May 5, 1942. E. G. GAGE 2,281,571

SAFETY CIRCUITS FOR THERMIONIC APPARATUS

Filed May 29, 1940 2 Sheets-Sheet 1

Fig. 1.

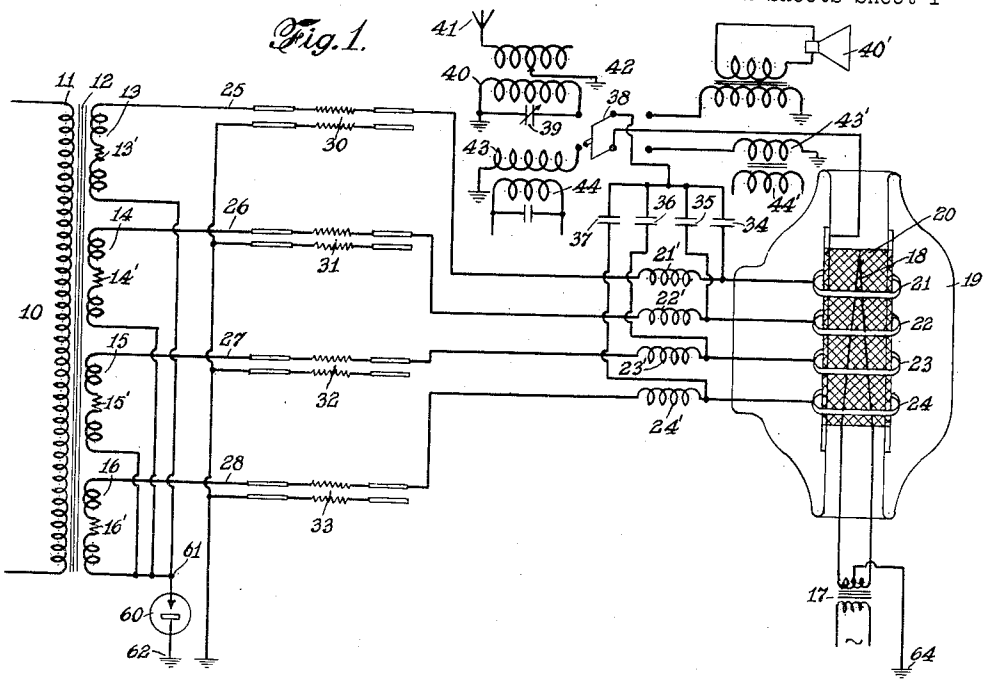


Fig. 3.

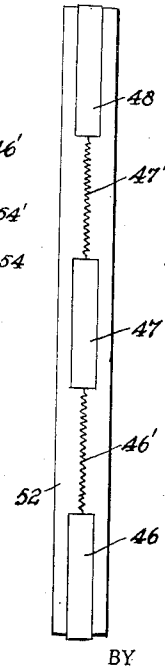


Fig. 2.

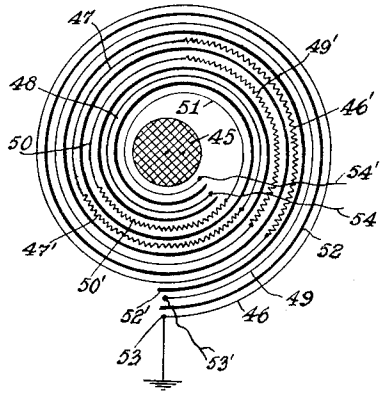
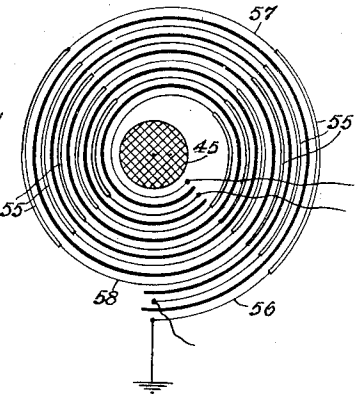


Fig. 4.



INVENTOR.
EDWARD G. GAGE
BY
ATTORNEY.

May 5, 1942. E. G. GAGE 2,281,571

SAFETY CIRCUITS FOR THERMIONIC APPARATUS

Filed May 29, 1940 2 Sheets-Sheet 2

Fig. 5.

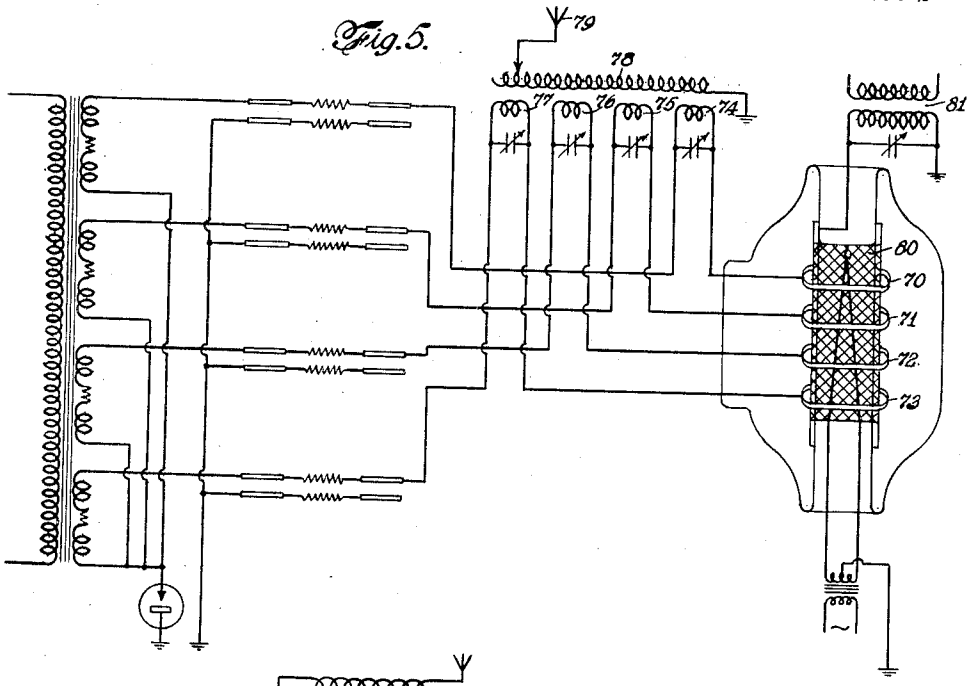


Fig. 6.

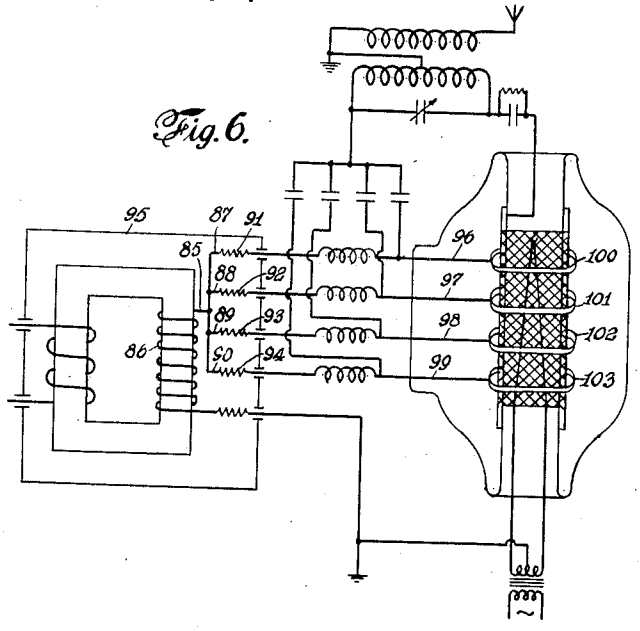
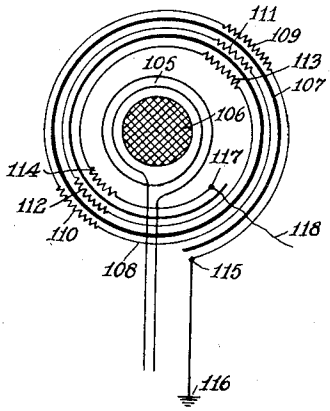


Fig. 7.



INVENTOR.
EDWARD G. GAGE
BY
ATTORNEY

Patented May 5, 1942

2,281,571

UNITED STATES PATENT OFFICE

2,281,571

SAFETY CIRCUITS FOR THERMIONIC APPARATUS

Edward G. Gage, Brooklyn, N. Y., assignor, by direct and mesne assignments, of two-thirds to Leon Ottinger, New York, N. Y.

Application May 29, 1940, Serial No. 337,806

4 Claims. (Cl. 250—27)

The invention relates to a method of operating thermionic apparatus and to electrical circuit arrangements and devices for making the conductors of a circuit carrying thereto a dangerously high current and voltage safe to handle; and in particular as applied to the circuits of vacuum tube transmitters and like apparatus which ordinarily carry a comparatively heavy current.

In a co-pending application Serial No. 281,511, I have disclosed a system wherein the total voltage of a dangerous circuit is divided by means of resistance inserted in series between sections of a source of high potential such as a battery. By interposing a resistance between any two sections of the battery likely to be contacted, and the body, it is impossible to effect contact with any section without at the same time including a resistance sufficient to limit the current to a safe value.

The present invention contemplates dividing both the current and the voltage in a dangerous voltage circuit, for example, current and voltage such as may be derived from a transformer or filter condenser, respectively, and feeding, for example, the plates of thermionic means, more especially as a tube including a plurality of anodes or as a plurality of tubes with individual plates.

An object of the invention is to provide in a circuit of the aforesaid nature a plurality of parallel paths for direct or alternating current flow, the total current or sum of the currents in all paths being dangerous, but the current in any single path being of a safe value.

Another object of the invention is to provide a filter condenser which is safe to handle and yet possesses high capacity and is charged to a dangerous voltage.

Still another object of the invention is to combine in a single unit a filter condenser, carrying a dangerous current and voltage, with a smoothing impedance.

The invention has for an object, also, to provide a novel construction of transformer capable of supplying a dangerous voltage but safe to handle.

In carrying out the invention, the circuit is so designed that the current paths, for example to a thermionic transmitter tube, are maintained separate by dividing the plate of the tube into separated sections, each section being fed by a separate conductor, the output paths being united as for radio frequency current flow by connecting each plate section to a section of a condenser having one common electrode. Or, as an alternative, the plate sections may be connected to respective primary coils of a transformer having a common output secondary. The filter condensers for the separate conductors, also, are of novel construction and embody coiled electrodes comprising conducting strips and alternate sections of high resistance elements or wire. A similar construction of transformer is contemplated.

The nature of the invention, however, will best be understood when described in connection with the accompanying drawings, in which:

Fig. 1 is a schematic diagram of the safety circuits of a vacuum tube for a radio frequency or audio frequency amplifier operating at a dangerous voltage and current.

Fig. 2 is a detail transverse section of a combined safety filter condenser and impedance carrying dangerous voltage.

Fig. 3 is a reduced plan view of a condenser electrode with intermediate resistance sections.

Fig. 4 is a transverse section illustrating a modification in the condenser construction.

Fig. 5 is a schematic diagram illustrating a modified form of the novel safety circuit.

Fig. 6 shows alternative means for providing a safety transformer for dividing the output circuit into parallel paths by means of resistances located inside a casing, and an oscillator circuit connected thereto.

Fig. 7 is a detail transverse section of a safety transformer carrying a dangerous voltage and embodying conductors of relatively high and low resistance connected in series.

Referring to the drawings, more particularly to Fig. 1, **10** designates a source of current voltage, for example alternating, which may, for convenience, have a frequency of sixty cycles, and is connected to the primary winding **11** of a multiple section transformer, of which **12** is the core.

Separate transformer secondary sections **13**, **14**, **15**, and **16** are provided on the core, each delivering the same and a relatively high voltage; and a further transformer **17** delivers a low voltage to the filament **18** of a high impedance transmission vacuum tube **19** of the three-element type having the grid **20**. Voltage from the secondary sections **13**, **14**, **15**, and **16** is delivered to the plate of said transmitter tube which, in accordance with the invention, is divided into a like number of sections **21**, **22**, **23**, and **24** connected respectively to the said transformer sections through leads **25**, **26**, **27**, and **28**, respectively, and series inductances **21'**, **22'**, **23'**, and **24'**. There is afforded thereby parallel paths each at substantially the same voltage and a safe current flow, say not in excess of 10 milliamperes. Respective

filter condensers 30, 31, 32, and 33, preferably of the novel construction hereinafter set forth, are included in the different leads.

The outputs from the tube plates or anodes are connected to respective parallel connected condensers 34, 35, 36, and 37 for uniting the high frequency outputs of the plate circuits as through a double-throw double-pole switch 38 to one terminal of a tank tuning condenser 39. There is associated therewith, also, an oscillator coil 40 for coupling the radio frequency circuit to the antenna 41 and ground 42, the grid 20 being grounded at the same time through the coil 43 coupled to an input coil 44. By throwing switch 38 in the opposite direction, the condensers may be connected to operate a sound reproducer 40', the grid then being grounded through a coil 43' coupled to the audio frequency input coil 44'.

As shown in Figs. 2 and 3, the filter condensers comprise a laminated iron core 45 which is surrounded by coiled condenser electrodes, each of which may consist of narrow strips of metal foil 46, 47, and 48, and 49, 50, and 51, respectively, with alternate conductors 46', 47' and 49', 50' connected between. These conductors may be of high resistance wire such as "Nichrome"; or, with lower power condensers, ordinary fine copper wire may provide the required resistance. Dielectrics 52 and 52' which may be of insulating paper are wound between the condenser electrodes with resistance wire in series. The combined filter condenser and impedance shown constitutes, in effect, a plurality of impedances in series with condensers in shunt between each impedance, as in the standard filter network. The advantage of such construction lies in the fact that the entire network is combined in a single unit with but four exposed terminals 53, 53', 54, and 54', one of which, preferably the outside foil terminal 53, may be grounded.

As all conductors as well as the foil portions are rolled up in a compact roll, it is not possible to contact any portion accidentally without including resistance in series with one's body sufficient to limit the condenser discharge, as determined by the capacity of the condenser, to a safe value.

The condenser capacity plays an important part in the safety feature of the device. Because the filter network is divided up into sections, a separate section being used for each plate section of the vacuum tube, the capacity of each condenser-impedance unit is only a fraction of the total capacity required for current smoothing, in the case cited being but one-fourth of such capacity as there are four plate sections. This means that the voltage and current through the body from accidental contact with any one section is reduced to one-fourth of what it would be if the capacity were combined in a single condenser.

Instead of using high-resistance wire to provide inductance and resistance between condensers, small carbon resistors in the form of short flat strips 55 or rods, Fig. 4, may be used in between the electrode portions 56, 57, and 58, and rolled with the condensers.

Each of the transformer sections 13, 14, 15, and 16 are similarly provided with one or more intermediate protective resistances 13', 14', 15', and 16'. Provision is also made, as by means of a high-voltage rectifier 60, for rectifying all currents passing from the common terminal 61 of transformer sections 13, 14, 15, and 16, which is connected to one terminal of the rectifier, the other being grounded at 62. The filament 18 of the vacuum tube 19 is also grounded as at 64.

In Fig. 5 a similar circuit is disclosed but the tube anodes 70, 71, 72, and 73 are connected respectively to primary coils 74, 75, 76, and 77 coupled to a common secondary 78 for the antenna 79, grid 80 of the tube being grounded through the input system 81. The coils are wound with respect to the secondary such that their effects thereon are additive and preferably are tuned alike.

Fig. 6 illustrates an oscillator type of circuit wherein, also, the safeguarding resistances of the transformer are arranged in a different manner in the dividing of the electrical energy into a plurality of paths. Thus, the one lead 85 of transformer secondary 86 is divided into four branches 87, 88, 89, and 90 which have safeguarding series resistances 91, 92, 93, and 94, all, together with the transformer as a whole, being encased in a suitable housing 95 from which extend the leads 96, 97, 98, and 99 to the anodes 100, 101, 102, and 103, respectively.

A convenient arrangement for interposing the secondary resistances in a transformer is illustrated in Fig. 7 of the drawings. As indicated therein, a primary winding 105 is coiled about a central core 106 of laminated iron and about this is wound in the required number of convolutions, together with an intermediate layer of insulation 107, the secondary wire winding 108 having interposed at different portions along its length safeguarding resistors 109, 110, 111, 112, 113, and 114. One terminal 115 of such secondary may be grounded as at 116, and to the other terminal 117 a lead 118 connects to the desired means to be operated. Different secondary sections similar to that hereinbefore described may be mounted adjacently along the core 106 to provide the desired number of paths for the energy to be supplied.

In the practical application of the invention, the thermionic tube supplied with the energy through the plurality of paths should preferably be one of high impedance, designed for upwards of 10,000 volts plate voltage. This is to reduce the plate current to as low an initial value as possible.

Assuming the total plate current to be forty milliamperes, a dangerous current, then it will be seen that by dividing up the plate into sections in parallel, each section will carry but 10 milliamperes, which is a safe current. If desired, the plate may be divided into more than the number shown, thus further decreasing the current in each individual section; or, by maintaining the current of each section of the same value, more power may be drawn from the tube with more sections. The same general rule holds good for the transformer secondary sections and the filter condenser with combined impedance, as well as the alternative systems shown in Figs. 5 and 6 of the drawings.

Assuming that each plate section carries 10 milliamperes, it would be necessary for a person to contact all four sections and the ground in order to receive the full current of 40 milliamperes. As this would be considerable of a feat, it would not be done accidentally, particularly as the different current paths are to be separated as far as practicable.

Contacting but one section and the ground, which would be the ordinary accidental contact, would pass not in excess of 10 milliamperes through the body.

Contacting the radio frequency path from the plate, i. e. the portion outside of the condenser electrodes **34**, **35**, **36**, and **37**, Fig. 1, which comprises the oscillating circuit of the tube, is without danger as the current is of radio frequency.

The maximum low frequency or direct current that may be obtained from the divided supply circuits shown in Fig. 1 would be determined by the lowest resistance which might be interposed between the points of contact of the body. If contact were made between ground and any one of the filter condenser output sections, then the lowest value would be the sum of the resistances in the transformer secondary section and the resistances in the filter condenser section.

It is important, therefore, that the lowest resistance possible to place between body and ground be such as to allow only a safe current to pass at the maximum voltage.

Because the resistances in series with a secondary winding of the transformer sections are wound up inside the secondary or suitably encased, only the outside terminals can be contacted, and this always includes the enclosed resistances in series. The same is true of a filter condenser. Because the foil or outside terminals only can be contacted, it is not possible to contact these without including in the circuit the resistances rolled up with the foil which are inside the roll and cannot be contacted.

As an example of safe values, the lowest resistance which should be allowed in circuit with 10,000 volts would be 1,000,000 ohms, which would pass 10 milliamperes, a safe current. For such high voltage the human body may be considered practically a short-circuit. This resistance should be divided between copper loss and loss through concentrated resistance such as the "Nichrome" wire winding or carbon resistors inserted in series with the copper winding as in both a transformer secondary and the filter condenser impedance circuit. The problem then becomes a simple economic one. With no concentrated resistance in series, the amount of copper wire, even of the smallest size, would have to be enormous, several hundred pounds being necessary in a transformer section alone, for a 200-watt transmitter.

With all concentrated resistance in series, such as in the case of a transformer secondary and impedances wound entirely with "Nichrome" or some such special resistance wire, as disclosed by me in a co-pending application Serial #330,636, the power losses in a transmitter are considerable, while in a cathode ray device they are negligible. Therefore, a combination should be chosen for the highest general efficiency. The actual total resistance of the plate circuit is, of course, only a fraction of that of each separate plate section path, in the present case one-fourth, since there are four sections.

I claim:

1. The combination with a source of electric current supply and unilateral means including a plurality of anodes operating at a combined dangerous voltage and current; of means, interposed between the said source of current supply and the said unilateral means, for separating the supply into a plurality of independent sources of dangerous voltage and corresponding paths to the respective anodes, each path including resistance permanently located in series with the respective sources of dangerous voltage such that all exposed parts of a path lie between a resistance and the unilateral means, said resistance being of such high magnitude that upon establishment of a closed circuit through said exposed parts and the human body the current in the particular path contacted is reduced by said resistance therein to a safe value, together with means for recombining in an electrical work circuit the currents from the respective anodes.

2. The combination with a source of electric current supply and unilateral means including a plurality of anodes operating at a combined dangerous voltage and current; of means, interposed between the said source of current supply and the said unilateral means, for separating the supply into a plurality of independent sources of dangerous voltage and corresponding paths to the respective anodes, each path including resistance permanently located in series with the respective sources of dangerous voltage such that all exposed parts of a path lie between a resistance and the unilateral means, said resistance being of such high magnitude that upon establishment of a closed circuit through said exposed parts and the human body the current in the particular path contacted is reduced by said resistance therein to a safe value, and filter condensers respectively connected in the circuits to said anodes and resistances permanently located in series therewith such that any exposed parts of a condenser beyond a resistance when contacted by a human body affords a closed circuit having resistance of an order of magnitude, commensurate with the potential at the point of contact, to limit to a safe value the current flow through the included portion of the condenser and the body, together with means for recombining in an electrical work circuit the currents from the respective anodes.

3. The combination with a source of electric current supply and unilateral means including a plurality of anodes operating at a combined dangerous voltage and current; of means, interposed between the said source of current supply and the said unilateral means, for separating the supply into a plurality of independent sources of dangerous voltage and corresponding paths to the respective anodes, each path including resistance permanently located in series with the respective sources of dangerous voltage such that all exposed parts of a path lie between a resistance and the unilateral means, said resistance being of such high magnitude that upon establishment of a closed circuit through said exposed parts and the human body the current in the particular path contacted is reduced by said resistance therein to a safe value, together with electrical condensers each having an electrode connected respectively with the said anodes, and an electrical work circuit connected to the combined other electrodes of said condensers.

4. The method of operating from an electrical source of dangerous voltage and current electrical apparatus including unilateral means having a plurality of anodes operative at a combined dangerous voltage and current, which comprises supplying energy from said source at a dangerous voltage and dividing the total supplied energy into a plurality of independent paths corresponding to the number of anodes, restricting the current flow in each path for individually supplying thereby each of said anodes with a safe current, and operating the electrical apparatus from the said anodes by combining the effects of the output currents therefrom.

EDWARD G. GAGE.