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ELECTRIC SYSTEM

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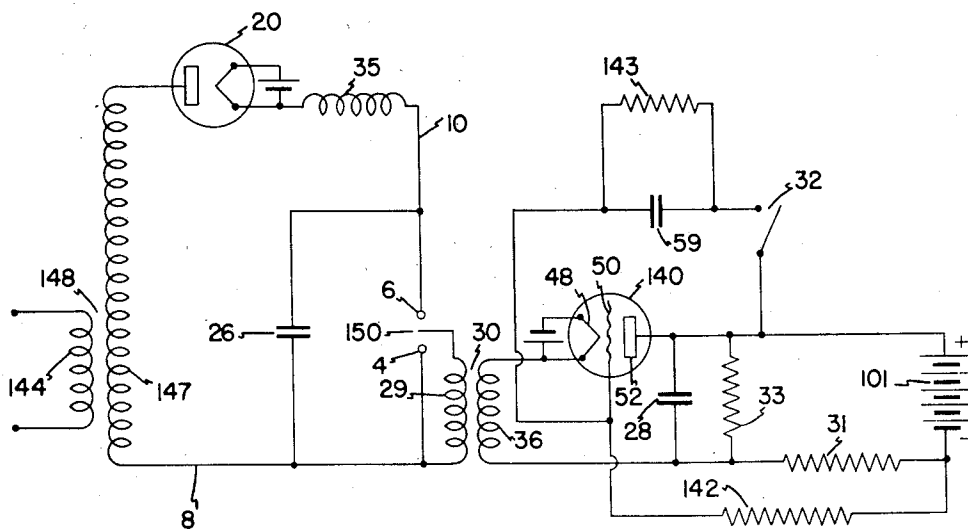


FIG. 1

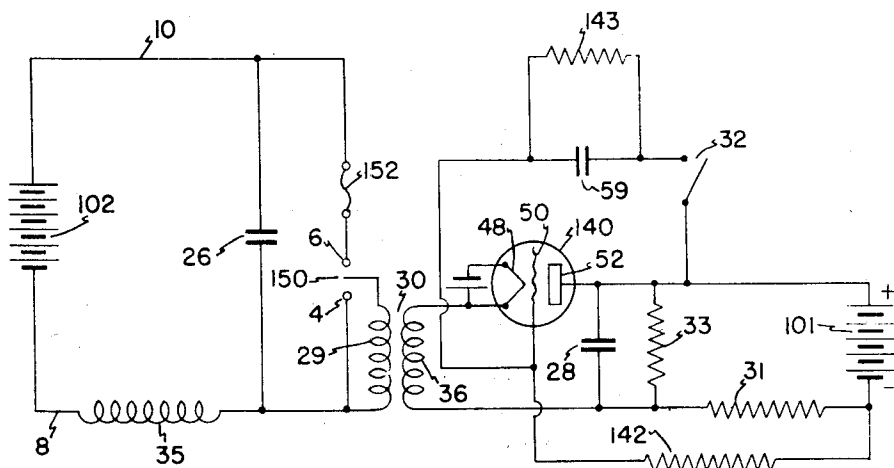


FIG. 2

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ELECTRIC SYSTEM

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19 Claims. (Cl. 326—1)

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The present invention, though having fields of more general usefulness in electric systems, is particularly related to electric-energy flash-producing or other pulse-producing systems in which the discharge of a condenser is employed for such purposes as to produce a single light flash or a single electric-energy pulse or a repetition of light flashes or electric-energy pulses of short duration and high intensity. The present application is filed in response to a requirement for division in application, Serial No. 685,501, filed August 16, 1933.

It has heretofore been proposed to initiate the discharge of the condenser by sending a spark through a two-electrode spark gap connected in series with the condenser and the light-flash device. A system of this character would offer the advantage that it would do away with the necessity for employing the large flash devices that are complicated by the presence of high-voltage triggering or starting electrodes. To send a spark through the two-electrode spark gap, however, has involved difficulties that have rendered the system impracticable.

An object of the present invention, therefore, is to provide a new and improved electric system of the above-described character that shall overcome these difficulties.

In the said application, there is disclosed a new and improved electric system for producing strong and intense substantially uniform pulses of electric energy by discharging a condenser quickly, reliably and accurately at high frequency through a gaseous-conductor device. This system is simple and rugged in construction, light in weight, portable and self contained, easily operable, without moving parts (except, in some cases, for a contactor), and thoroughly effective and reliable in operation.

An object of the present invention is to provide a new and improved electric system of the above-described character for producing light flashes or other pulses of electric energy.

In the said application, Serial No. 685,501, the source of the light flashes is disclosed as a three-electrode gaseous-conductor device. A further object of the present invention, on the other hand, is to provide a new and improved system of the above-described character in which a three-electrode gaseous-conductor device may serve as a control for a load, disclosed specifically as a two-terminal flash-producing device.

Other and further objects will be explained hereinafter and will be particularly pointed out in the appended claims.

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The invention will now be more fully explained in connection with the accompanying drawings, in which Fig. 1 is a diagrammatic view of circuits and apparatus illustrating one embodiment of the invention according to which the flash is provided by a three-electrode spark gap to the exclusion of any additional flash device; and Fig. 2 is a similar view illustrating a preferred embodiment of the invention, according to which the flash, provided chiefly by a flash device, is augmented by the flash of a three-electrode spark gap.

A three-electrode spark gap or other gaseous-discharge device is shown comprising two principal electrodes 4 and 6 and a starting triggering or control electrode 150 disposed substantially between the principal electrodes 4 and 6. The principal electrodes 4 and 6 are connected by wire conductors 8 and 10 to a source of direct current, in parallel with a flash condenser or capacitor 26. The source of direct current is shown in Fig. 2 as constituted of a battery 102. As shown in Fig. 1, however, the direct current may be supplied from any desired source of alternating energy of suitable voltage and frequency through a transformer 148. The primary winding 144 of the transformer 148 is connected to the alternating-current source, and the secondary winding 147, through a thermionic or gaseous-discharge rectifier 20, to the condenser 26.

A current-limiting charging impedance 35 may be series-connected in the charging circuit of the condenser 26, either in the wire conductor 10, as illustrated in Fig. 1, or the wire conductor 8, as shown in Fig. 2. The condenser 26 may be charged to a voltage of from 200 to 2000 volts. The principal electrodes 4 and 6 of the three-electrode spark gap are series-connected in the discharge circuit of the condenser 26. The flashes are produced by discharging the condenser 26, after it has become charged, through the air between the principal electrodes 4 and 6 of the spark gap.

A simple inexpensive triggering three-electrode spark gap is thus provided for efficiently handling the necessarily high-peak-discharge currents. The noise of operation may be reduced by enclosing the spark gap in a noise-proof chamber.

Because of the dielectric properties of the normally deionized air in the space between the spark-gap electrodes 4 and 6, the direct-current source will charge the condenser 26 through the impedance 35 without any of its energy traversing that space. A difference of potential will

therefore be established between the spark-gap electrodes 4 and 6 during the charging of the condenser 26 before each flash. The impedance 35 should be designed sufficiently large so that, after the creation of the spark between the principal electrodes 4 and 6, further current flow between them will be prevented until after the air of this gap shall have again become deionized. The impedance 35 should, however, be small enough to permit of the condenser 26 becoming recharged with energy from the direct-current source in time for the next flash.

The series-connected discharge circuit comprising the condenser 26 and the spark gap may include also an additional flash device 152, shown in Fig. 2 as a small fine two-terminal conducting wire. The flash device 152 may provide the principal or chief light of the flash, of substantial illumination intensity but the light from the three-electrode spark gap may itself be quite substantial to augment the flash of the flash device 152. The quantity of light in the flash is determined by the amount of energy in the condenser 26 and by circuit conditions.

A conductor is shown connecting the principal electrode 6 to one of the terminals of the additional flash device 152. The conductor 10 connects the other terminal of the additional flash device 152 to one side of the battery 102. The conductor 8 connects the principal electrode 4 to the other side of the battery 102.

The invention is not, of course, restricted to use with the two-terminal conductive wire 152. This two-terminal conductive wire 152 is quite efficient for the production of light flashes, but the invention is equally applicable to the production of other electric-energy pulses than light. The additional flash device 152 is therefore merely representative of a suitable load device that may be employed in accordance with the present invention under the control of the three-electrode gaseous-conductor device 4, 6, 150.

The discharge of the condenser 26 through the condenser-discharging circuit above described is initiated by energizing the normally unenergized control electrode 150, under the control of a trip circuit. The trip circuit is shown comprising a high-ratio step-up triggering flash transformer 30, a normally non-conducting or ineffective mercury-vapor thyatron rectifier trigger tube 140, two impedances 31 and 33, shown as resistors, and a small trip condenser 28. The secondary winding 29 of the transformer 30 is connected to the starting electrode 150. The trip condenser 28 is shown charged from a second battery 101, through the impedance 31, which may perform a function similar to that of the impedance 35. The thyatron 140 and the primary winding 36 of the transformer 30 are connected in the discharge circuit of the trip condenser 28. The resistor 33, shown shunted across the trip condenser 28, allows a small current to flow, in order to maintain upon the control-grid electrode 50 of the thyatron 140 a voltage bias suitably negative with respect to the thyatron cathode 48. The gas pressure of the thyatron 140 is such that the control electrode 50 loses control over a discharge already passing through the thyatron.

The trip circuit functions to discharge the trip condenser 28 through the mercury of the thyatron 140 when rendered effective and the primary winding 36 of the flash transformer 30. The direct-current energy of the second battery 101 becomes thus converted into sudden voltage

pulses in the primary winding. This discharge of the trip condenser 28 is effected at selected intervals, whenever it is desired to produce the flash, under the control of the thyatron grid 50. The potential on the grid 50, in turn, is controlled by a switch 32. The instant when the flash occurs is thus accurately timed, without the aid of any switches in the high-voltage circuit.

The grid 50 is shown connected to one side of the switch 32 through a small trip condenser 59, which may be as small as 0.00025 microfarad. The other side of the switch 32 is shown connected to the anode 52 of the thyatron 140. The grid 50 is connected also to the negative end of the resistor 31 in series with a resistor 142. The resistor 142 serves to limit any current that may tend to flow when the grid 50 becomes positive.

The voltage pulses produced in the primary winding 36 in response to the discharge of the trip condenser 28 are conveyed, through the secondary winding 29 of the transformer 30, to the starting electrode 150 of the spark gap to impress a high-potential stimulus thereon. The air in the vicinity of the starting electrode 150, between the principal spark-gap electrodes 4 and 6, becoming thereby ionized, the flash condenser 26 discharges suddenly through its discharge circuit. The initiation of the spark or discharge between the principal electrodes 4 and 6 is thus controlled by the control electrode 150 of the trigger circuit. A very large current, over one thousand amperes, thereupon surges through between the principal electrodes 4 and 6 of the spark gap, producing a very brilliant quick flash of light of substantial illumination intensity, concentrated in a small space. The duration of the flash is of the order of microseconds, as determined by the size of the capacity 26, the voltage to which it is charged, the dimensions of the spark gap, the impedance of the leads 9 and 10 connecting the condenser 20, and other factors. Under some conditions, the duration of the flash is less than one microsecond.

According to the embodiment of the invention illustrated by Fig. 2, the energy of the discharging condenser 26, in addition to creating a flash across the triggering spark gap between the principal electrodes 4 and 6, serves also to vaporize the fine wire 152. An additional arc discharge therefore takes place through the metal vapor, the time of occurrence of which is controlled by the spark gap. With suitable choice of metals for the wire, such as aluminum or magnesium, the arc through the vaporized metal may be caused to give considerably more light than can be obtained from the spark gap.

The arrangement of Fig. 2 has the further advantage that the wire 152 is isolated by the spark gap from the high direct-current potentials of the condenser 26 and the spark gap except at the instant of flashing. As these high-potential elements may be completely enclosed at some distance from the wire 152, the operator is protected from these high potentials, except at the moment of discharge.

Further modifications will occur to persons skilled in the art, and all such are considered to fall within the spirit and scope of the invention, as defined in the appended claims.

What is claimed is:

1. In an electric circuit, a spark gap, means connecting the gap into the electric circuit, a conducting wire in series with the gap, and means comprising a grid-controlled gaseous-discharge rectifier tube for vaporizing the wire.

2. In an electric circuit, a spark gap, means connecting the spark gap into the electric circuit, a normally unenergized gaseous-discharge device in series with the spark gap, and means comprising a grid-controlled, gaseous-discharge rectifier for energizing the gaseous-discharge device.

3. An electric system having, in combination, a condenser, means for charging the condenser, a load, a three-electrode spark gap, a discharge circuit for the condenser including the load and two of the electrodes of the spark gap, and means comprising a grid-controlled rectifier for impressing a voltage upon the third electrode of the spark gap to produce a spark between the said two electrodes, thereby to cause the condenser to discharge through the discharge circuit including the load and the said two electrodes.

4. A flash-producing system having, in combination, a condenser, means for charging the condenser, a flash device, a three-electrode spark gap, a discharge circuit for the condenser including the flash device and two of the electrodes of the spark gap, and means comprising a grid-controlled rectifier for impressing a voltage upon the third electrode of the spark gap to produce a spark between the said two electrodes, thereby to cause the condenser to discharge through the discharge circuit including the flash device and the said two electrodes.

5. An electric system having, in combination, a normally deionized spark gap, means for normally impressing across the spark gap a voltage insufficient to produce a spark across the spark gap when the spark gap is deionized but sufficient to produce a spark across the spark gap when the spark gap is ionized, a normally ineffective gaseous-discharge rectifier having a control electrode and operable when effective to ionize the spark gap, and means for controlling the control electrode to render the rectifier effective to ionize the spark gap in order to enable the impressed voltage to produce a spark across the spark gap.

6. An electric system having, in combination, a normally deionized spark gap, means for normally impressing across the spark gap a voltage insufficient to produce a spark across the spark gap when the spark gap is deionized but sufficient to produce a spark across the spark gap when the spark gap is ionized, a normally ineffective gaseous-discharge rectifier having a control electrode and operable when effective to ionize the spark gap, and means for controlling the control electrode to render the rectifier effective to ionize the spark gap in order to enable the impressed voltage to produce a spark across the spark gap, the gas pressure of the rectifier being such that the control electrode loses control over a discharge already passing through the rectifier.

7. An electric system having, in combination, a normally deionized spark gap, a condenser, a discharge circuit for the condenser connected to the spark gap to produce a spark across the spark gap in response to the discharge of the condenser through the discharge circuit, means for normally charging the condenser in order normally to impress across the spark gap a voltage insufficient to effect its discharge through the discharge circuit when the spark gap is deionized but sufficient to effect its discharge through the discharge circuit when the spark gap is ionized, a normally ineffective gaseous-discharge rectifier having a control electrode and operable when effective to ionize the spark gap, and means for controlling the control electrode to render the

rectifier effective to ionize the spark gap in order to enable the charged condenser to discharge through the discharge circuit to produce a spark across the spark gap.

8. An electric system having, in combination, a normally deionized spark gap, means for normally impressing across the spark gap a voltage insufficient to produce a spark across the spark gap when the spark gap is deionized but sufficient to produce a spark across the spark gap when the spark gap is ionized, and a trigger circuit comprising a triggering transformer having a primary winding and a normally ineffective secondary winding connected to the spark gap to ionize the spark gap when effective and a gaseous-discharge device having a normally ineffective control electrode, and means for rendering the control electrode effective to produce an electrical impulse upon the primary winding in order to render the secondary winding effective to ionize the spark gap in order to enable the impressed voltage to produce a spark across the spark gap.

9. A light-flash producer having, in combination, a normally deionized flash device comprising a three-electrode spark gap between two of the electrodes of which, when the spark gap is ionized, a spark may be produced to produce a flash of light of substantial illumination intensity, the third electrode of the spark gap being disposed substantially between the said two electrodes, a condenser, a discharge circuit for the condenser connected to the said two electrodes to produce the said spark between the said two electrodes in response to the discharge of the condenser through the discharge circuit, means for charging the condenser, and means for impressing a voltage upon the third electrode to ionize the spark gap in order to enable the charged condenser to discharge through the discharge circuit to produce the said spark between the said two electrodes.

10. A light-flash producer having, in combination, a condenser, a flash device through which the condenser may discharge to produce a light flash of substantial illumination intensity, a spark gap having two principal electrodes between which the condenser may discharge to produce a light flash of substantial illumination intensity and a control electrode disposed substantially between the principal electrodes, a circuit having a source of direct current for charging the condenser, a discharging circuit for the condenser connected to the principal electrodes and the flash device, and means for applying a condenser-discharge-initiating stimulus to the control electrode to effect a sudden discharge of the condenser through the condenser-discharging circuit and the principal electrodes and the flash device to produce a flash of light of substantial illumination intensity between the principal electrodes and a flash of light of substantial illumination intensity through the flash device.

11. A light-flash producer having, in combination, a condenser, a first flash device through which the condenser may discharge to produce a light flash of substantial illumination intensity, a second flash device having two principal electrodes between which the condenser may discharge to produce a light flash of substantial illumination intensity and a control electrode disposed substantially between the principal electrodes, a circuit having a source of direct current for charging the condenser, a discharging circuit for the condenser connected to the principal electrodes and the first flash device, and means

for applying a condenser-discharge-initiating stimulus to the control electrode to effect a sudden discharge of the condenser through the condenser-discharging circuit and the principal electrodes and the first flash device to produce a flash of light of substantial illumination intensity between the principal electrodes and a flash of light of substantial illumination intensity through the first flash device.

12. A light-flash producer having, in combination, a normally deionized flash device comprising a three-electrode spark gap between two of the electrodes of which, when the spark gap is ionized, a spark may be produced to produce a flash of light of substantial illumination intensity, the third electrode of the spark gap being disposed substantially between the said two electrodes, a condenser, a discharge circuit for the condenser connected to the said two electrodes to produce the said spark between the said two electrodes in response to the discharge of the condenser through the discharge circuit, means for charging the condenser, a triggering transformer having a primary winding and a secondary winding connected to the third electrode, and means for exciting the primary winding in order to impress a voltage upon the third electrode to ionize the spark gap, thereby to enable the charged condenser to discharge through the discharge circuit to produce the said spark between the said two electrodes.

13. A light-flash producer having, in combination, a condenser, a first flash device through which the condenser may discharge to produce a light flash of substantial illumination intensity, a second flash device having two principal electrodes between which the condenser may discharge to produce a light flash of substantial illumination intensity and a control electrode disposed substantially between the principal electrodes, a circuit having a source of direct current for charging the condenser, a discharging circuit for the condenser connected to the principal electrodes and the first flash device, a triggering transformer having a primary winding and a secondary winding connected to the control electrode, and means for exciting the primary winding in order to apply a condenser-discharge-initiating stimulus to the control electrode to effect a sudden discharge of the condenser through the condenser-discharging circuit and the principal electrodes and the first flash device to produce a flash of light of substantial illumination intensity between the principal electrodes and a flash of light of substantial illumination intensity through the first flash device.

14. An electric system having, in combination, a condenser, a load through which the condenser may discharge to produce a pulse of electric energy therein, the load having two terminals, a normally non-conductive gaseous-conductor device having two principal electrodes and a control electrode, a conductor connecting one of the principal electrodes to one of the load terminals, conductors connecting the other principal electrode and the other load terminal to the condenser, a circuit having a source of direct current for charging the condenser to a voltage of magnitude insufficient to effect a discharge of the condenser through the gaseous-conductor device between the principal electrodes and through the load between the load terminals when the gaseous-conductor device is non-conductive but sufficient to effect a discharge of the condenser through the gaseous-conductor device between

the principal electrodes and through the load between the load terminals to produce a pulse of electric energy in the load when the gaseous-conductor device is conductive, and a trip circuit comprising a discharge device, means for connecting the discharge device to the control electrode, means for impressing an impulse upon the discharge device, means controlled by the discharge device in response to the impulse for producing a sudden violent electrical transient impulse, and means for transmitting the transient impulse to the control electrode to render the gaseous-conductor device suddenly conductive in order to effect a discharge of the condenser through the gaseous-conductor device between the principal electrodes and through the load between the load terminals to produce a pulse of electric energy in the load.

15. A light-flash producer having, in combination, a condenser, a flash device through which the condenser may discharge to produce a light flash of substantial illumination intensity, the flash device having two terminals, a normally non-conductive gaseous-conductor device having two principal electrodes and a control electrode, a conductor connecting one of the principal electrodes to one of the flash-device terminals, conductors connecting the other principal electrode and the other flash-device terminal to the condenser a circuit having a source of direct current for charging the condenser to a voltage of magnitude insufficient to effect a discharge of the condenser through the gaseous-conductor device between the principal electrodes and through the flash device between the flash-device terminals when the gaseous-conductor device is non-conductive but sufficient to effect a discharge of the condenser through the gaseous-conductor device between the principal electrodes and through the flash device between the flash-device terminals to produce a light flash when the gaseous-conductor device is conductive and a trip circuit comprising a discharge device, means connecting the discharge device to the control electrode, means for impressing an impulse upon the discharge device, means controlled by the discharge device in response to the impulse for producing a sudden violent electrical transient impulse, and means for transmitting the transient impulse to the control electrode to render the gaseous-conductor device suddenly conductive in order to effect a discharge of the condenser through the gaseous-conductor device between the principal electrodes and through the flash device between the flash-device terminals to produce a light flash of substantial illumination intensity.

16. An electric system having, in combination, a condenser, a load through which the condenser may discharge to produce a pulse of electric energy therein, the load having two terminals, a normally non-conductive gaseous-conductor device having two electrodes, a conductor connecting one of the electrodes to one of the load terminals, conductors connecting the other electrode and the other load terminal to the condenser, a circuit having a source of direct current for charging the condenser, means whereby the condenser is charged by the condenser-charging circuit from the source without producing a substantial pulse in the load during the charging of the condenser, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor device to render the gaseous-conductor device suddenly conductive in order to effect a sudden discharge of the condenser

through the gaseous-conductor device between the electrodes and through the load between the load terminals to produce a pulse of electric energy in the load.

17. A light-flash producer having, in combination, a condenser, a flash device through which the condenser may discharge to produce a light flash of substantial illumination intensity, the flash device having two terminals, a normally non-conductive gaseous-conductor device having two electrodes, a conductor connecting one of the electrodes to one of the flash-device terminals, conductors connecting the other electrode and the other flash-device terminal to the condenser, a circuit having a source of direct current for charging the condenser, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor device to render the gaseous-conductor device suddenly conductive in order to effect a sudden discharge of the condenser through the gaseous-conductor device between the electrodes and through the flash device between the flash-device terminals to produce a flash of light of substantial illumination intensity.

18. An electric system having, in combination, a condenser, a load through which the condenser may discharge to produce a pulse of electric energy therein, a spark gap having two principal electrodes and a control electrode disposed substantially between the principal electrodes, a circuit having a source of direct current for charging the condenser, a discharging circuit for the condenser connected to the principal electrodes and the load, and means for applying a condenser-discharge-initiating stimulus to the control electrode to effect a sudden discharge of the condenser through the condenser-discharging circuit and the principal electrodes and the load to produce a pulse of electric energy in the load.

19. A light-flash producer having, in combination, a condenser, a flash device through which the condenser may discharge to produce a light flash of substantial illumination intensity, a spark gap having two principal electrodes and a control electrode disposed substantially between the principal electrodes, a circuit having a source of direct current for charging the condenser, a discharging circuit for the condenser connected to the principal electrodes and the flash device, and means for applying a condenser-discharge-initiating stimulus to the control electrode to effect a sudden discharge of the condenser through the condenser-discharging circuit and the principal electrodes and the flash device to produce a flash of light of substantial illumination intensity.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,586,524	Heising	June 1, 1926
1,684,108	Phelps	Sept. 11, 1928
1,738,464	Wade	Dec. 3, 1929
1,745,830	Bethenod	Feb. 4, 1930
2,030,228	Randolph	Feb. 11, 1936
2,147,472	Ulrey	Feb. 14, 1939
2,405,069	Tonks	July 30, 1946

FOREIGN PATENTS

Number	Country	Date
450,939	Great Britain	July 24, 1936