the load connections and to decrease the tension of the impulses of opposite sign.

4. An apparatus for producing unidirectional high tension current, comprising a magnetic core, means for producing an alternating magnetic flux in said core, a load circuit including a winding on said core, a controlling circuit including a winding on said core and also including a circuit controller, and means for operating said circuit controller in synchronism with the alternations of magnetic flux in said core and during alternate half waves thereof, so as to increase the tension of the current produced in the load circuit during half waves of one sign and decrease the tension of the impulses of opposite sign.

5. An apparatus for producing unidirectional high tension current, comprising an alternating energizing circuit, a transformer having an energizing winding connected to said circuit, a secondary winding with load connections, and a controlling winding, all of said windings being in inductive relation, an energy absorbing controlling circuit connected to said controlling winding, and including contacts, and means for making and breaking connection between said contacts in synchronism with the alternating induction produced in said transformer, to increase the tension of the current impulses of one sign produced in the load circuit and to decrease the tension of the current impulses of opposite sign.

6. The method of producing unidirectional current impulses in a load circuit, which consists in energizing by an alternating current, a magnetic circuit in inductive relation to said load circuit, and controlling the energization of said magnetic circuit by closing and opening, in synchronism with the alternating magnetization in said magnetic circuit, an energy absorbing circuit in inductive relation thereto, so as to generate high tension impulses of one sign, in the load circuit by change of magnetization in the magnetic circuit, on opening of the controlling circuit, and to reduce the tension of impulses of opposite sign in the load circuit, by the action of said controlling circuit.

In testimony whereof I have hereunto set my hand, at Los Angeles, California, this 6th day of February, 1917.

JAMES E. SEELEY.