Aug. 2, 1927. 1,637,401

C. S. WEYANDT

METHOD OF AND MEANS FOR CONTROLLING RECIPROCATING MOTORS

Filed March 5, 1924 2 Sheets-Sheet 1

Fig. 1

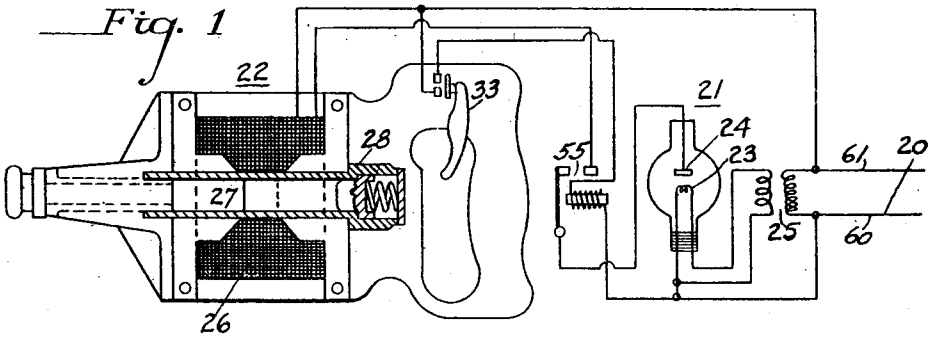


Fig. 2

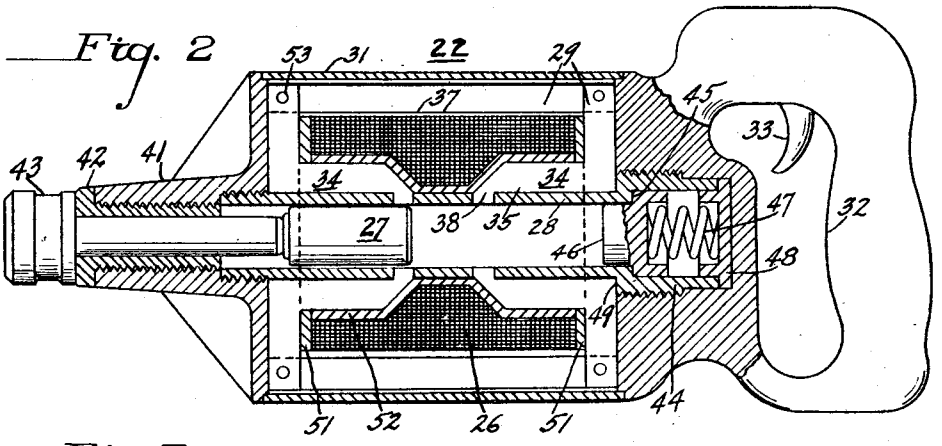


Fig. 3

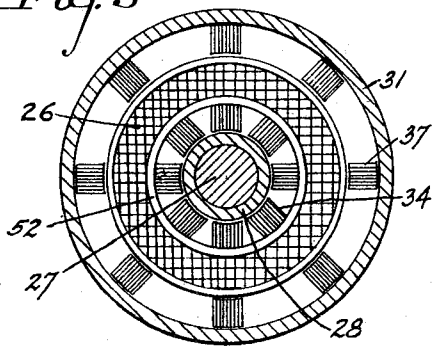


Fig. 4

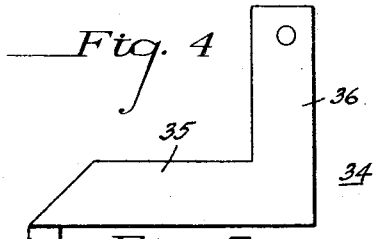


Fig. 5

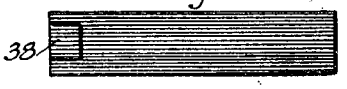
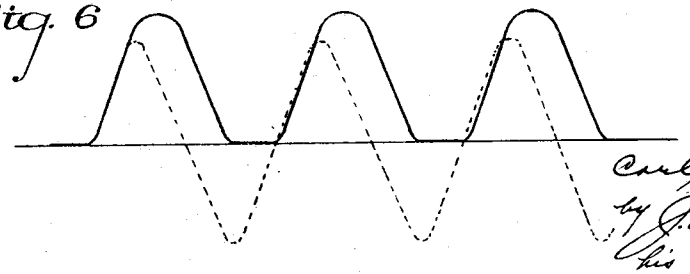


Fig. 6



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METHOD OF AND MEANS FOR CONTROLLING RECIPROCATING MOTORS

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Fig. 7

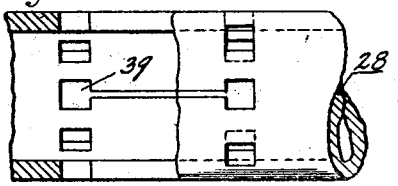


Fig. 8

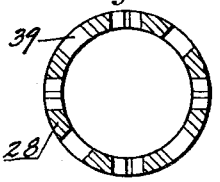


Fig. 9

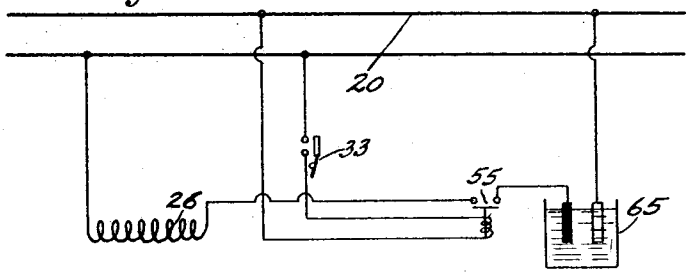


Fig. 10

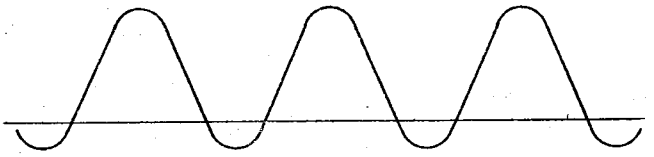
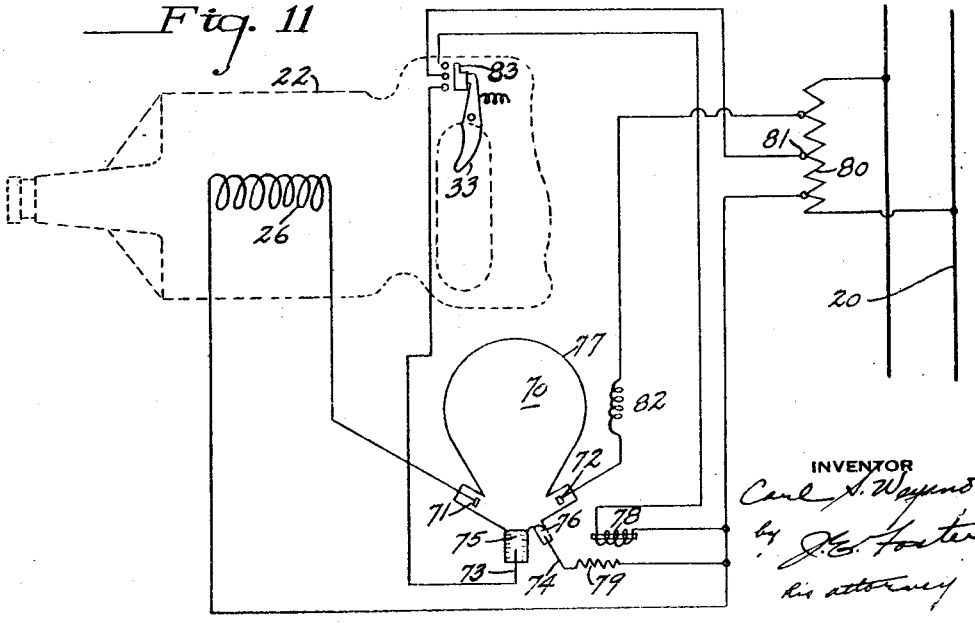


Fig. 11



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Patented Aug. 2, 1927. 1,637,401

UNITED STATES PATENT OFFICE.

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METHOD OF AND MEANS FOR CONTROLLING RECIPROCATING MOTORS.

Application filed March 5, 1924. Serial No. 697,054.

This invention relates to reciprocating electric motors and particularly to a method of and means for controlling the same.

One object of my invention is to provide a novel method of and means for controlling an electric hammer of the reciprocating motor type, whereby the necessity for switching devices, that comprise contact members susceptible to arcing during the operation of a hammer, shall be obviated.

Another object of my invention is to provide an electric hammer system in which only one part or element shall be in motion during the operation of the hammer, viz, the striking or impact element.

Another object of my invention is to provide a system for controlling a reciprocating motor, that shall comprise a closed circuit whereby all energy stored in magnetic flux fields shall be utilized to do useful work instead of being permitted to dissipate, as heat, in arcing between separating contact surfaces.

In the electric hammer which I employ and control in accordance with the principles of my invention, I provide a barrel or guide of non-magnetic material as a guide for a core in a solenoid which constitutes the actuating winding of the motor or hammer. In order to reduce the reluctance of the magnetic circuit, and to concentrate the magnetic flux developed by the actuating winding, I provide a plurality of laminations of substantially C-shape comprising two end portions separated to form an air gap. The laminations are disposed around the solenoid, or winding, with the air gap adjacent the side of the barrel and opposite the middle region of the winding. The tips extend through openings in the barrel to within a few thousandths of an inch from the inner surface of the barrel engaged by the moving core. By reason of the tips being disposed very close to the core, leakage flux is reduced to a minimum and substantially the complete magnetic flux is concentrated upon the core to actuate it in either direction. With this construction the efficiency of the motor is considerably increased over that heretofore obtained.

It has been customary, heretofore, to use switching devices for supplying current impulses to the operating windings of electric hammers to procure a reciprocating movement of the core. Arching between the contact surfaces has always necessitated giving considerable care and attention to the switch devices.

An object of my invention has been to obviate the disadvantages inherent in a system employing switching devices to control the operation of an electric hammer. Instead of a switching device embodying contact surfaces subject to and susceptible to arcing, I provide an asymmetric conductor or electric valve comprising stationary terminals or electrodes for controlling the energization of the hammer operating winding. When connected between an alternating current circuit and the hammer only current waves of predetermined polarity are transmitted, or, in some instances, depending upon the nature of the valve, only preponderatingly unidirectional current impulses. All arcing is thus obviated and all energy is rendered available for useful work.

When applied to a system of the character here considered, the electric valve is particularly advantageous. An electric hammer is highly inductive and the inductance varies as the core reciprocates. Moreover, considerable energy is stored in the magnetic field established in such a device. In a switching device, such as a mechanical rectifier, the switching operation could not always be effected at zero current value. After the switching operation which opens the circuit of the hammer main winding, the energy stored in the magnetic field must dissipate itself in some way. When a mechanical switching device is employed, the energy dissipates itself in the arcing between the contact surfaces, merely as heat. Where an electric valve is employed, however, the circuit is not opened and the complete current energy impulse is transmitted to do useful work. The energy stored in the magnetic field is not now wasted as heat but is transformed into useful energy.

The electric valve, moreover, is automatic in operation. Such a valve is responsive to the polarity of the current traversing a circuit including the valve, and, automatically by electrical action, renders its circuit conductive or non-conductive to currents of one or the other polarity that may be de-

rived from an alternating current circuit. The electric valve does not arbitrarily control the conductivity of a circuit and the transmission of current at a definite time, irrespective of the character of the current, as the mechanical rectifier does, but instead, controls the circuit conductivity and current transmission automatically in accordance with the current polarity.

Electric valves of different kinds may be used. The familiar vacuum valve, commonly used for battery charging and comprising an electron emitting body, such as a heated filament, as the cathode and a plate as the anode, is particularly suitable for this application. It is light in weight, portable, relatively economical and rugged. Such valve transmits current waves of only one polarity from a source of alternating current. The energy impulses are separate and distinct.

The mercury valve or rectifier is similar in operation in that it embodies relatively stationary terminals or electrodes, and transmits the complete energy impulse of waves of one polarity only.

The electrolytic valve or rectifier offers the advantages of stationary electrodes although it transmits preponderatingly unidirectional current energy impulses rather than impulses composed of a current wave of only one polarity. The electrolytic valve transmits, for example, the normal positive current wave and a negative wave of relatively small value. When such a valve is employed to control an electric hammer, the energy transmitted constitutes, in effect, however, unidirectional current impulses.

Solid rectifiers or valves of the metal type, or of the metal to metal type, or of the type in which the element surfaces are in contact, which have unidirectional current conducting characteristics also offer the advantages of stationary electrodes requiring no attention.

Fig. 1, of the accompanying drawings is a diagrammatic view of an electric hammer system containing an electric hammer constructed and controlled in accordance with my invention;

Fig. 2, is a longitudinal view, partially in section, and partially in elevation, of the hammer illustrated in Fig. 1;

Fig. 3, is a sectional view, taken laterally, of the hammer in Fig. 2;

Figs. 4 and 5 are elevational side and bottom views of the laminations employed in the magnetic circuits of the hammer illustrated in Fig. 2;

Fig. 6, is an oscillogram illustrating the wave form of current transmitted by the electronic valve in the system shown in Fig. 1;

Fig. 7, is a longitudinal view, partially in section, and partially in elevation, of the barrel or guide for the core or striking element;

Fig. 8, is a transverse sectional view of the barrel illustrated in Fig. 7;

Fig. 9, is a diagrammatic view of a modified system similar to that shown in Fig. 1 but utilizing an electrolytic valve instead of an electronic valve;

Fig. 10, is an oscillogram illustrating the wave form of current transmitted by the electrolytic valve in the system shown in Fig. 9;

Fig. 11, is a diagrammatic view of a system similar to that shown in Fig. 1 except employing a mercury arc valve.

The arrangement of the system may be understood upon reference to Fig. 1. Energy is derived from an alternating current circuit 20 and transmitted through an electric valve 21, to an electric hammer 22 of the reciprocating motor type.

The electric valve 21 here illustrated is of the electronic type, comprising an electron-emitting element, such as a filament 23, as a cathode, and a plate 24 as an anode. A transformer 25 supplies energy to the filament cathode 23 to render it incandescent and electron-emitting to establish an operative condition in the valve 21 for transmitting current waves of one polarity to the hammer 22.

The hammer 22 comprises, as may be seen in Figs. 2 to 8, inc. an operating coil or solenoid 26, a movable core 27 controlled thereby, a barrel or guide 28 of non-magnetic material, such as bronze, for the core 27, coaxially disposed in the coil 26, laminated magnetic circuit conductors 29 for directing the magnetic force developed by the coil 26, a casing 31 enclosing the coil and the laminated magnetic circuit conductors 29 and a handle 32 provided with a trigger switch 33 for controlling the operation of the hammer.

The laminated magnetic circuit conductors 29 comprise two members of L shape 34 having a base portion 35 and a side portion 36, and a straight connecting member 37. Some of the L shape members 34 are provided with tips 38 disposed at the ends of the base portions 35, that are adapted to fit tightly in openings 39 in the barrel.

The laminations 29 are arranged in sets as illustrated in Figs. 4 and 5. The inner laminations of each set comprise those provided with the tips 38 that fit tightly in the barrel. The laminations thus serve the twofold purpose of locking the coil 26 in predetermined position relative to the barrel 28, and of directing and concentrating the magnetic flux at the most effective position to influence the core.

The tips 38 extend through the side of the barrel to within a few thousandths of an inch from the inner surface of the barrel 28,

which is engaged by the core in its reciprocating movements. The relatively short air gap between the tips of each set of laminations reduces the reluctance of the magnetic circuit to a minimum value and insures a highly efficient magnetic circuit having a relatively small amount of magnetic leakage.

The sets of laminations are disposed radially around the barrel 28 and the coil 26, as illustrated in Fig. 3. The separate air gaps of the respective sets together constitute an air gap of annular shape which is adapted to be bridged or shunted by the core 27 in its reciprocating movements.

The barrel 28 serves as a guide for the core 27 and as a supporting structure for the different elements whereby they may be assembled into a compact unit. The barrel comprises a cylindrical tube of bronze provided with the openings 39 to receive the tips of the laminations. The forward end of the barrel is threaded to receive an open end cap 41 provided with a threaded opening within which a tool guide 42 is disposed. The tool guide 42 is provided with an opening within and through which the shank of a tool 43, such as a drill, chisel, rivet set or the like, may be disposed in the path of travel of the core 27. The rear or handle end of the barrel is provided with an enlarged flange like cylinder 44 that is externally threaded. The end of the barrel at the cylinder 44 constitutes a seat 45 for a spring-cushioned backstop 46. A spring 47 is disposed between the backstop 46 and a cap 48 which together with the cylinder 44 fits into a recess in the handle. The handle cooperates with the end surface of the cylinder 44 to secure the cap 48 in position. The outer surface of the base of the cylinder 44 joins the outer surface of the barrel to constitute a shoulder 49 against which the rear laminations 34 are seated.

Although the barrel should be of non-magnetic material, any non-magnetic material will not be satisfactory merely because of its non-magnetic character. A barrel employed in such an application, as a guide for a reciprocating element of steel, such as the core must be, requires, in addition to a nonmagnetic characteristic, physical characteristics of hardness, toughness and high tensile strength. The barrel must be hard to resist abrasive action of the core, and must be tough and have a high tensile strength to resist stresses set up by the end plate 41 and the handle 32 in tightly securing all the parts as a unit.

I have found that a bronze barrel having a content of about 60% copper, 39% zinc and from traces to 1% manganese, has the qualities and characteristics essential for a barrel employed as a guide in a reciprocating motor or electric hammer. Such a barrel resists abrasive action of a reciprocating core and permits tightly securing all parts to form a compact unit, as is illustrated in Fig. 2.

The respective dimensions of the tool shank and the core should be such that when one end of the core engages the end of the tool shank, as illustrated in Fig. 2, the other end should be within the path of magnetic influence of the laminations. One end of the core should always be subject to the influence of the magnetic flux at the extreme positions of the core. The backstop 46 should accordingly have such dimensions as to insure that the core will extend into the flux field when the stop is engaged.

In assembling the hammer the L shape laminations on the right hand or left hand side are first placed in position, in and around the barrel. Two fibre washers 51 are placed around the barrel on the inside of the laminations. The opposite sets of L shape laminations are then placed in position. A layer of insulation 52 is wound over the surfaces of the base portions of the barrel between the tips. The insulation 52 serves to hold the L shape laminations in position while the operating coil 26 is wound on the barrel, and also serves to hold the fiber washers 51 in position against the sides of the perpendicular or lateral portions 36. After the coil is wound upon the barrel, the straight laminated portions 37 are placed in position and secured to the L-shape portions by suitable means such as rivets 53. The backstop parts are then placed in position and the handle is securely threaded onto the barrel. The casing 31 is placed around the coil, the core 27 is inserted through the front end of the barrel and the front end cap 41 is threaded onto the barrel to clamp the casing securely between the end cap and the handle. The tool guide is then placed in position so that the plane of the front surface is a predetermined distance from the front surface of the backstop. When a tool having a shank of predetermined length is inserted through the tool guide, the core will be held in the magnetic path when engaging the tool shank, and proper operation of the core will be ensured.

When operation of the hammer is desired, the trigger switch 33 is closed and connects a relay switch 55 to the circuit 20. The relay switch 55, when closed, connects one terminal of the operating coil of the hammer to the circuit conductor 60 through the electronic valve 21. The other terminal of the coil being already connected to circuit conductor 61, the valve transmits alternate current waves, that is, only current waves of the same polarity, to the operating coil. The current wave form is illustrated in Fig. 6.

The operation of the valve 21 is such that when the filament is negative with respect to the plate, current is transmitted by the valve,

but when the filament is positive with respect to the plate or anode, no current traverses the valve. The valve may therefore be regarded as transmitting positive waves or impulses.

Assuming the core 27 to be in the position illustrated in Figs. 1 and 2 when the trigger switch is closed, the first positive alternation or current wave will traverse the valve 21 and energize the operating coil 26 to establish a magnetic flux field across the annular air gap between the laminations 34. The core will be pulled backward toward the backstop 46. When the core reaches the central part of the barrel the positive alternation or current wave diminishes to zero value and the winding then remains unenergized until the next positive alternation begins. During the interval between the positive waves, however, the core continues its travel on its own momentum or inertia, from the central region of the barrel until it engages the backstop 46. At that time the second positive alternation traverses the valve and the operating coil, and the magnetic flux field is reestablished across the air gap. The core is then pulled forward to strike the end of the tool shank to deliver a working blow to the tool. The coil becomes de-energized about the time the core reaches the middle region of the barrel and again the core continues its travel during the interval until the coil is again energized. Such reciprocating action of the core continues in synchronism with the transmitted current waves so long as the trigger switch is held closed. When the trigger switch is opened the magnet switch opens and the valve is disconnected from the operating winding. The hammer thereupon ceases operating.

It should be here noted that, in addition to obviating moving contact surfaces and arcing incident thereto for transmitting current to the operating winding, all electromagnetic energy stored in the magnetic field by the operating coil is translated into useful mechanical energy stored in the reciprocating core. In devices embodying movable contact members, considerable energy is dissipated as heat, in the arc between such members. A valve of the type which I here employ, however, having no moving contact members, permits all energy stored in the magnetic field to be utilized for useful work. In the present system stationary terminals or electrodes are employed and the conducting medium between them is periodically rendered conductive to transmit current.

In the system that is illustrated in Fig. 9, an electrolytic valve 65 is employed instead of the electronic valve 21 illustrated in Fig. 1. When operation of the hammer is desired, the trigger switch 33 is closed to energize the relay switch 55. The relay switch connects the hammer actuating coil in series with the electrolytic valve 65 to the alternating current circuit 20. The action of the electrolytic valve is substantially similar to that of the electron valve except that, instead of entirely suppressing the negative current, a small negative current is transmitted to the hammer, as illustrated in Fig. 10. The negative current transmitted is merely sufficient to neutralize any residual magnetism in the magnetic circuit of the hammer but is not sufficient to influence the actuation of the core to any great extent. The electrolytic valve therefore transmits preponderatingly unidirectional current impulses that act upon the core to acetuate it in synchronism with the current impulses.

With the electrolytic valve, as with the electronic valve, the advantage of stationary, non-arcing terminals or electrodes, is present. The electrolytic valve also permits all of the energy, stored in the magnetic field to expend itself in doing useful work storing energy in the core, instead of wasting itself as heat.

A mercury arc valve may be employed in a manner similar to that in which the electron valve is used in the system illustrated in Fig. 1. The mercury valve also constitutes a control device which embodies stationary electrodes and a conducting medium to transmit all energy stored in the magnetic field. A simple system containing a mercury arc valve is diagrammatically illustrated in Fig. 11.

The mercury arc valve 70 is of the usual form and comprises two anodes 71 and 72, a cathode 73, an auxiliary anode 74, and two mercury pools 75 and 76 associated with the cathode 73 and the auxiliary anode 74, respectively, all disposed in a glass bulb 77. A tilting magnet 78 operates when energized to tilt the rectifier bulb 77 to effect momentary engagement between the mercury pools 75 and 76. When the bulb resumes its normal position and the mercury pools separate, an arc is established between them and a condition of activity is established in the bulb which promotes current conduction between the cathode 73 and the anodes 71 and 72. A limiting resistor 79 is disposed in circuit with the auxiliary anode 74 to limit the value of current that may traverse that circuit. An autotransformer 80 is provided to establish an artificial neutral point 81.

The trigger switch is provided with an additional contact portion 83 to control the circuit of the tilting magnet 78. As the trigger switch is moved toward the closed position, the contact 83 momentarily energizes the tilting magnet to tilt the bulb and establish a condition of activity in the bulb. In the fully closed position, the bridging contact of the trigger switch is in contact only with the fixed contacts controlling the bulb circuit. The mercury vapor produced

by the arc, established between the pools of mercury, constitutes a stream or conducting medium between the anode and the respective cathodes, but will only conduct current when the anode 71 or 72 is positive with respect to the cathode 73.

Since the cathode 73 is connected to the artificial neutral point 81, the anodes 71 and 72 will alternately be positive and negative relative to the cathode.

When the anode 71 is positive relative to the cathode, current is transmitted to, and traverses, the operating coil of the hammer to actuate the core in one direction or the other. A current wave or impulse will be transmitted to the hammer each time the anode 71 is positive and the core will be reciprocated in synchronism with such impulses, as in the system illustrated in Fig. 1.

The continued operation of the mercury valve is dependent upon the maintenance of the condition of activity in the bulb. To sustain the active condition between the intervals during which current is transmitted to the hammer coil a reactor 82 is disposed in the circuit of the anode 72. The current traversing the reactor circuit is sufficient to sustain the arc to maintain the condition of activity in the bulb but is not of such character as to impose a load upon the transformer 80.

In the mercury valve, as in the electrolytic and the electron valve, the energy stored in the electromagnetic field of the hammer coil is transmitted to do useful work.

The operation of an electric valve in controlling the energization of the electric hammer is automatically controlled by the polarity of the electrodes and is thus electrical and automatic, as distinguished from arbitrary operation of mechanical rectifiers irrespective of variations in the operation of the core and, consequently, in the development of the magnetic field. The electrical valve transmits all energy stored in the magnetic field, whereas the mechanical rectifier permits a great portion of such energy to be wasted as heat in arcing between contact surfaces. The electric valve is more efficient and economical, and requires less servicing and attention than the mechanical rectifier.

In the present system employing an electric valve, all energy derivable from the current waves is available for transformation into mechanical energy to be stored in the reciprocating core. None is wasted in arcing.

The feature of a system of the described character, embodying the principles of my invention, is a single moving part during operation, viz, the core 27 that is moved back and forth in the bronze barrel. While the hammer is operating, the valve is stationary, the magnet switch is stationary and the trigger switch is stationary. The wear and tear incident to operation of a percussive tool are reduced to an absolute minimum in a system of the character herein described. The advantages of a system of this character are self evident.

In the example of my invention herein more particularly illustrated, the air gap, between the longitudinally spaced pole tips 38, is disposed intermediate the ends of the exciting winding 26; the reciprocating core 27, whatever its length, passes the position of minimum length of air gap between itself and the field structure in the forward stroke or stroke in which it delivers impact to the tool; similarly, the core passes the position of minimum length of air gap between itself and the field structure on the return stroke; and the length of the core is preferably such as at least completely to bridge the gap between the aforesaid longitudinally spaced pole tips 38.

Furthermore, in the particular example of my invention illustrated, the core or reciprocating system is actuated in both directions by the same field winding by current impulses admitted thereto from an alternating current source through an electric valve; and more particularly, there is admitted a current impulse for each complete cycle of electro-motive-force of the supply circuit, the impulse having a duration through the valve and winding materially greater than the duration of a half cycle of electro-motive-force of the supply circuit; and the periods of zero current flow are due solely to the electric valve, and are not dependent upon either mechanical switching mechanism or an unusual or particular wave form of the electro-motive-force of the supply circuit.

My invention thus comprehends a method of and means for controlling a reciprocating motor, or other inductive translating device, by a system involving devices comprising stationary electrodes between which the electrical conductivity is varied by electrical action to regulate the transmission of current in unidirectional or preponderatingly unidirectional impulses.

My invention further comprehends a system for controlling a reciprocating motor, or other inductive translating device, whether requiring periodic impulse energization or not, so that all energy stored in the magnetic field of the motor or other translating device may be utilized to do useful work.

My invention is not limited to the apparatus or system shown since other devices having the desired characteristics may be employed and their arrangements modified without departing from the spirit and scope of the invention as set forth in the appended claims.

Certain of the subject matter herein disclosed, particularly features and structure of the reciprocating motor or percussive tool per se, is not herein claimed, but is claimed in my application Serial No. 697,053, filed March 5, 1924.

I claim as my invention—

1. The method of operating a reciprocating motor provided with a movable magnetizable member, which comprises selecting solely by asymmetrical electrical conduction successive current impulses from a source of single phase alternating current, and effecting movement of said magnetizable member by undulatory electro-magnetism produced by said impulses.

2. The method of operating a reciprocating motor provided with a movable magnetizable member, which comprises selecting solely by asymmetrical electrical conduction successive current impulses from a source of single phase alternating current, and effecting successive movements of said magnetizable member in both directions by undulatory electro-magnetism produced by said impulses.

3. The method of operating a reciprocating motor provided with a movable magnetizable member, which comprises selecting solely by asymmetrical electrical conduction successive current impulses from a source of single phase alternating current, producing a fluctuating electro-magnetic field by said impulses, and effecting movements of said magnetizable member by said field.

4. The method of operating a reciprocating motor provided with a movable magnetizable member, which comprises selecting by asymmetrical electrical conduction successive current impulses from a source of single phase alternating current, producing a fluctuating electro-magnetic field by said impulses, and effecting movements of said magnetizable member in both directions by said field.

5. The method of operating a reciprocating motor provided with a movable magnetizable member, which comprises selecting solely by asymmetrical electrical conduction successive current impulses from a source of single phase alternating current, producing a fluctuating electro-magnetic field by said impulses, and effecting movements of said magnetizable member in both directions by said field.

6. The combination with a reciprocating motor comprising an actuating winding and a reciprocating magnetizable member, of a source of single phase alternating current, and an electric valve in circuit with said source and said winding and serving as the sole means for selecting current impulses from said source for energization of said winding to effect magnetically movement of said magnetizable member in each direction.

7. The combination with a reciprocating motor comprising an actuating winding and a reciprocating magnetizable member moved in both directions by said winding, of a source of single phase alternating current, and an electric valve in circuit with said source and said winding and serving as the sole means for selecting current impulses from said source for energization of said winding, whereby alternate impulses so selected move said magnetizable member successively in one direction, and the intervening selected impulses move said magnetizable member successively in opposite direction.

8. The combination with a reciprocating motor comprising electro-magnetic field-producing means and a magnetizable member reciprocated thereby, of a source of single phase alternating current, and a thermionic valve in circuit with said source and said means and serving as sole means for controlling energization of said field-producing means to produce a magnetic flux impulse for each complete cycle of the electro-motive-force of said source to effect movement of said magnetizable member.

9. The combination with a reciprocating motor comprising electro-magnetic field-producing means and a magnetizable member reciprocated thereby, of a source of single phase alternating current, and a thermionic valve in circuit with said source and said means and serving as means for controlling energization of said field-producing means by successive unidirectional current impulses from said source for effecting movements of said magnetizable member magnetically in each direction.

10. The combination with a reciprocating motor comprising electro-magnetic field-producing means and a magnetizable member, reciprocated thereby, of a source of single phase alternating current, asymmetrically conducting means in circuit with said source and said means and serving as means for selecting current impulses from said source for energization of said first named means to effect movement of said magnetizable member, and a tool receiving the impact of said magnetizable member, said magnetizable member magnetically returned from its impact stroke by energization of said first named means by current traversing said asymmetrically conducting means.

11. The combination with a tool, of a magnetizable member for delivering impact thereto, and means for effecting return of said magnetizable member from impacting position comprising a source of single phase alternating current, a winding for producing a field for actuating said magnetizable member for effecting its return stroke magnetically, and an electric valve in circuit

with said winding and said source for selecting current impulses for energizing said winding to effect successive return movements of said magnetizable member.

12. The combination with a reciprocating motor comprising a field winding, a magnetizable core reciprocated thereby axially thereof, and magnetizable field members forming an air gap with respect to which said magnetizable core is movable, of a source of single phase alternating current, and an electric valve in circuit with said source and said winding and serving as means for selecting current impulses from said source for energization of said winding to effect movement of said magnetizable core past position of minimum air gap length.

13. The combination with a reciprocating motor comprising a field winding, a magnetizable core reciprocated thereby axially thereof, and magnetizable field members forming an air gap with respect to which said magnetizable core is movable, of a source of single phase alternating current, an electric valve in circuit with said source and said winding and serving as means for selecting current impulses from said source for energization of said winding to effect magnetically movement of said magnetizable core in each direction past position of minimum air gap length, and a tool receiving the impact of said core after its movement past said position.

14. The combination with a reciprocating motor comprising a field winding, a magnetizable core reciprocated thereby axially thereof, and magnetizable field members forming an air gap with respect to which said magnetizable core is movable, of a source of alternating current, an electric valve in circuit with said source and said winding and serving as means for selecting current impulses from said source for energization of said winding, and a tool receiving impact of said core, energization of said winding serving to actuate said core on its return stroke past position of minimum air gap length.

15. The combination with a reciprocating motor comprising a field winding, a magnetizable core reciprocated thereby axially thereof, and magnetizable field members forming an air gap with respect to which said magnetizable core is movable, said core having a length in the direction of its movement sufficient substantially completely to bridge said air gap, of a source of alternating current, and an electric valve in circuit with said source and said winding and serving as means for selecting current impulses from said source for energization of said winding to effect movement of said magnetizable core past position of minimum air gap length.

In testimony whereof, I have hereunto subscribed my name this 29th day of February, 1924.

CARL S. WEYANDT.