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PRODUCTION OF HIGH TENSION ELECTRIC CURRENTS BY MEANS OF TRANSFORMERS SUCH AS INDUCTION COILS

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Fig. 1.

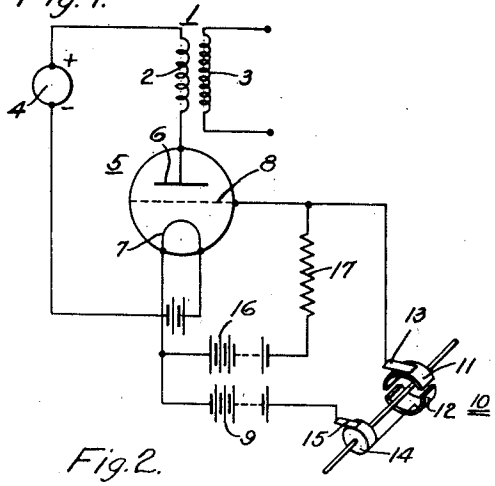


Fig. 2.

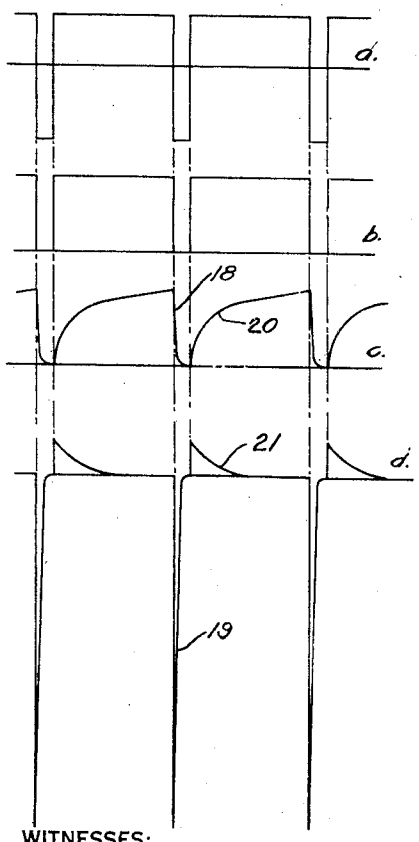


Fig. 3.

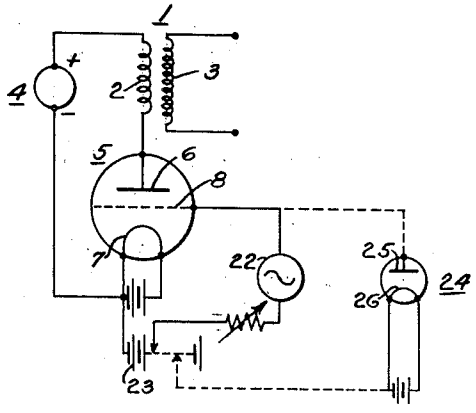
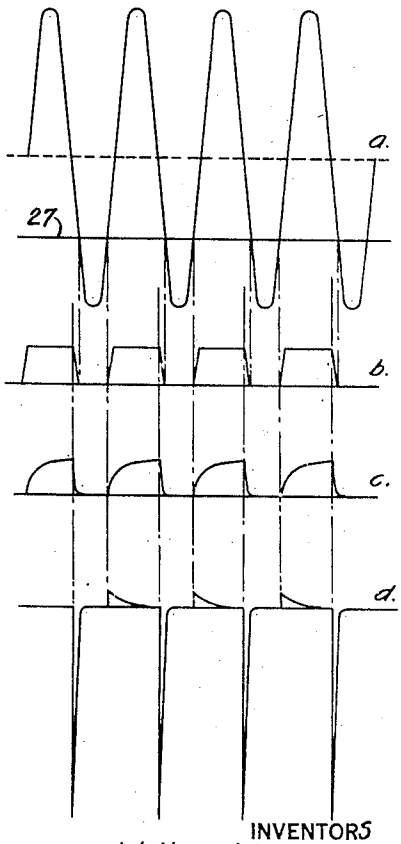


Fig. 4.



WITNESSES:

S. H. Voelker.

W. A. Blatter Jr.

INVENTORS

Walter John Brown &
Ernest Yeoman Robinson.

BY

Merle G. Carr

ATTORNEY

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UNITED STATES PATENT OFFICE.

WALTER JOHN BROWN, OF STOCKPORT, AND ERNEST YEOMAN ROBINSON, OF MANCHESTER, ENGLAND, ASSIGNORS TO ASSOCIATED ELECTRICAL INDUSTRIES LIMITED, A BRITISH COMPANY.

PRODUCTION OF HIGH-TENSION ELECTRIC CURRENTS BY MEANS OF TRANSFORMERS SUCH AS INDUCTION COILS.

Application filed October 4, 1924, Serial No. 741,640, and in Great Britain September 10, 1923.

This invention relates to the production of high tension electric currents by means of step-up transformer devices such as induction coils. The voltage induced across the secondary winding of an induction coil or transformer, the primary winding of which is energized by a current which is interrupted either at certain times or periodically, is proportional to the rate of change of current when the primary current is interrupted. There is also of course an electromotive force induced in the secondary when the primary current is started but this secondary electromotive force is relatively low and depends on the voltage applied to the primary winding and the ratio of transformation of the transformer. The rate of decrease of current when a mechanical break is employed is limited by reason of the temporary formation of an arc between the contacts of the breaking device. Hence in an induction coil it has heretofore been necessary to obtain the required high voltage by employing a relatively large transformation ratio.

According to the present invention an interrupter for the primary circuit of an electrical transformer is provided which consists of a vacuum electric tube device having controlling means associated therewith for rendering the said device alternately conducting and non-conducting. In a vacuum electric tube device such as a thermionic valve there is no inertia effect and consequently the change from the conducting state to the non-conductive state which effects breaking of the primary current can be made practically instantaneously whereby a high rate of change of primary current and a consequent high secondary voltage is obtained.

The arrangement is therefore notably suitable where a high potential is desired such as for the operation of X-ray tubes for example. Moreover since the ratio of the inverse voltage of the coil to the operating voltage is proportional to the ratio of the rate of increase of the primaray current to the rate of decrease thereof, the inverse voltage of the coil having its primary current interrupted by a valve or like device may be made very low relative to the operating voltage. This is of considerable importance when the coil is employed for the operation of X-ray tubes since the rectifier may then be dispensed with.

In carrying out the invention the electrical transformer can be of a nearly closed iron circuit type or can have a long air gap as is common in the construction of induction coils. Current is supplied to the primary winding of the transformer from any suitable source such as a direct current generator, a thermionic valve being included in series therewith. This device can be made alternately conducting and non-conducting by any suitable means, for example by varying the potential of a controlling electrode.

In order that the invention can be fully understood it will be described with reference to the accompanying drawings in which Fig. 1 illustrates diagrammatically an interrupter comprising a thermionic valve the grid of which is associated with a variable source of potential; Fig. 2 consists of curves illustrating characteristics of the arrangement shown in Fig. 1; Fig. 3 illustrates a modification of the circuits of Fig. 1, and Fig. 4 consists of curves illustrating the characteristics of this modified arrangement.

Referring to Fig. 1, the electrical transformer is shown at 1 having a primary winding 2 and a co-operating secondary winding 3. A direct current generator 4 and a thermionic valve 5 are connected in series with the primary winding 2 of the transformer. The anode 6 of the valve 5 is connected through the primary winding 2 to the positive terminal of the generator 4, and the negative terminal of the filament 7 is connected to the negative terminal of the generator. The valve 5 is provided with a grid 8 the potential of which can be varied by means of a battery 9 and a commutator 10. This commutator comprises two insulated segments 11 and 12 which are adapted as the commutator rotates successively to engage with a brush 13 which is connected to the grid 8. The segment 12 is connected to a slip ring 14 which is connected to the positive terminal of the battery 9 by means of a brush 15. The other commutator segment 11 is completely insulated. The commutator is rotated by suitable means not shown on the drawings. A biasing battery 16 is provided the negative terminal of which is con-

nected to the grid 8. A high resistance 17 is included between this biasing battery and the grid. When the brush 13 engages with the commutator segments 11 the grid potential is made negative and the primary circuit is interrupted. When the brush 13 engages with the commutator segment 12 which is connected to slip ring 14, the grid potential is made positive and the primary circuit is re-established. A short circuit current between the batteries 9 and 16 is prevented by the high resistance 17. Preferably the commutator is arranged to rotate at a high speed.

Alternatively the polarities of the two batteries 9 and 16 can be reversed so that the grid is normally biased to a positive potential by the battery 16, in which case the resistance 17 must not be high and must be suitably adjusted, and the grid potential periodically made negative from the battery 9 as the commutator rotates.

In Fig. 2 various operating characteristics of the arrangement described with reference to Fig. 1 are illustrated. Curve *a* shows the grid potential of the valve 5 plotted against time. The relative breadth of the loops above and below the line depend on the proportions of the commutator segments. Preferably the time during which the grid is negative is made smaller than that when it is positive, since the time required for breaking the primary current is much smaller than for making it. In curve *b* the valve conductivity is plotted against time. In this curve the variations correspond with the variations in the grid voltage, the conductivity of the valve being zero whenever the grid voltage is sufficiently negative. In curve *c* the anode current which flows through the primary winding 2 of the transformer 1 is plotted against time, the variations corresponding to the variations in conductivity shown in curve *b*. In curve *d* the induced secondary voltage corresponding to the variations in the primary current is shown. During the rapid decrease in the primary current indicated for example by 18 in curve *c*, a high secondary voltage illustrated by the peak 19 in curve *d* is induced while during the gradual make of the primary current shown by 20 in curve *c* a small inverse secondary current 21 is induced.

Referring to Fig. 3 which illustrates a modification of the arrangements shown in Fig. 1, the primary winding 2 of the transformer 1 is again shown connected in series with the direct current generator 4 and a three electrode thermionic valve 5. The potential of the grid 8 is varied by means of an alternating current generator 22. This generator is preferably a vacuum tube oscillator so that high frequencies can be employed. A positive bias for the grid 8 of the valve 5 is applied from a battery 23. By means of this positive grid bias the ratio of the period during which the valve is conducting to the period during which it is non-conducting can be made as large as desired. The amplitude of the alternating grid voltage however has to be limited since very large grid currents in the valve are not permissible. Consequently the maximum sharpness of change from the conducting to the non-conducting state of the valve is limited. This disadvantage can be overcome by means of a rectifier 24 which may conveniently be a two electrode thermionic valve, said diode rectifier having an anode 25 and a filament 26, connected between the grid 8 and a tapping point off the battery 9 as indicated in Fig. 3 by dotted lines. When therefore the voltage applied to the anode of the diode is positive the current will flow through the diode and owing to the internal resistance of the generator 22 the voltage applied to the grid 8 will be limited by the internal drop in the generator.

The generator therefore should be of high resistance or an external high resistance may be included in its output leads. Alternatively it may be arranged that the grid 8 of the thermionic valve 5 is arranged to function in a similar manner. The amplitude of the alternating grid voltage can then be safely increased since the grid current flowing when the grid is positive is restricted by reason of the current flowing through the diode. The negative peak voltage of the grid is unaffected by the presence of the diode.

In Fig. 4 the characteristics of the arrangement described with refernce to Fig. 3 are illustrated. For convenience the curves illustrate the effect obtained when limitation of the grid voltage by means of a diode or by means of the grid current of the valve 5 is not employed. In a curve *a* the grid voltage is plotted against time, the effect of the grid bias on the ratio of the conducting and non-conducting periods being shown by the line 27. In curve *b* the corresponding anode conductivity is shown. Curve *c* illustrates the anode current in the valve 5 which flows through the primary winding 2 of the transformer 1. The corresponding induced secondary voltage is shown in curve *d*.

It is to be understood that various modifications can be made in the arrangements described without departing from the scope of the invention. For example the valve 5 may be made periodically conducting and non-conducting by other means than those described, for example, by means of the magnetic field from a suitable coil which is arranged to control the space current through the valve.

We claim as our invention:—

1. An interrupter for the primary circuit

of a transformer comprising a vacuum tube having a third electrode, means for impressing an alternately positive and negative potential on said electrode and an asymetrically conductive device connected to said means for limiting one of said potentials.

2. In a device for producing a high, substantially uni-directional potential, a transformer having a step-up turn-ratio, means for supplying uni-directional current to said transformer primary and means for interrupting said current, said interrupting means including a vacuum tube having a grid, a direct source of potential, an alternating source of potential and a resistance tential on said electrode and an asymmetrically conductive path in shunt to said alternating source and resistance, the conductive direction of said path being away from the grid.

In testimony whereof we have hereunto subscribed our names this 17th day of September, 1924.

ERNEST YEOMAN ROBINSON.
WALTER JOHN BROWN.