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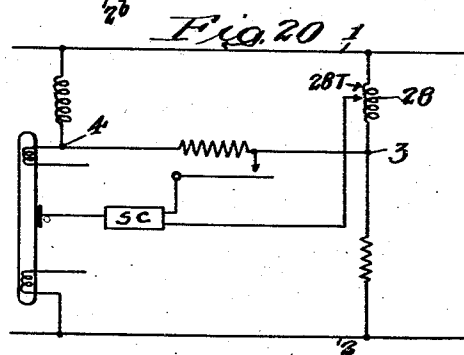
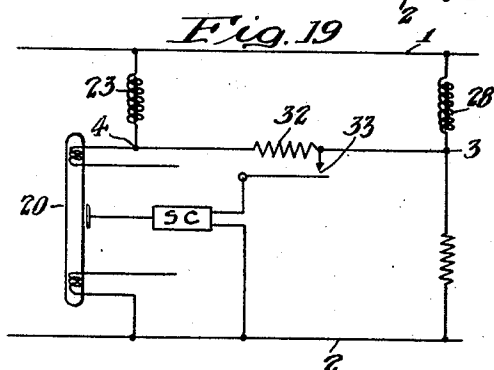
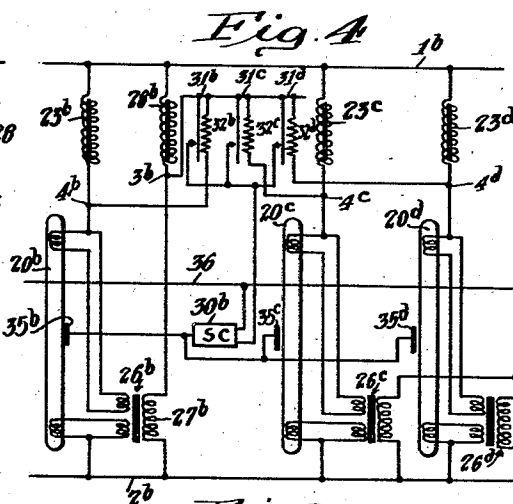
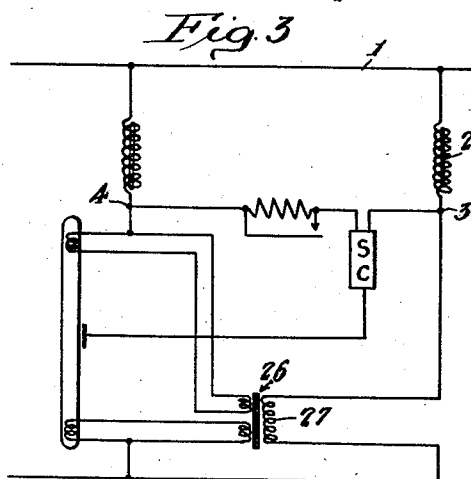
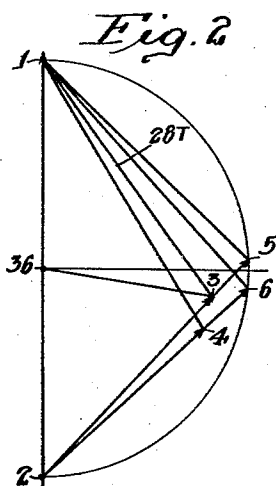
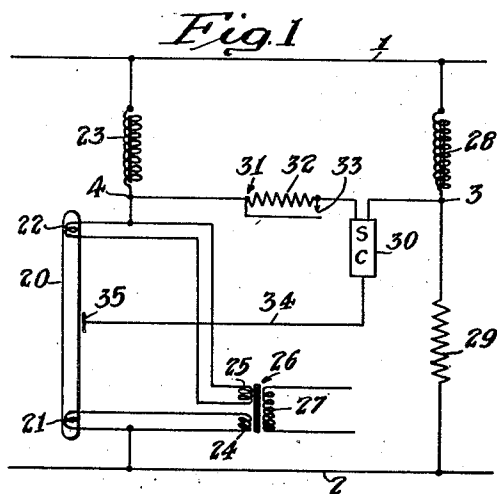
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1,977,231

GASEOUS DISCHARGE LAMP CIRCUIT

Filed April 3, 1933

7 Sheets-Sheet 1



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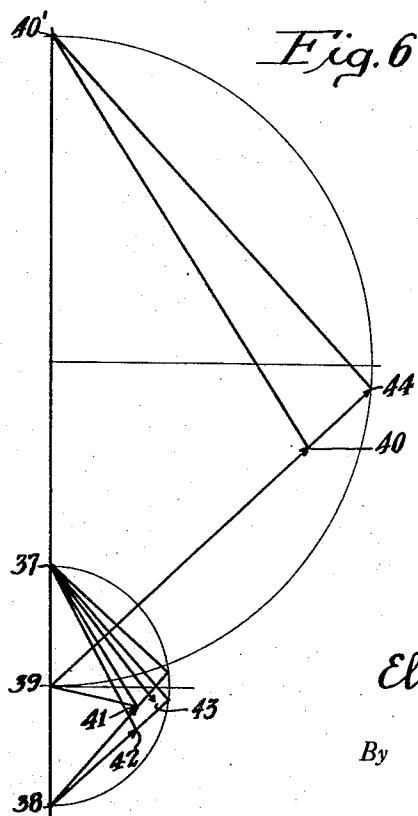
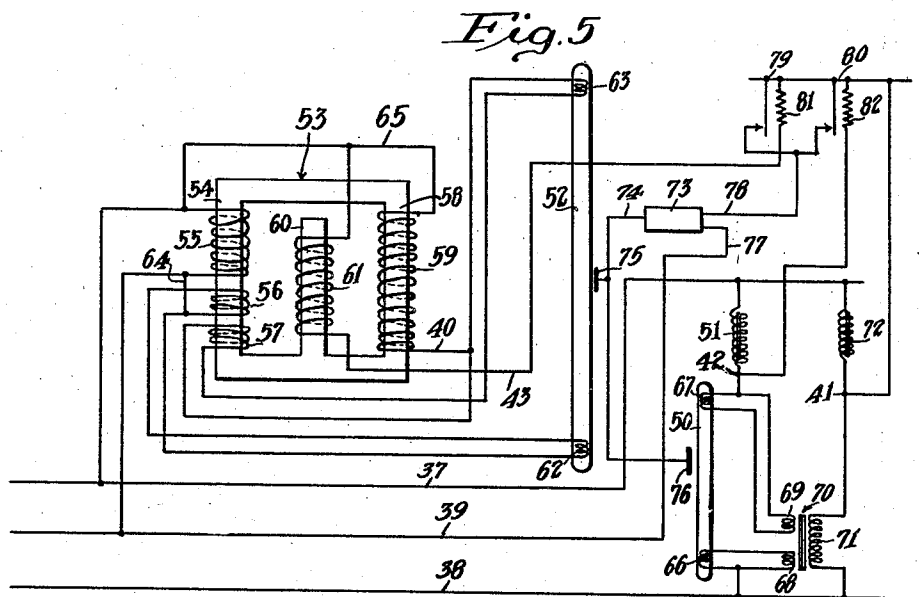
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GASEOUS DISCHARGE LAMP CIRCUIT

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7 Sheets-Sheet 2



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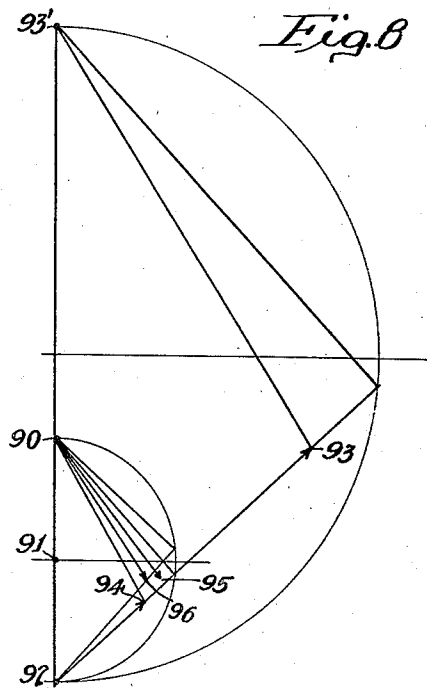
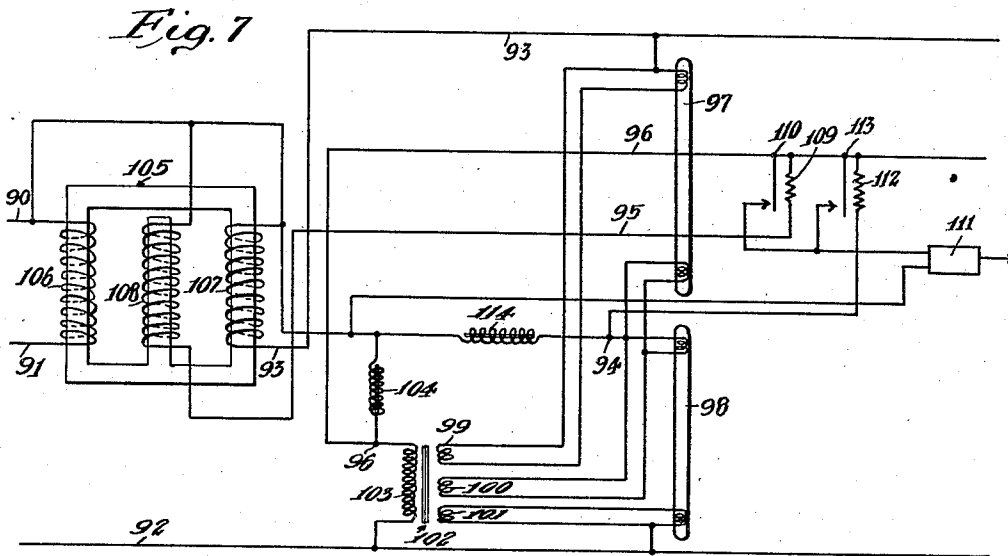
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GASEOUS DISCHARGE LAMP CIRCUIT

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GASEOUS DISCHARGE LAMP CIRCUIT

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Fig. 9

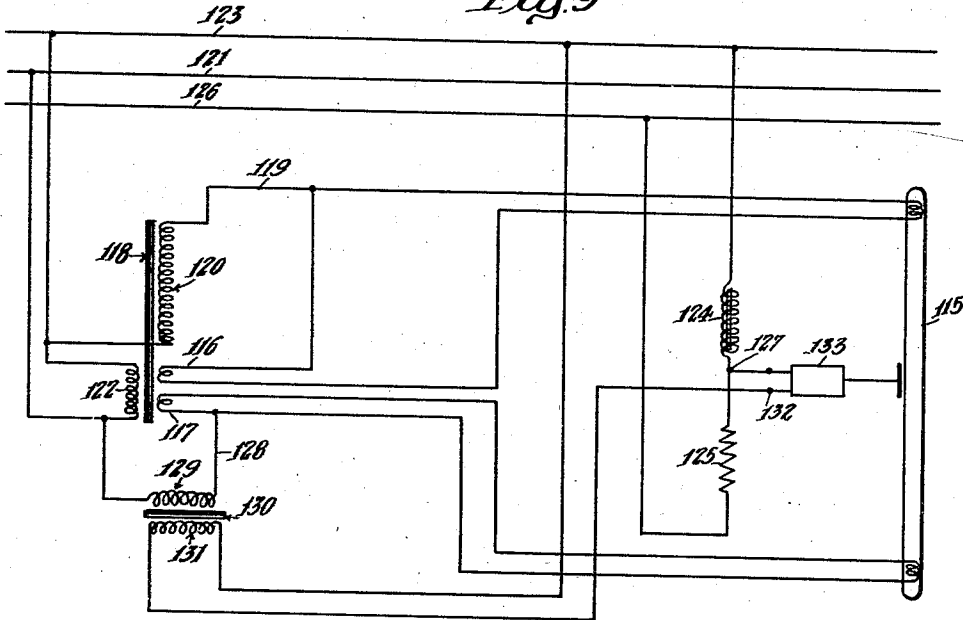
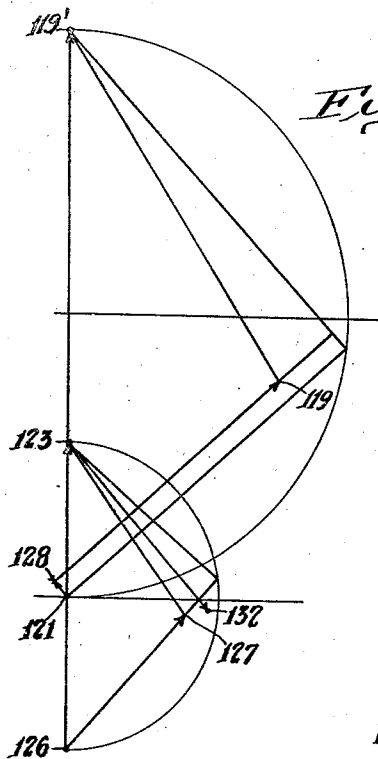


Fig. 10



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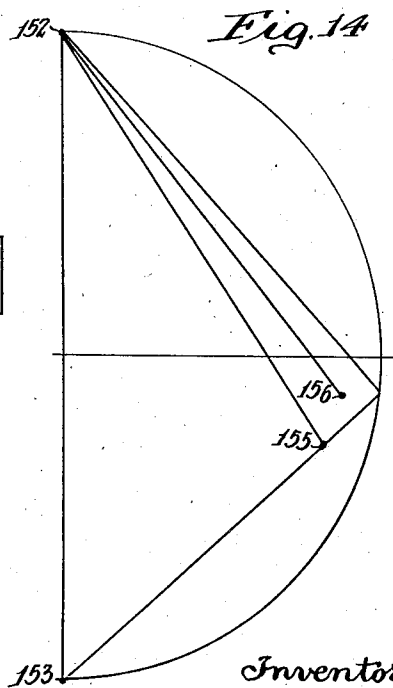
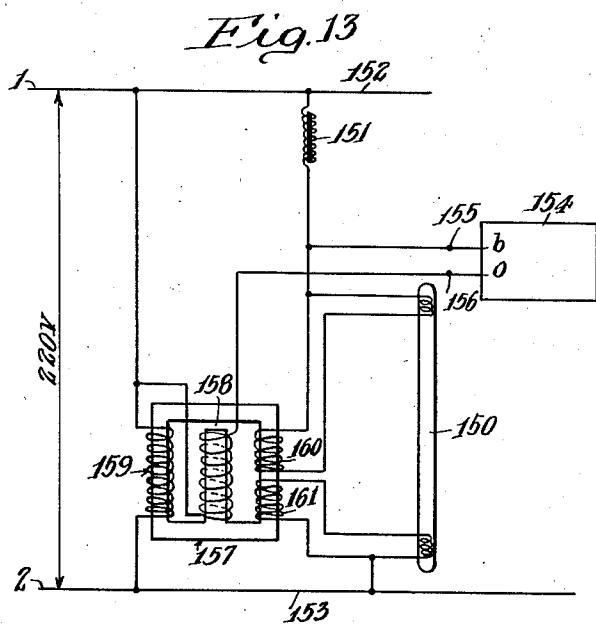
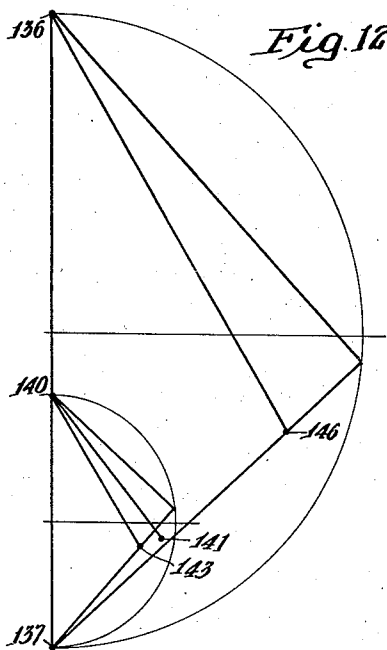
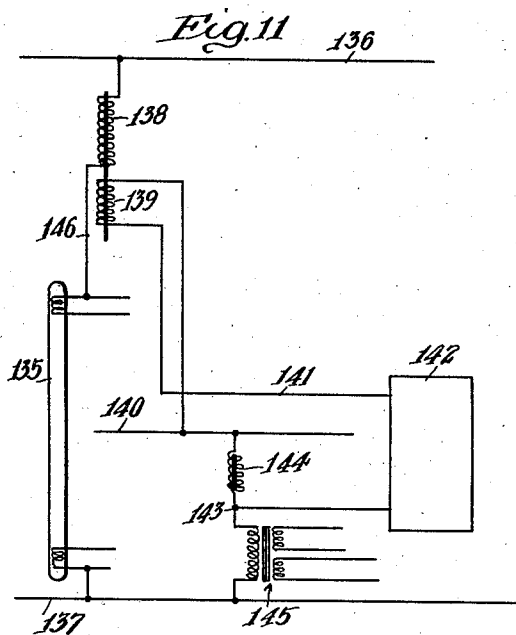
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GASEOUS DISCHARGE LAMP CIRCUIT

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7 Sheets-Sheet 5



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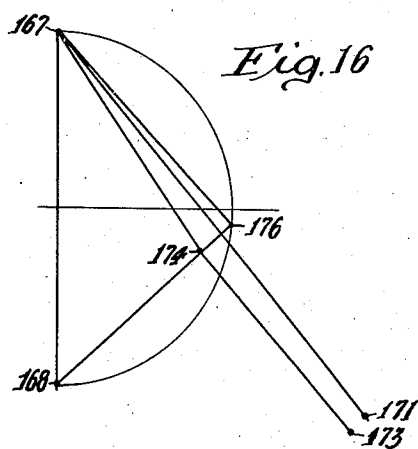
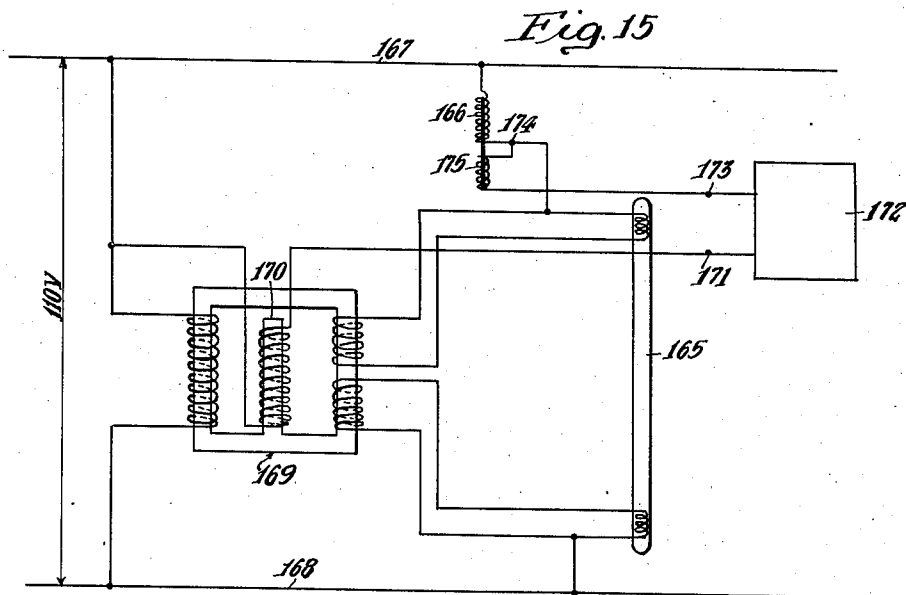
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GASEOUS DISCHARGE LAMP CIRCUIT

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7 Sheets-Sheet 6



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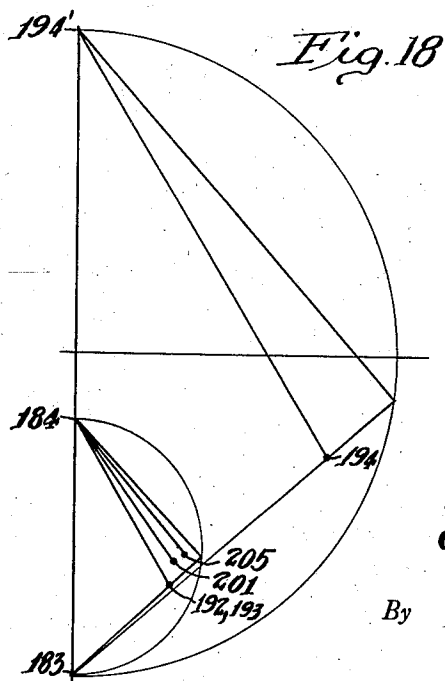
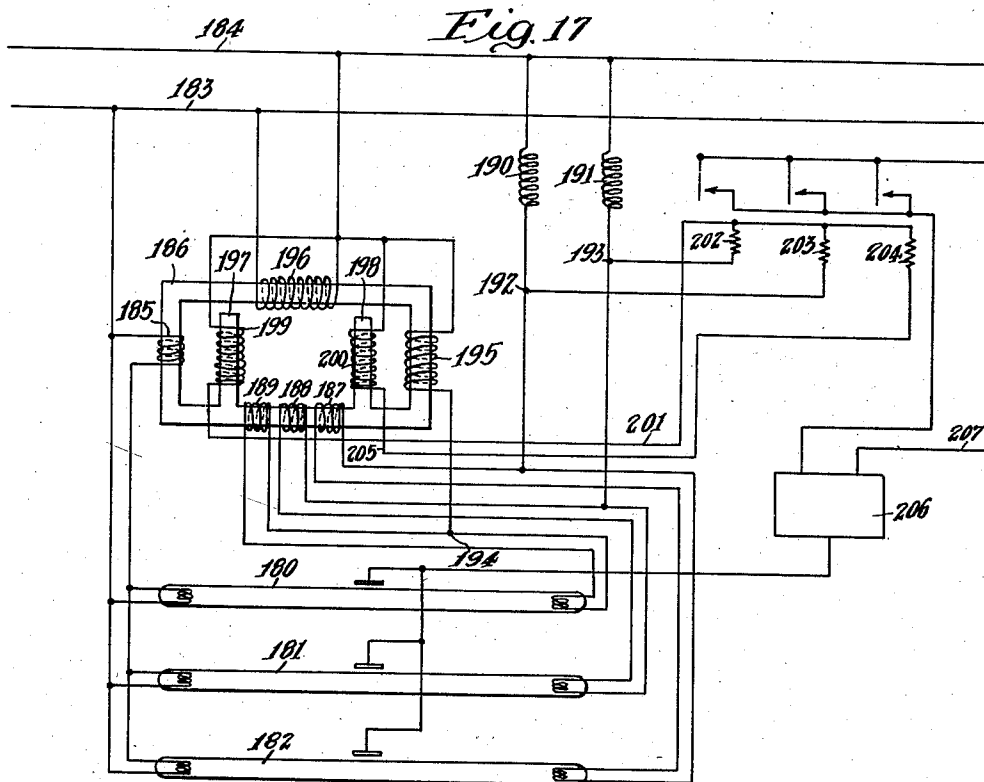
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GASEOUS DISCHARGE LAMP CIRCUIT

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7 Sheets-Sheet 7



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1,977,231

GASEOUS DISCHARGE LAMP CIRCUIT

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Application April 3, 1933, Serial No. 664,191

32 Claims. (Cl. 176—124)

This invention relates to circuits for operating electrical apparatus that requires special impulses for starting, but that will thereafter operate automatically on current supplied thereto from a relatively low potential source of electric energy. The invention relates particularly to the operation of gaseous discharge lamps of the type generally known as "neon" lamps.

Gaseous discharge lamps having heated electrodes have recently been developed for commercial use. These lamps have certain very desirable characteristics, one of which is that they operate at relatively low potentials. However, they have the undesirable characteristic of not always starting automatically in response to closure of the relatively low potential energizing circuit.

Such lamps may be initially set into operation in various ways, one of which is to produce a high frequency discharge in the vicinity of the lamp, which discharge produces initial ionization of the gas sufficient to start the flow of current through the lamp from the low potential energizing circuit. The high frequency discharge is commonly produced by a spark coil, or Tesla coil, energized from the same source of electric energy that the lamp is operated from, this source usually being a commercial power circuit supplying alternating current at 110 or 220 volts.

It is highly desirable, of course, that some provision be made for automatically energizing the spark coil, or other source of high frequency waves, in response to closure of the lamp switch to start the lamp, and to automatically de-energize the spark coil after the lamp has started and is operating in a normal manner. It is also desirable that the spark coil be re-energized automatically should the lamp accidentally be extinguished from any cause, such as momentary failure of the power supply.

Heretofore, to the best of my knowledge, the only known practicable way of automatically controlling the energization of the spark coil involved the use of a rather complicated relay system.

A broad object of the present invention is to provide an automatic starting circuit for a gaseous discharge device that is extremely simple, is positive in operation, and is inexpensive.

Another object of the invention is to provide a practicable starting circuit that can be operated without the use of any relays, although in its preferred form my circuit incorporates a limited number of very simple relays of the thermostatic type.

A feature of the invention is an A. C. gaseous discharge lamp circuit containing reactance elements and resistance elements in which actuating potential for energizing a starting device (such as a spark coil), is taken from two points in the circuit which, because of the peculiar characteristics of A. C. circuits containing reactance and resistance, are at substantially the same potential when the lamp is operating and drawing current, but are at widely different potentials when the lamp is not operating but has potential applied thereto.

Another object of the invention is to provide an A. C. gaseous discharge lamp circuit containing a plurality of lamps and a single starting device for all the lamps, which starting device is automatically energized if any lamp is unlighted while power is applied thereto.

Still another feature of the invention is a circuit and apparatus for automatically starting any or all of a plurality of gaseous discharge lamps from a single starting device, in which some of the lamps are operated at a potential less than the line potential and others of the lamps are operated from a step-up transformer at potentials greater than the line potential.

Other objects and features of the invention and its operation and advantages will be apparent from the following detailed description, which refers to the drawings.

In the drawings:

Figure 1 is a schematic circuit diagram of a simple circuit incorporating my invention.

Figure 2 is a vector diagram illustrating the operation of the circuit shown in Figure 1.

Figure 3 is a schematic circuit diagram of a modification of the system shown in Figure 1.

Figure 4 is a schematic diagram of a system including several gaseous discharge lamps energized from the same source, with a single starting means for starting any or all of the lamps.

Figure 5 is a schematic circuit diagram of a system including two lamps, one of which is energized directly from the line potential and the other of which is energized from a step-up transformer, in which both lamps are started from a single starting device.

Figure 6 is a vector diagram illustrating the operation of the circuit shown in Figure 5.

Figure 7 is a schematic circuit diagram of a system including two lamps connected in series with starting means for starting both of the lamps.

Figure 8 is a vector diagram illustrating the operation of the circuit shown in Figure 7.

Figure 9 is a schematic circuit diagram for a gaseous discharge lamp, in which a current transformer having its primary winding connected in series with the lamp is utilized for deriving a variable potential for actuating the starting device.

Figure 10 is a vector diagram illustrating the operation of the circuit shown in Figure 9.

Figure 11 is a schematic circuit diagram of a gaseous discharge light circuit, in which a special winding on the regulating reactance for the lamp is utilized to develop a variable potential for actuating the starting device.

Figure 12 is a vector diagram illustrating the operation of the circuit of Figure 11.

Figure 13 is a schematic circuit diagram of a gaseous discharge lamp circuit, in which a special filament lighting transformer is utilized to develop a reference potential for starting purposes.

Figure 14 is a vector diagram illustrating the operation of the circuit of Figure 13.

Figure 15 is a schematic circuit diagram of a gaseous discharge lamp circuit, in which a special winding on the lamp regulating reactance is utilized to derive a variable potential and a special filament lighting transformer is used to derive the constant reference potential for actuating the starting device.

Figure 16 is a vector diagram illustrating the operation of the circuit shown in Figure 15.

Figure 17 is a schematic circuit diagram of a circuit for energizing a plurality of lamps of different characteristics utilizing a single transformer for deriving a high potential for energizing one of the lamps, lighting the filaments of all the lamps and for deriving one of the constant reference potentials, and the variable potential for controlling the operation of the starting device.

Figure 18 is a vector diagram illustrating the operation of the circuit shown in Figure 17.

Figure 19 is a schematic circuit diagram of a lamp circuit similar to that shown in Figure 1, in which an alternative connection for energizing the spark coil is used.

Figure 20 is a schematic circuit diagram of a lamp circuit similar to that shown in Figure 1, showing still another alternative connection for supplying energizing potential to the spark coil.

Referring to Figure 1, I have shown a gaseous discharge lamp 20, having a pair of filamentary electrodes 21 and 22, respectively, which are connected across power leads 1 and 2. Thus, the electrode 22 is connected through a reactance coil 23 and to the lead 1, and the electrode 21 is connected directly to lead 2. The filamentary electrodes 21 and 22 are heated from any convenient source of energy; thus, they have been shown connected to secondary windings 24 and 25, respectively, of a transformer 26, the primary winding 27 of which may be connected to any desired source of energy.

With the lamp 20 extinguished and normal line potential impressed across the leads 1 and 2, no current will flow through the lamp 20, because the line potential is insufficient to initiate a discharge in the lamp. However, under these conditions, the voltage impressed across the lamp terminals 21 and 22 is the full line potential, because (disregarding the remaining elements of the circuit which will be described later) since there is no current flow there is no voltage drop across the reactance element 23. On the other hand, after the lamp 20 has been

once set into operation by some external starting means, there is a substantial flow of current through the reactance 23 and the lamp 20 and a substantial potential then exists across the reactance element 23 because of the potential drop therein.

The reactance element 23 is preferably so designed that its reactance is substantially equal to the resistance of the lamp 20 when the latter is in operation.

Thus referring to the vector diagram of Figure 2, the line potential existing across the leads 2 and 1 is represented both as to phase and magnitude by the vector 2—1.

When the lamp is not operating, this vector 2—1 represents the potential impressed across the lamp. When the lamp is operating and is conducting current there is a potential drop across the reactance element 23, as was previously stated. Because of the fact that the impedance of a lamp 20, when operating, is largely resistive, and since the impedance of the reactance element 23 is largely inductive reactance, the potentials across the lamp 20 and reactance element 23 will be out of phase with each other, and are represented by vectors 2—4 and 4—1, respectively. Thus the total voltage consumed by the resistances of the lamp 20 and the reactance element 23 is represented by the vector 2—6, of which the vector 2—4 represents the potential across the lamp 20 and the short vector 4—6 represents the potential drop due to the resistance of the reactance element 23, the vector 6—1 representing the total voltage consumed by the inductive reactance of the reactance element 23.

It is to be understood that the potential across the lamp 20, when the lamp is operating, is not actually a sinusoidal potential (vector diagrams apply only to sinusoidal functions). Because of the peculiar impedance characteristics of such lamps the curve of the actual potential thereacross is very irregular. However, it is convenient in studying circuits of the type herein disclosed to represent the actual voltage wave across the lamp by that sine wave which is most nearly equivalent in phase and amplitude to the actual wave. The phase and magnitude of this equivalent sine wave is represented approximately correctly by the vector 2—4 in Figure 2.

From the foregoing discussion with reference to Figure 2 and Figure 1, it will be observed that when the lamp 20 is not operating, (it is assumed in this discussion that line potential is constantly impressed between the leads 1 and 2), that the potential across the lamp—in other words the potential between lead 2 and the junction point 4—is the full line potential represented by the vector 2—1 in Figure 2. On the other hand, when the lamp 20 is conducting current, there is a substantial potential drop across reactance element 23 and because of the phase relations existing between the potential drop across the lamp and the potential drop across the reactance element 23, the potential between the lead 2 and the junction 4, instead of being represented by the vector 2—1 is represented by the vector 2—4.

I utilize this variation in potential between the lead 2 and the junction 4 between lighted and unlighted conditions, respectively, of the lamp 20 to produce starting impulses only when the lamp is extinguished, in the following manner:

Connected across leads 1, 2, in series, are a reactance element 28, a resistor 29 and a start-

ing circuit including a spark coil 30 and a thermostatic control relay 31 connected between the junction 4 of the lamp 20 and the reactance element 23 and the junction 3 of the reactance element 28 and register 29. The absolute magnitudes of the reactance element 28 and resistor 29 are not important, but they are so chosen that the ratio of the reactance element 28 to the resistance of resistor 29 is substantially the same as the ratio of the reactance of the element 23 to the operating resistance of the lamp 20. Since the reactance element 28 and the resistor 29 are permanently connected across the leads 1 and 2, the potential at the junction 3 is always different from the potential of either lead 1 or lead 2, and is a function of the potential drops across the reactance element 28 and resistor 29. Thus, the potential across reactance element 28 comprises (Figure 2) a reactance drop represented by vector 5—1 and a resistance drop represented by vector 3—5 and the potential drop across the resistor 29 is represented by a vector 2—3. The total voltage drop across the reactance element 28 is, therefore, represented by the vector 3—1.

It will be observed from Figure 2 that when the lamp 20 is conducting current, the potential of the junction 4 (indicated at point 4 in Figure 2), is only slightly different from the potential of the junction 3 (represented in Figure 2 by the point 3). This difference of potential between junctions 3 and 4 can be, for all practicable purposes, made as small as desired by properly proportioning the reactance element 28 and the resistor 29 and can readily be made so small that it will not actuate the thermostatic relay 31. Since the winding 32 of the relay 31 has a relatively high resistance, no substantial current is drawn by it; therefore, the contacts 33 of the relay remain open and no appreciable current is applied to the spark coil 30. The condition described is that existing when the lamp 20 is operating.

Now assume that the lamp 20 is extinguished either by momentary failure of the power supplied to leads 1 and 2, or from any other cause; thereupon, the potential of the junction 4 rises to substantially the potential of the lead 1. The potential of the junction 3, however, is always substantially different from the potential of lead 1 because of the voltage drop 3—1 existing across the reactance element 28. Therefore, with the lamp 20 extinguished, the potential existing between junction points 3, 4 is substantially equal to the potential represented by the vector 3—1. This potential is substantially greater than half the potential 2—1 across the leads 2 and 1, and is sufficient to actuate the thermostatic relay 31 to close the contacts 33 and apply substantially the full potential represented by vector 3—1 to the spark coil 30. This potential is sufficient to energize the spark coil to produce high frequency oscillations which are applied over a conductor 34 to an electrode 35 positioned adjacent the lamp 20. Electrode 35 may comprise merely a plate or it may comprise a few turns of wire wrapped about the lamp 20. The high frequency discharge thus produced in the vicinity of the lamp 20 ionizes the gas therein and causes the lamp to start, and operate in the usual manner.

Immediately after the lamp has started, the potential existing across the junctions 3 and 4 drops to the small values represented in Figure 2 by the distance between points 3 and 4 in the

vector diagram. Therefore, the current supply for the spark coil 30 is automatically cut off, by the reduction of the potential between junctions 3 and 4 to a value insufficient to operate the spark coil 30, upon the starting of the lamp. However, should the lamp again go out at any time for any cause, the potential between points 4 and 3 will immediately rise to a value sufficient to again close the thermostat contacts, energize the spark coil, and again set the lamp 20 to operating.

The spark coil 30 is fully described in my co-pending application, Serial No. 657,486, filed February 20, 1933. However, since such devices are well known, it is unnecessary to describe the specific construction herein.

In the actual design of gaseous discharge lamp circuits, it is customary to supply a means, such as the reactance coil 23 connected in series with the tube to control the voltage applied to the lamp during the operation because of the negative resistance characteristics of gaseous discharge lamps. The reactance in series with the lamp is preferably of magnitude substantially equal to the operating resistance of the lamp, or slightly greater, so that the relative potentials existing in an actual circuit are approximately as represented by the vectors 2—4 and 4—1 in Figure 2, although they may vary slightly from the values there shown.

It is to be understood, of course, that the voltage existing across a gaseous discharge lamp can be only approximately represented in a vector diagram for the reason that the current flowing through such a gaseous discharge lamp is not strictly sinusoidal and vector diagrams apply only to sinusoidal quantities. However, the potentials obtained in practice correspond very closely to those arrived at by vector studies and the use of vector diagrams in the explanation of operation is, therefore, fully justified.

Although the relay 31 has been shown connected in series with the spark coil 30, it is to be understood that this relay is not absolutely essential to the operation of the system. The main purpose of the relay is to introduce a time delay between the application of power to mains 1 and 2 and the application of starting impulses to the lamp. This delay (of only a few seconds) is to permit the electrodes of the lamp which are energized from the mains 1 and 2, to become heated before the lamp is started. A secondary function of the relay is to increase the efficiency by reducing to an insignificant value the small current which would otherwise flow continuously in the spark coil unless the reactances and resistances in the system were so delicately balanced as to cause the point 3 in vector diagram of Figure 2 to fall exactly on the point 4.

In the system shown in Figure 1, there is a continuous loss of energy in the resistor 29. This loss is not of great consequence because the current required to energize the spark coil 30 is not very large and therefore the element 28 and resistor 29 may have substantial reactance and resistance, respectively. However, the efficiency of the system can be increased by connecting the filament energizing transformer 26 in series with the reactance element 28, as shown in Figure 3, the primary winding 27 of the filament lighting transformer 26 being substituted for the separate resistance 29. The filament lighting transformer 26 is designed to have low leakage reactance, and since the filaments 21 and 22 of the lamp 20 have impedances which

are substantially pure resistances, the load provided by the transformer 26 in series with the reactance element 28 is largely resistive. Of course the magnitude of this resistance load
5 provided by transformer 26 is determined by the characteristics of the lamp filaments and is therefore fixed.

However, the ratio between the resistance of the lamp loads and the reactance of the reactance element 28 may be brought to the desired value by selecting a reactance element of
10 desired, suitable reactance.

The system shown in Figure 3 functions exactly the same, in so far as the starting circuit is concerned, as the circuit shown in Figure 1,
15 and, therefore, no further explanation of the operation of this circuit is necessary. The efficiency of the circuit shown in Figure 3 is very high, since the power consumed in reactance element 28 is very slight.

It is often desirable to operate several gaseous discharge lamps in parallel from a single power circuit, and in a single installation. Under such conditions, a single spark coil may be
25 used to start all of the lamps by means of the circuit shown in Figure 4. In Figure 4, I have shown three lamps 20b, 20c, and 20d, each connected in series with an individual reactance element 23b, 23c, and 23d, respectively, and each energized from an individual filament lighting
30 transformer 26b, 26c and 26d, respectively. In this circuit the lamps are energized from a source of alternating current of 220-volt potential, and the filament lighting transformers 26c, 26d and are energized directly from a source of alternating current of 110-volt potential. Thus all of the lamps 20b and 20c and 20d,
35 and their associated reactance elements 23b, 23c and 23d are shown connected across 220-volt leads 1b and 2b, respectively, of a three-wire, 220-A. C. circuit, and the filament lighting transformers 26c and 26d are shown connected between the lead 2b and the neutral wire 36 of the three-wire system. The connections to
40 the filament lighting transformer 27b will be described later.

A single spark coil 30b is used to start all three of the lamps, terminals 35b, 35c and 35d being provided adjacent the respective lamps
50 and all connected to the output terminal of the single spark coil 30b. One side of the input circuit of the spark coil is connected directly to the neutral conductor 36 and the other input terminal of the spark coil, is adapted to be connected
55 through the contacts of three thermostatic switches 31b, 31c and 31d, respectively, to the junction point 3b between a reactance element 28b and the primary winding 27b of the filament lighting transformer 26b associated with
60 the lamp 20b.

It will be observed that the junction point 3b is also connected to one terminal of each winding 32b, 32c and 32d, respectively, of the thermostatic switches 31b, 31c and 31d, respectively,
65 and that the other terminals of these three windings are connected, respectively, to the junction 4b between reactance element 23b and lamp 20b; the junction point 4c between the reactance element 23c and the lamp 20c;
70 and the junction point 4d between the reactance element 23d and the lamp 20d.

The filament lighting transformers 26b, 26c and 26d may all be of the same type, adapted to be energized from a source of current of 110-
75 volt potential. This potential is supplied directly

to transformers 26c, 26d by connecting them between the 220-volt lead 2b and the neutral lead 36. The filament lighting transformer 26b is also supplied with current of 110-volt potential
80 by reason of the fact that although it is connected across the 220-volt leads 1b and 2d, the reactance element 28b, connected in series therewith, is so designed as to reduce the potential applied to the primary winding 27b of transformer 26b to substantially 110-volts.
85

Referring now to the operation of the system shown in Figure 4, assume that operating potential is applied to the conductors 1b and 2b and 36, and that lamps 20c and 20d are operating
90 but that lamp 20b is not operating. Under these conditions, the potential existing at the points 4c and 4d (the junctures between lamps 20c and 20d and their associated reactances 23c and 23d) will correspond to the potential represented by the point 4 of the vector diagram in Figure 2.
95 Since the potential of point 4 differs only slightly from the potential at point 3, which corresponds to the potential at point 3b in Figure 4, to which the common terminals of actuating circuits 32c and 32d are connected, the potential impressed
100 across actuating circuits 32c and 32d is insufficient to close the contacts associated with those actuating circuits. (It is to be understood that with reactance 28b designed to deliver exactly
105 110 volts to transformer 27b, the vector 2-3 will be shorter than shown in Figure 2, but the point 3 will still be adjacent point 4.)

Thus the contacts remain open. However, because of the fact that lamp 20b is not operating, the potential of the junction 4b between that
110 lamp and its regulating reactance 23b is substantially at the potential of the conductor 1b, which corresponds to the potential of the point 1 in the vector diagram of Figure 2. Furthermore, since the potential of point 1 in Figure
115 2 is substantially different from the potential of point 3, which is the potential at the junction 3b in Figure 4, the potential represented by the vector 3-1 in Figure 2 is applied across the actuating circuit 32b of the relay 31b (in Figure
120 4) and closes the contact associated with that relay which connects one terminal of the spark coil 30b to the point 3b. Since the other terminal of the spark coil 30b is connected to the
125 neutral conductor 36 of the supply circuit, a potential sufficient to energize the spark coil 30b is applied thereto to actuate the latter to produce starting impulses which are applied through the
130 electrode 35b to the lamp 20b to start the latter.

It will be observed from an inspection of the vector diagram of Figure 2 that the potential of the neutral conductor 36, which is midway between the potentials of the conductors 1b and 2b,
135 is represented by the point 36 midway on the vector 1-2. Since, as previously pointed out, the potential of the point 3b in Figure 4 is that of point 3 in the vector diagram of Figure 2, the potential applied to the spark coil terminals, by closure of the contacts associated with
140 relay 31b, is that represented by the vector 36-3 in Figure 2. The spark coil may be designed to operate on this potential.

Following the actuation of the spark coil 30b in the manner described, the starting impulses produced by the coil initiate a flow of current in
145 the lamp 20b. Thereupon the potential of the point 4b immediately falls to a value corresponding to the potential of the point 4 in Figure 2, which differs from the potential at
150

joint 3 by an insufficient margin to actuate the relay 31b. The latter therefore opens its contacts and disconnects the spark coil.

Since the relays 31c and 31d respectively are connected between the point 3b (Figure 4) and the points 4c and 4d, respectively, and the potentials of points 4c and 4d are substantially at the potential of point 3b when lamps 20c and 20d are operating, the contacts of relays 31c and 31d are, like the contacts of relay 31b, normally open when all of the lamps are operating. However, should the lamps 20c and 20d be extinguished at any time while normal line potential is applied to the conductors 1b, 36 and 2b, the potential of the point 4c or 4d, depending upon which lamp is extinguished, will become substantially equal to the potential of the conductor 1b, and this potential will be impressed upon the actuating circuit of the associated relay 31c or 31d to close the contacts of that relay and energize the spark coil exactly as was described in connection with the starting of lamp 20b.

In case all the lamps are extinguished while line potential is applied, which would be the case when the power was first applied to the line, then all three relays, 31b, 31c and 31d, will be energized to close their contacts and energize the spark coil 30b. Therefore, so long as line potential is applied to the conductors 1b, 36 and 2b, the spark coil will be energized to supply starting impulses to all the lamps should any or all of the lamps be extinguished, whereas, so long as all of the lamps are operating, the contacts of the relays 31b, 31c and 31d will be open and the spark coil will be disconnected.

It will be observed from Figure 4 that the filament lighting transformers 26c and 26d, associated with lamps 20c and 20d, have their primary windings connected across the neutral conductor 36 and one side of the line 2b, whereas, the filament lighting transformer 26b, associated with the lamp 20b, has its primary winding connected in series with the reactance 28b across the lines 2b and 1b. The potential between conductors 1b and 2b is twice the potential across the conductors 36 and 2b, but the reactance 28b reduces the potential applied to the primary winding 27b of the filament lighting transformers 26b. This potential, as represented in Figure 2 by vector 2-3, is somewhat greater than the potential across the neutral conductor 36 and the line 2b, which is represented by vector 2-36 in Figure 2. It is possible, however, as previously indicated, to so design the reactor 28b as to make the potential applied to the filament transformer 27b (vector 2-3 in Fig. 2) within a volt of the 110 volt potential existing across the line conductor 2b and the neutral conductor 36. Therefore, the transformers 26b, 26c and 26d may all be of the same type, adapted to be energized from the potential existing across the conductors 2b and 36.

The circuits thus far described, related either to the operation of single lamps or to the operation of a group of similar lamps all of which demand essentially the same operating potentials.

In Figure 5, I have shown in schematic form the wiring diagram of a system for operating a plurality of lamps which require different operating potentials.

Thus, referring to Figure 5, I have shown a three-conductor supply circuit comprising two main conductors 37 and 38, which may be main-

tained at a potential difference of 220-volts from a suitable supply circuit, and a neutral conductor 39 maintained at a potential of 110-volts with respect to the main conductors 37 and 38. The system includes a lamp 50 adapted to operate after being once started from a source of potential of 220-volts connected in series with a regulator reactance 51 across the main line conductors 37 and 38 and a second lamp 52, requiring an operating potential substantially greater than 220-volts, which is energized with suitable high potential derived from a transformer 53.

Transformer 53 is of a type used for energizing gaseous discharge lamps and is especially designed to have a relatively high leakage reactance. Thus it comprises a magnetic core comprising a first leg 54, upon which a primary winding 55 and a pair of filament lighting secondary windings 56 and 57 are positioned, a leg 58 upon which a secondary winding 59 is positioned, and a magnetic shunt section 60 for providing desired leakage reactance between the primary and the secondary windings 55 and 59, respectively, when the secondary winding is drawing current.

In conventional transformers of the type described, the magnetic shunt section 60 carries no winding, but as a part of my system for automatically starting the lamps, I provide a tertiary winding 61 upon the magnetic shunt section 60.

The primary winding 55 is connected across the line conductors 37 and 39, which provide a potential of 110-volts. The two filament lighting secondary windings 56 and 57 are connected, respectively, to electrodes 62 and 63, respectively, of lamp 52, and the electrode 62 is also connected to the neutral conductor 39 by a conductor 64 between one end of the primary winding 55 and one side of the secondary winding 56. The electrode 63 is connected by a conductor 40 to one end of the main secondary winding 59 and the other end of this secondary winding is connected by a conductor 65 to the line conductor 37.

It will be observed that as a result of these connections, the primary winding 55 and the main secondary winding 59 are connected effectively in series between the neutral conductor 39 of the supply circuit and the electrode 63. Thus both the line potential between conductors 37 and 39 and the potential developed in the secondary winding 59 are added together to provide a desired high potential for operating the lamp 52.

The lamp 50, like lamp 52, is provided with a pair of electrodes 66 and 67, respectively, which are heated from a pair of secondary windings 68 and 69, respectively, of a filament lighting transformer 70 having a primary winding 71 connected in series with a reactance coil 72 across the main line conductors 37 and 38. Reactance element 72 has a reactance approximately equal to or slightly greater than the input resistance of the filament lighting transformer 70 and the junction point 41 between reactance 72 and the primary winding 71 of transformer 70, supplies a substantially constant potential of desired magnitude for use in connection with the starting device next to be described.

The starting device comprises a spark coil 73 having a high frequency output terminal 74 which connects with electrodes 75 and 76 positioned adjacent the lamps 52 and 50, respec-

tively. The spark coil 73 is likewise provided with a pair of input terminals 77 and 78, across which potential is applied for energizing the spark coil. The input terminal 77 is connected

5 directly to the neutral conductor 39 of the supply circuit and the other terminal 78 is connected to a pair of contacts associated, respectively, with two thermostatic control relays 79 and 80. Each relay 79 and 80 has another cooperating contact connected directly to the point 41 between reactance 72 and winding 71 of transformer 70, and each relay also has an actuating circuit 81 and 82, respectively, one end of each of which is likewise connected to the point 41. The other end of actuating circuit 81 is connected through a conductor 43 and the tertiary winding 61 of transformer 53 to conductor 65, which is in turn connected to the line conductor 37. The other end of actuating circuit 82, associated with relay 80, is connected to point 42 between the regulating reactance 51 and the lamp 50.

The operation of the system described can be most conveniently explained with reference to the vector diagram of Figure 6. Thus, the vector 39—37 represents the line potential of 110-volts existing between line conductors 39 and 37. The open circuit potential developed in secondary winding 59, i. e., the open circuit potential between conductors 37 and 40, is represented by the vector 37—40' which is in phase with the potential across the conductors 39 and 37, and the total open circuit potential developed across conductors 39 and 40 (the open circuit potential developed across the primary winding 55 and secondary winding 59) is, therefore, represented by the vector 39—40'. Therefore, when the lamp 52 is not operating, and no current is flowing in the secondary winding 59, the potential of conductor 40 is the potential of point 40' in the vector diagram of Figure 6. However, when the lamp 52 is conducting current, there is, because of the leakage reactance introduced by the shunt core section of the transformer, an apparent potential drop in the primary winding and secondary winding 55 and 59, respectively. This potential drop is out of phase with the potential across conductors 39 and 37, and is represented in the vector diagram in Figure 6 by the vector 44—40'. There is also a slight potential drop in the windings 55 and 59 due to the resistance of those windings, which potential drop is substantially 90° out of phase with the vector 44—40' and is represented by the short vector 40—44.

The operating impedance of the lamp 52 is substantially resistive, and, therefore, the potential across the lamp, when the latter is operating, is represented in Figure 6 by the vector 39—40 which is in phase with the vector 40—44. The potential conditions described in connection with the transformer 53 and the lamp 52 are those existing in the conventional circuit.

Referring now to the operating characteristics of the circuit including lamp 50 and reactance 51, the total potential applied across these elements is the potential between the line conductors 37 and 38 and is indicated by the vector 37—38 in Figure 6. When the lamp 50 is operating, the reactance element 51 produces a substantial potential drop thereacross, which is out of phase with the potential across conductors 37 and 38, and is represented in phase and magnitude by the vector 37—42 in Figure 6. The potential drop across the lamp 50, on the

other hand, is approximately 90° out of phase with the potential represented by the vector 37—42, and is represented by vector 38—42.

It will be observed, therefore, that when lamp 50 is operating, the potential of point 42, in Figure 5, is approximately indicated by the position of point 42 in the vector diagram of Figure 6. Of course when the lamp is not operating, there is no current flowing through the lamp, or through the reactance element 51, and the potential of point 42 is then the same as the potential of the conductor 37, which is indicated in Figure 6 by the point 37.

The potential applied across the series connection including the reactance 72 and the primary winding of the filament lighting transformer 70, is likewise the potential existing across line conductors 37 and 38, corresponding to points 37 and 38 in Figure 6, and the potential of the junction point 41 between these elements is that of point 41 in Figure 6, the vector 37—41, representing the phase, position and magnitude of the potential drop across the reactance 72 and the vector 38—41, representing the phase, position and magnitude of the potential across the primary winding 71, of transformer 70.

Referring now to the tertiary winding 61 of the transformer 53, it will be observed that one end of this winding is connected through conductor 65 to line conductor 37. Therefore the potential of this end of winding 61 is at the potential represented by point 37 in Figure 6. The potential of the other end of winding 61, which connects to conductor 43, varies from substantially zero to a potential in phase with the apparent reactance drop across the secondary winding 59, when the secondary winding is not conducting current and is conducting current, respectively. Thus, when the lamp 52 is not operating and no current is flowing through the secondary winding 59, substantially all of the flux developed in leg 54 of the core of the transformer circulates through leg 58 and very little flux is developed in the shunt core section 60. Therefore, under these conditions, very little potential is developed in the winding 61 and the potential of conductor 43 is substantially at the same potential as conductor 37. When the lamp 52 is operating, however, the current flowing in secondary winding 59 tends to develop a flux in the leg 58, opposing the flux developed in leg 54 by the primary winding 55, with the result that a substantial flux is generated in the shunt core section 60. This develops a potential in the tertiary winding 61, which potential, because of the particular proportioning and poling of winding 61, is approximately equal to the potential of the point 41 and is represented in Figure 6 by the vector 37—43.

It is apparent from the foregoing description that when both lamps 52 and 50 are operating, the potentials of the conductor 43 and the potential at the point 42, which potentials are indicated by points 43 and 42 in Figure 6, are approximately equal to the potential of the point 41. Since the relay actuating circuits 81 and 82 are connected across points 41 and 43, and points 41 and 42, respectively, the potential across these actuating circuits, when the lamps are operating, is insufficient to close the relay contacts associated with these actuating circuits. Therefore, when both lamps are operating, the spark coil 73 is not energized.

However, if, while line potential is applied to

the line conductors 37—38 and 39 the lamp 52 is not operating, then no potential is developed in the tertiary winding 61 and the potential of conductor 43 is the same as that of the conductor 37. Therefore a potential of substantial value, represented by the distance between points 37 and 41 in the vector diagram of Figure 6, is applied to the actuating circuit 81 of relay 79, which closes the contacts of that relay and connects the terminal 78 of spark coil 73 to the point 41. This results in the application of a potential to the input terminals of the spark coil 73 corresponding in value to the distance between points 39 and 41 in Figure 6 which is sufficient to energize the spark coil 73 and apply starting impulses to the lamps.

After the lamp 52 has started, the potential applied to the actuating circuit 81 of relay 79 again falls to a small value, represented by the distance between points 43 and 41 in Figure 6, and the contacts of relay 79 thereupon open to disconnect the spark coil 73.

Likewise, if the lamp 50 is not operating while line potential is applied to the line conductors 37, 38 and 39, the potential of point 42 is the same as the potential of the conductor 37 (represented by point 37 in Figure 6), and therefore a potential represented in magnitude by the distance between points 37 and 41 in Figure 6 is applied to the actuating circuit 82 of relay 80 which closes the contacts of that relay and applies operating potential to the input terminals of spark coil 73 exactly as described in the preceding paragraph. The spark coil 73 thereupon develops starting impulses which are applied to the lamps and start the lamp 50 into operation. Immediately following the starting of normal operation of lamp 50 the potential of junction point 42 rises to the value represented by the point 42 in Figure 6, which differs only slightly from the potential of point 41. Therefore the potential applied to the actuating circuit 82 of relay 80 falls below a value sufficient to maintain the contacts of that relay closed; the contacts thereupon open and disconnect the spark coil 73.

Although I have shown in Figure 5, a system including only two lamps, it is obvious that the number of lamps may be increased to any desired number by providing an additional transformer similar to transformer 53 for each high potential lamp added, and by adding a regulating reactance corresponding to reactance elements 51 for each low potential lamp added. Regardless of the number of lamps in the system, the point 41 constitutes one potential reference point for the actuation of the starting device, the junction point between each low potential lamp and its regulating reactance constituting the other potential reference point for the control of the starting device in response to failure of that lamp, and the free end of the tertiary winding of the transformer associated with each high potential lamp constituting the other voltage reference point for controlling the operation of the single starting device in response to failure of that high potential lamp.

In Figure 7, I have shown a circuit for operating two lamps of different characteristics in series. Thus, I have shown a lamp 97, which may contain as its chief active gas neon, and a lamp 98, which may contain mercury. In a circuit actually tested, the lamp 97 required an energizing current of approximately one ampere at a potential substantially above the line potential of 220 volts and the lamp 98 required a current of ap-

proximately two amperes at a potential substantially less than the line potential of 220 volts.

The filaments of the two lamps are supplied with heating current from three secondary windings 99, 100 and 101 of a transformer 102, the primary winding 103 of which is connected in series with a reactance element 104 across the 220-volt mains 90 and 92 of the supply circuit. Secondary winding 100 energizes the two filaments of the two lamps which are connected together and the windings 99 and 101 heat the remaining filaments of the lamps which are connected to points of different potential. The reactance element 104 and the primary winding 103 of the filament transformer provide a constant reference potential at their junction point 96 for controlling the starting device.

A transformer 105 having a primary winding 106 connected between one side 90 of the 220-volt circuit and the neutral conductor 91 thereof provides the high potential necessary to energize the lamp 97 and also provides the variable potential for actuating the starting device. Thus, the transformer is provided with a secondary winding 107 connected between the line conductor 90 and one terminal of the lamp 97, the circuit being completed from the other terminal of lamp 97 through lamp 98 to the other line conductor 92 of the supply circuit. A tertiary winding 108 on the shunt core section of transformer 105 is connected between the line conductor 90 and the conductor 95 extending to the starting circuit. Thus, the starting circuit comprises a thermostatic relay having an energizing winding 109 connected between the conductor 96 of constant reference potential and the conductor 95 extending from the tertiary winding 108 and a pair of contacts 110 for closing a circuit from conductor 96 through a spark coil 111 to the line conductor 90 in response to energization of the winding 109.

A second relay comprising an energizing winding 112 connected between the conductor 96 and the junction point 94 between the upper terminal of lamp 98 and the lower terminal of lamp 97 may also be provided, this winding controlling a pair of contacts 113, which are connected in shunt to the contacts 110. Although not shown in Figure 7, it is to be understood that the high potential terminal of the spark coil 111 is connected to starting electrodes adjacent both lamps 97 and 98.

As previously stated, the mercury lamp 98 requires a substantially greater operating current than the neon lamp 97. To supply this additional current, the upper terminal of lamp 98 (the junction point 94) is connected through a regulating reactance 114 to the line conductor 90.

Referring now to Figure 8, assume that both lamps are extinguished and that the supply conductors 90, 91 and 92 are supplying potential. The potential existing across conductors 92 and 90 is represented by the vector 92—90 and the potential between either of these conductors and the neutral conductor 91 by the vectors 92—91 and 91—90, respectively. Since the lamps are not operating, the secondary winding 107 of transformer 105 will be supplying no current and will apply its full developed potential to conductor 93. This potential is in phase with the potential of the conductors 92 and 90 but is of greater magnitude and is represented by the vector 92—93'. With no current flowing in secondary winding 107, the tertiary winding 108

develops no appreciable potential and, therefore, the potential of conductor 95 is substantially the same as the potential of conductor 90 and is represented by the position of the point 90 in Figure 8. Point 90, therefore, represents the potential applied to the lower end of the energizing winding 109. The other end of winding 109 is connected through conductor 96 to the junction point of the reactance 104 and the primary winding 103 of the filament transformer 102. The potential drop across the reactance 104 is represented by the vector 90—96 in Figure 8 and, therefore, the potential applied across the relay energizing winding 109 is represented by the vector 90—96. This potential is of sufficient magnitude to energize the winding 109 and close contacts 110, which connects the spark coil 111 between the conductor 96 and conductor 90 and the potential existing between those two conductors (vector 90—96 in Figure 8) is sufficient to actuate the spark coil and set the tubes 97 and 98 in operation.

Following the starting of the lamps 97 and 98, the potential applied to lamp 97 is substantially reduced because of the apparent potential drop in the transformer 105, this drop in the transformer being represented by the vector 93—93' in Figure 8 and the potential consumed in the lamps being represented by the vector 92—93. Of this potential, the component consumed in lamp 97 is represented by the vector 94—93 and the component consumed in the lamp 98 by the vector 92—94. Therefore, while the lamps are in operation the potential of the junction point 94 between the two lamps is represented by the position of point 94 in the vector diagram. It will be noted that one end of the relay energizing winding 112 is connected between junction point 94 and conductor 96. Since the potential of conductor 96 is represented by the point 96 in the vector diagram, which is spaced only slightly from the point 94, insufficient potential is supplied to the winding 112 to energize it. Therefore, the contacts 113, associated with this winding, remain open.

Furthermore, when the secondary winding 107 of transformer 105 is supplying the lamp 97 with current, a potential substantially in phase with the apparent reactance drop in winding 107 is developed in the tertiary winding 108. The tertiary winding 108 is so proportioned and poled as to apply a potential between the line conductor 90 and the conductor 95, which may be represented in approximate phase and magnitude by the vector 90—95 in Figure 8, the point 95 representing the potential of conductor 95. It will be noticed that this point 95 is only slightly spaced from the point 96 representing the potential of conductor 96 so that insufficient potential is applied to the energizing winding 109 to close the contacts 110. Therefore, these contacts, which were previously closed, open and disconnect the spark coil 111 from its source of energizing potential.

Since, as has been previously specified, the mercury lamp 98 requires a greater current than the neon lamp 97, the junction point 94 is connected to the supply conductor 90 through regulating reactance 114. The potential drop in regulating reactance 114 is represented by the vector 90—94.

Should lamp 97 go out, current would cease to flow through the secondary winding 107 of transformer 105, whereupon the potential of conductor 95 would rise approximately to the

potential of conductor 90 and again apply sufficient potential to the energizing winding 109 to close the contacts 110 and energize the spark coil 111 to start the lamp into operation, precisely as was stated at the beginning of the description of operation of this circuit. Likewise, should the mercury lamp 98 be extinguished, the potential of the junction point 94 would rise approximately to the potential of supply conductor 90 and a potential approximately represented by the vector 90—96 would be applied to the relay energizing winding 112 to close contacts 113 and apply potential to the spark coil 111 to again start the lamp.

In the particular combination of lamps described, the relay comprising the energizing winding 112 and contacts 113 may be eliminated since tests indicate that if lamp 98 is not passing current, the potential applied to lamp 97 through the reactance 114 is insufficient to maintain lamp 97 in operation. Therefore, should either lamp go out from any cause, both lamps would be extinguished, thereby applying potential to the relay energizing winding 109 to close the contacts 110 and energize the spark coil 111. It is possible, however, that if lamps of different characteristics than those described are used in this circuit, conditions might be such as to permit the operation of one lamp without the other and it would then be necessary to have the spark coil under the control of both lamps.

It will be observed from the foregoing description that the circuit of Figure 7 resembles those previously described in that it incorporates means (the reactance element 104 and the primary winding 103 of the filament lighting transformer connected in series across the source of supply) for developing a reference potential of constant magnitude and other means (either the tertiary winding 108 of transformer 105 or the regulating reactance 114) for producing variable potentials descriptive of the condition of the lamps with which they are associated for producing a potential substantially equal to the reference potential when the lamps are in operation and a substantially different potential when their associated lamps are not operating but have potential applied thereto.

In the circuits heretofore described incorporating lamps requiring an operating potential substantially above line potential, the required high potential being supplied by a special transformer, the variable potential for the control of the starting circuit has been derived from a tertiary winding on the lamp transformer. It is possible, however, to provide the necessary variable control potential without using transformers having tertiary windings by employing a special current transformer connected in series with the lamp. A circuit incorporating such a special transformer is disclosed in Figure 9, which is a diagrammatic circuit. Referring to Figure 9, there is shown a lamp 115 having a pair of electrodes adapted to be heated from secondary windings 116 and 117, respectively, of a transformer 118 and also connected to one end 119 of a high potential secondary winding 120 and to a neutral conductor 121 of a supply circuit, respectively. Transformer 118 is provided with a primary winding 122 connected across the neutral conductor 121 and one side 123 of the supply circuit. The primary and secondary windings 122 and 120 are connected together in auto transformer fashion, as was previously described in connection with Figure 5.

A reactance element 124 and a resistance element 125 are connected in series across the two sides 123 and 126 of the supply circuit for developing a reference potential of constant value at the junction point 127. If desired, the resistance element 125 may comprise the primary winding of a transformer having a resistance load, such as the filaments of other lamps, connected to its secondary.

As previously stated, one electrode of lamp 115 is connected to the high potential end 119 of the secondary winding 120. The other electrode is connected through a conductor 128 and the primary winding 129 of a current transformer 130 to the neutral conductor 121. The secondary winding 131 of the current transformer 130 is connected between the line conductor 123 and a terminal 132, a starting means indicated diagrammatically at 133 being connected between the junction point 127, previously referred to, and conductor 132. This starting means may comprise a spark coil, such as has been shown in the previous diagrams, or a spark coil together with a relay, its operation being fully understood from the previous descriptions.

Referring now to Figure 10 for an understanding of the operation of the circuit of Figure 9, the potential across the supply conductors 123 and 126 is represented by the vector 126—123 and the potential of the neutral conductor 121 with respect to the main conductors by the vectors 126—121 and 121—123, respectively. The open circuit potential developed by the secondary winding 120 is represented by the vector 123—119' and the total potential applied to the lamp 115 when the lamp is operating by the vector 121—119.

When the lamp 115 is not conducting current, there is no current flow in the primary winding 129 of the current transformer 130 and no potential is developed in the secondary winding 131. Therefore, the potential of terminal 132 is substantially that of the line conductor 123, to which it is connected through winding 131, which potential is represented by the position of the point 123 in Figure 10. The potential of the junction point 127 between the reactance element 124 of the resistance element 125 is represented, however, by the point 127 in Figure 10, the potential drop across the reactance element 124 being represented by the vector 127—123 and the potential drop across the resistance element 125 by the vector 126—127. Therefore, when the line conductors are supplying potential but the lamp 115 is not operating, a potential exists between the junction point 127 and the terminal 132 approximately equal in phase and magnitude to the vector 127—123 in Figure 10. This potential is applied to the starting means 133 and energizes the latter to start the lamp 115 in operation.

With the lamp 115 operating and conducting current, a substantial potential drop occurs in the transformer 118 because of the fact that the latter is designed to have high leakage reactance for regulation purposes. This potential drop, due to the reactance and resistance of windings 122 and 120 of transformer 118, is represented by the vector 119—119' in Figure 10 and the potential drop across the lamp 115 is represented by the vector 119—128. There is also a slight potential drop in the primary winding 129 of the current transformer 130 and this

drop is represented in Figure 10 by the vector 128—121.

As clearly shown in the diagram of Figure 10, the potential drop across the primary winding 129 of the current transformer (vector 121—128) leads the potential drop across the lamp (vector 128—119) by approximately 90°. This current flow through the primary winding of the current transformer develops a potential in the secondary winding 131 which is approximately 180° out of phase with the potential across the primary (vector 121—128) and is represented by vector 123—132. This brings the potential of the point 132 approximately equal to the potential of the junction point 127 so that only a very small potential is applied to the starting means 133 and the latter ceases to operate.

It will be apparent from the foregoing description that whenever the line conductors 123, 121 and 126 are supplying potential and the lamp 115 is not operating, a potential of substantial magnitude (vector 123—127) will be applied to the starting means 133 to actuate the latter and that, as soon as the lamp 115 starts and conducts current, the potential applied to the starting means drops to a very low value insufficient to actuate it.

It is to be understood, of course, that many modifications may be made in the circuit of Figure 9. Thus, if desired, the primary winding of a filament lighting transformer may be substituted for the resistance element 125 and the electrodes of the lamp 115 heated by current from secondary windings on this transformer instead of from secondary windings on the main transformer 118.

In referring to transformer 130 as a current transformer, I mean a transformer having a relatively low impedance primary winding so that the current flow in its primary winding is determined by the impedance characteristics of other elements connected in series with the primary winding rather than by the characteristics of the load connected to the secondary of the transformer. Transformers of this type are sometimes referred to as series transformers.

In Figure 11, there is disclosed an alternative method of deriving a variable potential descriptive of lamp operation. In this embodiment, the lamp 135 is connected directly between a pair of supply conductors 136 and 137 in series with a regulating reactance 138. The variable control potential is derived from a control winding 139 which is on the same core and is closely coupled to the winding of the regulating reactance 138. One end of the winding 139 is connected to a third supply conductor 140 and the other end to a conductor 141, which connects to the starting means 142. The other terminal of the starting means 142 is connected to the junction point 143 of a reactance element 144 and a resistance element 145, which are connected in series across the supply conductors 137 and 140. The resistance element 145 is shown as a filament lighting transformer 1, but, as has been previously stated, this may be a simple resistor or any other device having predominantly resistive impedance. The reactance element 144 and resistance device 145 serve to produce at the junction point 143 the desired constant reference potential. The supply conductors 140 and 137 may be the leads of a commercial power circuit and the conductor 136 may constitute either a third conductor of the power system or the output terminal of the secondary

winding of a step-up transformer, the other end of which is connected to conductor 137. Suffice it to say that, referring to Figure 12, the conductors 137 and 140 provide a potential represented by the vector 137—140 and that the conductors 137 and 136 provide a potential represented by the vector 137—136. In a manner that has been fully described in connection with previous circuits, the reactance element 144 and resistance element 145 provide a potential at the junction point 143, as represented by the point 143 in the vector diagram. When the lamp 135 is not operating, the potential existing thereacross is the full potential represented by the vector 137—136 and when the lamp is operating a potential drop occurs across the regulating reactance 138, which is represented by the vector 146—136 and the potential existing across the lamp is then represented by the vector 137—146.

When the lamp 135 is not operating, no current flows in the winding of the regulating reactance 138 and no potential is induced in the control winding 139. Therefore, under these conditions, the potential of the conductor 141 is substantially equal to the line conductor 140, which potential is represented by the point 140 in Figure 12. Since the junction point 143, however, is maintained at a constant different potential, represented by the point 143 in Figure 12, the potential represented approximately both in phase and magnitude by vector 143—140 exists across the input terminals of the starting device 142, which potential is sufficient to actuate the latter and start the lamp. As soon as the lamp starts and conducts current, however, the current flow in the winding of the regulating reactance 138 induces a potential in the control winding 139, which potential is substantially opposite in phase to the potential drop across the winding 138. The relative phase of the potential developed in the control winding 139 is, therefore, shown approximately correctly by the vector 140—141 in Figure 12; furthermore, the control winding 139 is so proportioned as to develop a potential of magnitude represented by the length of the vector 140—141. As clearly shown in the vector diagram, this brings the point 141 close to the point 143, which two points represent the potentials of the two input terminals of the starting device 142 when the lamp is operating, and the difference between these potentials is insufficient to actuate the starting device 142.

In all of the circuits heretofore described, the constant reference potential of desired phase and magnitude has been derived from the junction point of a reactance element and resistance element connected in series across the line conductors. However, the constant reference potential may be derived in other ways, one of which is shown in Figure 13. In Figure 13 there is shown a lamp 150 which is connected in series with the regulating reactance 151 across line conductors 152 and 153, respectively, which line conductors may supply any desired potential, for instance, 220 volts. A starting device for starting the lamp is represented at 154, which operates in response to a pre-determined difference of potential applied to its input terminals 155 and 156, respectively. The input terminal 155 is connected directly to the junction point of the regulating reactance 151 and the lamp 150 so that its potential varies from a value very nearly the same as the potential of line conductor 152 when the lamp is not operating

to a substantially different potential when the lamp is operating. A constant reference potential is applied to the input terminal 156 by a special high reactance filament heating transformer 157. The transformer 157 comprises a closed core having two legs, upon which are mounted primary windings 159 and secondary windings 160 and 161, respectively, and a shunt core section upon which is mounted a tertiary winding 158. The operation of transformer 157 is substantially identical with that of transformer 53 in Figure 5, previously described. The secondary windings 160 and 161 are connected to the filamentary electrodes of the lamp 150, which provide a substantially constant resistive load connected to the windings at all times.

Referring now to the vector diagram of Figure 14, the potential across the line conductors 153 and 152 is represented by the vector 153—152. This vector also, of course, represents the phase of the potential applied to the primary winding 159 of the filament lighting transformer. For the reasons outlined in the description previously given with reference to Figure 5, the potential developed in the tertiary winding 158 is substantially 45° out of phase with the potential applied to the primary winding 159 and this tertiary winding 158 is so proportioned and poled as to develop a potential represented in phase and magnitude by the vector 152—156. Since the lamp filaments are constantly connected to the secondary windings 160 and 161, this potential represented by point 156 is developed and applied to the input terminal 156 of the starting device 154 at all times when the line conductors 152 and 153 are energized. The terminal 156 is, therefore, maintained at a constant reference potential and this reference potential is made (by properly designing the transformer 157) to be substantially equal to the potential at the junction of the regulating reactance 151 and lamp 150 (represented by the point 155 in Figure 14) when the lamp is operating. It follows that when the lamp 150 is operating, the potential applied to the starting device 154 is very small, being represented by the distance between points 155 and 156 in Figure 14. However, should the lamp 150 be extinguished while potential is applied to conductors 152 and 153, the potential of the junction point (terminal 155) immediately rises substantially to the potential of the line conductor 152, which potential is represented by the point 152 in Figure 14. Therefore, if the lamp is not conducting current, the potential represented by the vector 152—156 is applied to the starting device 154 to start the lamp into operation.

In Figure 15, a modification of the circuit shown in Figure 13 is disclosed. In the circuit of Figure 15, a lamp 165 is connected in series with the winding 166 of a regulating reactance across line conductors 167 and 168 and the filamentary electrodes of the lamp are energized in precisely the same manner as in Figure 13 from a high reactance transformer 169 having a tertiary winding 170 for developing a constant reference potential and applying it to one of the input terminals 171 of a starting device 172. In this case, however, the other input terminal 173 of the starting device, instead of being connected directly to the junction point 174 of the winding 166 and lamp 165, is connected thereto through an auxiliary winding 175 which is closely coupled to the winding 166. The vector relations of

the potentials existing in various parts of this circuit are shown in Figure 16. Thus, the line potential between conductors 168 and 167 is represented by the vector 168—167 and the constant reference potential developed by the tertiary winding 170 of transformer 169 and applied to the input terminal 171 is represented by the vector 167—171. When the lamp 165 is not operating, there is no potential drop across either windings 166 or 175 and the potential of the other input terminal 173 of the starting device 172 is substantially that of conductor 167. Therefore, when the lamp is not operating, a potential represented by the vector 167—171 is applied to the starting device 172 and energizes the latter to start the lamp 165. However, when the lamp 165 has been started and is conducting current, there is a substantial potential drop in the winding 166 which is represented by the vector 167—174 and there is added to this potential the potential induced in the auxiliary winding 175, which potential is in phase with the reactance component of the potential drop across winding 166 (the latter being represented by the vector 167—176) and which is represented in magnitude and phase by the vector 174—173. Therefore, when the lamp 165 is conducting current, the potential of the input terminal 173 is represented by the point 173 in Figure 16 and differs only by a very slight amount from the constant reference potential applied to the input terminal 171. This small potential is insufficient to energize the starting device.

The chief advantage of providing the auxiliary winding 175 on the regulating reactance and connecting it as shown in Figure 15, is that such construction permits adjustment of the potential applied to the input terminal 173. In other words, with this construction the tertiary winding 170 on the filament transformer 169 may be so designed as to develop a constant reference potential (represented by the vector 167—171) of magnitude suitable for the operation of standard spark coils which are designed to operate at a particular potential. Thus, if standard spark coils for operation of 110 volts are available, the tertiary winding 170 may be so proportioned as to develop substantially 110 volts, and the auxiliary winding 175 on the regulating reactance may be then designed to yield a potential (represented by vector 174—173) of the proper value and phase to bring the point 173 (Figure 16) very close to the point 171.

In Figure 5, there was disclosed a circuit in which a high leakage reactance transformer for supplying high potential to a lamp was provided with a tertiary winding for producing a variable potential of desired phase and magnitude which was descriptive of lamp operation, i. e. a potential of one value when the lamp was operating and another value when the lamp was not operating, and in Figure 13 a circuit was disclosed in which a high leakage reactance transformer for supplying filament lighting potential to the lamp was provided with a tertiary winding for providing a constant reference potential for use in actuating the starting device. It is possible to combine the functions of the two separate transformers used in these different circuits in a single transformer and a circuit including such a transformer is disclosed in Figure 17. Thus, Figure 17 discloses three lamps 180, 181 and 182, each having a pair of filamentary electrodes adapted to be heated and all the electrodes at one end of each lamp being

connected together and to a line conductor 183 and adapted to be energized from a single secondary winding 185 of a transformer 186. The three lamps may have different characteristics requiring different operating currents and/or potentials. The electrodes at the opposite ends of these lamps are, therefore, connected to independent windings 187, 188 and 189 on the transformer 186, these windings serving only to supply heating current to the electrodes to which they are connected. Lamps 182 and 181 may be designed to operate at potentials less than line potential and their opposite electrodes are, therefore, connected through regulating reactances 190 and 191, respectively, to the other line conductor 184. Variable potentials for controlling a starting device in response to failure of either of these lamps 180 or 181 to operate are derived from the junction points of the lamps with their respective regulating reactions, which junctions are identified with the reference numerals 192 and 193, respectively.

The characteristics of lamp 180 are such that it requires a higher operating potential than is available from the line conductors 183 and 184. It, therefore, has its opposite electrode connected to one terminal 194 of a high potential secondary winding 195 on the transformer 186, the other end of this winding 195 being connected to the line conductor 184. Since the first mentioned electrodes of lamps 180, 181 and 182 are all connected together and to the line conductor 183, the potential applied to lamp 180 will be the sum of the potentials developed in the primary winding 196 and the secondary winding 195.

Transformer 186 is provided with two shunt core sections 197 and 198, respectively, upon which are mounted auxiliary windings 199 and 200, respectively. These auxiliary windings are each connected at one end to the line conductor 184. Winding 199 is used to derive a constant reference potential for the control of the starting device and it, therefore, has its free end connected to a conductor 201 which is connected to one terminal of each of the actuating windings of three separate starter control relays 202, 203 and 204. The other ends of the actuating windings of these three relays are connected, respectively, to the junction point 193, junction point 192 and to the free end 205 of the auxiliary winding 200.

Referring now to the vector diagram of Figure 18 for an understanding of the operation of the circuit of Figure 17, the vector 183—184 represents the potential across line conductors 183 and 184 and the vector 183—194' represents the open circuit potential developed in the primary winding 196 and the secondary winding 195 and applied to the lamp terminal 194. When lamp 180 is operating, the current drawn thereby from the transformer produces a voltage drop in the transformer represented by the vector 194—194', this drop being caused chiefly by the leakage reactance between the primary winding 196 and the secondary winding 195, and the potential consumed in the lamp 180 is represented by the vector 183—194.

Referring now to the construction of transformer 186, it will be observed that the filament windings 187, 188 and 189, and the primary winding 196 are on opposite legs. Therefore, substantially all of the flux threading the primary winding 196 also threads the windings 187, 188 and 189 so that these windings are closely coupled together. The filament winding 185, 150

however, is on the end leg of the core that is shunted by core section 197 carrying winding 199. Therefore, a substantial component of the flux generated by the primary current threads the shunt core section 197, thereby introducing substantial leakage reactance between the primary winding 196 and filament winding 185. The resulting phase shift in the current supplied by filament winding 185 is of no moment insofar as the heating of the lamp electrode to which it is connected is concerned. The leakage flux threading the shunt core section 197 develops a potential in winding 199 which is represented by the vector 184—201 in Figure 18 and establishes the constant reference potential represented by point 201, which is constantly applied to one end of the energizing winding of each relay 202, 203 and 204 for starter control purposes so long as the line conductors 183 and 184 are supplying potential. This potential represented by point 201 is constant because it is determined by the current flowing in the filament winding 185, which current is substantially constant at all times because the winding is permanently connected to one electrode of each of the three lamps 180, 181 and 182 and the impedances of these electrodes are substantially constant regardless of whether the lamps are lighted or extinguished.

When all three lamps are operating, the potentials of the junction points 192 and 193 and of the terminal 205 are approximately equal in value to the potential of the point 201 in Figure 18. Thus, the potential of the terminal 205 is indicated by the point 205 in the vector diagram and the potentials of the points 192 and 193 are substantially the same and are indicated by the point 192, 193 in the vector diagram. It will be readily apparent from previous explanations that the potential of the points 192 and 193 has the value shown in Figure 18 because of the potential drops in the regulating reactances 190 and 191. Likewise, the potential of the point 205 is determined by the auxiliary winding 200 on the shunt core section 198, which shunt core section forms a magnetic path in shunt to the leg of the transformer, upon which the high potential secondary winding 195 is positioned.

Should lamp 180 be extinguished from any cause while the line conductors 183 and 194 are energized, there will be no current flow in the high potential secondary winding 195 and substantially all of the flux developed by the primary winding 196 will follow the low reluctance path through the leg upon which winding 195 is positioned and only a very small flux will then be developed in the shunt core section 198. Hence, only a very small potential will be induced in winding 200 and the potential of point 205 will immediately rise from the value indicated by the position of point 205 in Figure 18 to the value indicated by the point 184. Therefore, a potential represented in phase and magnitude by the vector 184—201 will be impressed upon the winding of relay 204, which will close the contacts of that relay and supply actuating current to the starting device 206 which will be energized to apply starting impulses to all of the lamps and again set lamp 182 into operation.

Likewise, should either lamp 180 or 181 be extinguished while line conductors 183 and 184 are energized, the potential of the junction point 192 or 193 between that lamp and its associated

regulating reactance 190 or 191, will immediately rise to the potential of conductor 184. A potential represented in phase and magnitude by the vector 184—201 will, therefore, be applied to the winding of one or the other of the two relays 202, 203 which will supply energizing current to the starting device 206 and apply starting impulses to all of the lamps.

In Figure 17 the starting device 206 is shown supplied with energizing current over two conductors 207 and 208, which may be connected to any desired source of energy of suitable potential. Obviously, if desired, the starting device 206 could be energized from the same sources that were used to energize the windings of relays 202, 203 and 204.

If desired, the filament windings 187, 188 and 189 of the transformer 186 could be positioned upon the same leg of the transformer as the filament winding 185 since all of these filament windings are connected to loads (the filaments or the respective lamps) of substantially constant impedance and, in order that the reference potential developed in winding 199 be constant, it is only necessary that the windings on the transformer leg in shunt thereto be connected to loads of constant impedance. It is desirable, however, to position the windings 187, 188 and 189, as shown, in order to obtain a higher power factor for the transformer since any winding positioned on the leg in shunt to the shunt core section 197 would have very high leakage reactance. Of course, windings 187, 188 and 189 could be positioned on the same leg as the primary winding 196, if desired, and in that position the transformer would have substantially the same characteristics as in the construction shown. It is to be particularly observed that the potential developed in winding 199 is substantially constant so long as the current drawn from winding 185 is constant, variations in the current drawn from winding 195 having very little effect on the flux threading the shunt core section 197.

The circuit disclosed in Figure 17 has substantial practical advantages in that only a single transformer is required for an assembly of three different lamps.

In my copending application, Serial No. 657,486, filed February 20, 1933 on Starting circuits for gaseous discharge lamps, I have shown that the starting efficiency on an A. C. operated gaseous discharge lamp of impulses from a spark coil depends to a great extent on the phase of the potential applied to the input terminals of the spark coil relative to the phase of the operating potential across the lamp terminals. I also disclosed in the aforementioned application various methods of supplying potential to the spark coil in proper phase to give a high starting efficiency.

An approximation to the desirable phase relation between the lamp operating potential and the spark coil operating potential may be provided by deriving the spark coil potential from suitable points in the lamp circuits herein described. Thus, in Figure 1, the energizing potential for the spark coil 30 is derived between the line conductor 1 and the junction point 3 and the phase and relative magnitude of the potential applied to the spark coil is indicated by vector 3—1 in Figure 2. I have found by experiment that the starting effectiveness of a spark coil energized from a source of potential of phase represented by vector 3—1 is approxi-

mately $2\frac{1}{2}$ times as great as if the spark coil were energized from a potential in phase with the line potential across conductors 2—1. The connection shown in Figure 1 has the disadvantage, however, that the potential between line conductor 1 and the junction point 3 is more than half the line potential and, therefore, the spark coil would need to be especially designed to operate from this abnormal potential.

In the circuit disclosed in Figure 5, the input terminals of the spark coil 73 are connected between the neutral conductor 39 of the supply circuit and the junction point 41 between the reactance elements 72 and the filament lighting transformer 70. With this connection the phase and magnitude of the potential applied to the spark coil are represented by vector 39—41 in Figure 6. I have found that a spark coil energized from a potential of phase represented by vector 39—41 has an extremely high starting efficiency, its effectiveness being nearly four times as great as it would be if energized from a potential of the same magnitude in phase with the potential of the supply conductors (vector 38—37). The potential (vector 39—41), however, has the disadvantage that it is of relatively low magnitude, being substantially less than the magnitude of the line potential between the neutral conductor 39 and one of the main conductors 37 or 38. It is, therefore, necessary when employing the circuit connection shown in Figure 5 to specially design the spark coil to operate at reduced potential.

It is to be understood in all these descriptions that in practice the line potentials employed will be either 110 volts or 220 volts in the case of two-wire supply circuits and 110 volts and 220 volts in the case of three-wire supply circuits. Heretofore the spark coils usually employed for starting gaseous discharge lamps have been designed to operate from a potential of 110 volts.

Referring now to Figures 19 and 20, I have shown two methods of supplying energizing potential to the spark coil which are alternative to the methods disclosed in Figures 1 and 5. Except for the connections of the spark coils, the circuits of Figures 19 and 20 are identical with the circuit of Figure 1.

In Figure 19 the spark coil is shown connected to receive operating potential between the junction point 3 and the line conductor 2. The potential between these two points is represented by vector 2—3 in Figure 2. This potential can be made substantially equal to 110 volts by properly proportioning the reactance element 28 and the resistance element 29, so that standard spark coils may be employed. The phase of the potential between points 2 and 3 (vector 2—3 of Figure 2) is such that the starting efficiency of a spark coil energized therefrom is relatively low as compared to that of a coil connected, as shown in Figures 1 and 5. However, the connection of Figure 19 still gives a starting effectiveness substantially twice that when the coil is energized directly from the line potential.

In Figure 20, the spark coil is shown connected between the junction point 3 and a tap 28T on the reactance element 28. This is a very desirable connection for the reason that the starting efficiency of a spark coil energized from a potential of the phase of the potential existing across the reactance element 28 (vector 3—1 in Figure 2) is relatively high, being about $2\frac{1}{2}$ times that of a potential in phase with

the line potential, and by suitably locating the tap 28T on the reactance element 28, the magnitude of the potential developed may be regulated substantially exactly to 110 volts, the potential at which standard spark coils are designed to operate.

Obviously, the spark coil connection shown in the various circuits described may be varied. In any case, it is only necessary that a relay for controlling the application of potential to the spark coil be connected between the reference point of constant potential and the point of variable potential which is descriptive of lamp operation. The spark coil itself may be connected, through the contacts of the relay, across any two points in the circuit between which points there exists a potential of suitable phase and magnitude, or the spark coil energized from a source entirely distinct from the lamp circuit shown. This separate source may be that disclosed in my earlier application above referred to.

Having fully described the preferred embodiments of this invention, it is to be understood that I do not limit myself to the exact construction herein set forth, which may obviously be varied in detail without departing from the spirit of this invention, but only as set forth in the appended claims.

I claim:

1. In a circuit for operating a device the impedance of which varies between widely different values when not operating and when operating, respectively, and which is incapable of starting operation in response to application of normal operating potential thereto without special excitation, starting means for exciting said device, means for deriving a first substantially constant potential from the operating potential applied to said device, means including said device for deriving a second potential from the operating potential applied to said device, which second potential varies according to the impedance of said device from a value approximately equal to said first potential when the device is operating, to a value substantially different from said first potential when the device is not operating, and means for actuating said starting means in response to a substantial potential difference between said first and second potentials.

2. In combination, an electrical device having a high impedance when not conducting current and a lower impedance when conducting current; a source of current of potential sufficient to maintain current flow in said device but insufficient of itself to initiate a flow of current therein; means including an impedance element connected in series with said device across said source, the impedance of said element being comparable in magnitude to the impedance of said device when the latter is conducting current, whereby a substantial potential drop exists across said impedance element when said device is conducting current, the impedance of said element being much lower than the impedance of said device when the latter is not conducting current whereby, under the latter condition, the potential drop across said element is small; a terminal; circuit means including said source for constantly maintaining said terminal at a potential at least approximately equal to the potential of the junction between said electrical device and said impedance element when said electrical device is conducting current; and means for starting said electrical device in response to a difference in

potential between said junction and said terminal.

3. In combination, an electrical device having a high impedance when not conducting current and a lower impedance when conducting current; a source of current of potential sufficient to maintain current flow in said device but insufficient of itself to initiate a flow of current therein; means for supplying current from said source to said device, including a first element having an impedance comparable in magnitude to the impedance of said device when the device is conducting current, connected in series with said device; starting means for lowering the impedance of said device, said starting means functioning in response to electrical potential applied thereto; a second and a third element connected in series across said source and having impedances the ratio between which is at least approximately the same as the ratio between the impedance of said first impedance element and the impedance of said device when the device is conducting current; and circuit means for connecting said starting means between the respective circuit junctions of said electrical device and first element and said second and third elements.

4. In combination; an electrical device having a high impedance when not conducting current and a lower impedance when conducting current; a source of current of potential sufficient to maintain current flow in said device but insufficient of itself to initiate a flow of current therein; means for supplying current from said source to said device including a first element having an impedance comparable in magnitude to the impedance of said device when the device is conducting current connected in series with said device; starting means for lowering the impedance of said device, said starting means functioning in response to electrical potential applied thereto; a second and a third element connected in series across said source and having impedances the ratio between which is at least approximately the same as the ratio between the impedance of said first impedance element and the impedance of said device when the device is conducting current; circuit means for connecting said starting means between the respective circuit junctions of said electrical device and first element and of said second and third elements, said circuit means including a relay having a high impedance actuating circuit permanently connected between said two junction points and having contacts closing in response to a predetermined potential across said actuating circuit, said contacts being connected in series with said starting means for controlling the application of energizing current thereto.

5. In combination; an electrical device having a high impedance when not conducting current and a lower impedance when conducting current; a source of current of potential sufficient to maintain current flow in said device but insufficient of itself to initiate a flow of current therein; means for supplying current from said source to said device including a first element having an impedance comparable in magnitude to the impedance of said device when the device is conducting current connected in series with said device; starting means for lowering the impedance of said device, said starting means functioning in response to electrical potential applied thereto; a second and a third

element connected in series across said source and having respective impedances the ratio between which is at least approximately the same as the ratio between the impedance of said first impedance element and the impedance of said device when the device is conducting current; circuit means for connecting said starting means between the respective circuit junctions of said electrical device and first element and of said second and third elements, said circuit means including a relay having a high impedance actuating circuit connected in series with said starting means between said two junction points and having a pair of contacts shunted across said actuating circuit for shorting out the actuating circuit in response to closure of said contacts.

6. A system as described in claim 4, in which said relay is slow acting.

7. In combination; an electrical device having a high impedance when not conducting current and a lower, substantially resistive impedance when conducting current; a source of alternating current of potential sufficient to maintain current flow in said device but insufficient of itself to initiate a flow of current therein; means for supplying current from said source to said device including a first element having inductive reactance comparable in magnitude to the resistance of said device when the device is conducting current, connected effectively in series with said device; starting means for lowering the impedance of said device, said starting means functioning in response to electrical potential applied thereto; a second and a third element connected in series across said source and having impedances which are substantially inductively reactive, and resistive, respectively, and the ratio between which is at least approximately the same as the ratio between the reactance of said first element and the resistance of said device when the device is conducting current; and means for connecting said starting means between the respective circuit junctions of said electrical device and first element and of said second and third elements.

8. A system as described in claim 7, in which said electrical device comprises a gaseous discharge device.

9. A system as described in claim 7, in which said electrical device comprises a gaseous discharge device having an electrode adapted to be heated by passing electrical current therethrough independently of currents flowing through said gaseous discharge device and in which said electrode provides at least a part of the resistive impedance of said third element.

10. In combination; an electrical discharge device having a high impedance when not conducting current, and a lower, substantially resistive impedance when conducting current, said device having at least one electrode adapted to be heated by passing electric current therethrough independently of current flowing through said device; a source of alternating current of potential sufficient to maintain current flow in said device but insufficient of itself to initiate a flow of current therein; means for supplying current from said source to said electrical discharge device including an element having inductive resistance comparable in magnitude to the resistance of said device when the device is conducting current connected effectively in series with said device; starting means for lowering the impedance of said electrical discharge

device, said starting means functioning in response to electrical potential applied thereto; a transformer having a secondary winding connected to said electrode for supplying current to heat the electrode, and having a primary winding; means having substantial inductive reactance connected in series with said primary winding for connecting said primary winding to said source, the ratio of the input resistance of said primary winding to the reactance of the means connected in series therewith being at least approximately the same as the ratio between the resistance of said electrical discharge device when the latter is conducting current, and the reactance of said element connected in series with the electrical discharge device; and circuit means for connecting said starting means between the respective circuit junctions of said electrical discharge device and said element connected in series therewith, and of said primary winding and the inductive reactance means connected in series therewith.

11. In combination; a gaseous discharge device having a pair of electrodes, said electrodes being adapted to be heated by passing electric current therethrough independently of current flow through said discharge device; a source of alternating current of potential sufficient to maintain current flow between the electrodes of said device but insufficient of itself to initiate a flow of current therebetween, said source comprising a first and a second terminal; a transformer having a pair of secondary windings connected respectively to the two electrodes of said discharge device, and having a primary winding; a low impedance connection between said first terminal of said source and one of said electrodes of said device; a low impedance connection between said first terminal and one end of the primary winding of said transformer; an inductive reactance element having reactance comparable in magnitude to the resistance of said discharge device when the latter is conducting current, connected in series between the other electrode of said discharge device and said second terminal; another inductive reactance element connected between the other end of said primary winding of said transformer and said second terminal of said source, the ratio of the reactance of said last reactance element to the input resistance of said primary winding of said transformer being at least approximately the same as the ratio of reactance of said first mentioned reactance element to the resistance of said discharge device when the latter is conducting current; and starting means for starting the discharge device connected between the respective circuit junctions of said first mentioned reactance device and the second electrode of said discharge device, and of said primary winding and the reactance element connected in series therewith.

12. In combination; a plurality of electrical discharge devices having high impedances when not conducting current and lower, substantially resistive impedances when conducting current; a source of alternating current of potential sufficient to maintain current flow in said devices but insufficient of itself to initiate a flow of current therein, connected to each of said electrical discharge devices; a plurality of inductive reactance elements each connected in series with one of said respective discharge devices to regulate the current flow in that device; a device having substantially resistive impedance,

and a reactance device, connected in series across said source and having resistance and reactance, respectively, approximately proportional to the resistance and reactance, respectively, of each of said electrical discharge devices and the inductive reactance element connected in series therewith; a single starting means for starting any of said discharge devices in response to substantial electrical potential applied to said starting device; a plurality of relays, one for each electrical discharge device, each having an actuating circuit and a pair of contacts adapted to be closed in response to energization of the actuating circuit, the actuating circuits of the resistive relays being connected between the circuit junction of said resistance impedance device and reactance device and the respective circuit junctions of said several electrical discharge devices and their associated inductive reactance elements; and means for applying actuating current to said starting device in response to closure of the contacts on any one of said relays by energization of the actuating circuit of that relay.

13. In combination; a plurality of electrical discharge devices having high impedances when not conducting current, and lower, substantially resistive impedances when conducting current; a three conductor alternating current supply circuit supplying a predetermined potential between a first and second of said conductors and supplying a lower potential between either of said first and second conductors and the third conductor; a plurality of reactance elements, one for each discharge device, each having a reactance approximately equal in magnitude to the resistance of the discharge device with which it is associated when the discharge device is conducting current; each of said electrical discharge devices having a pair of electrodes one of which is connected to said second conductor of said current supply circuit and the other of which is connected to one end of the reactance element associated therewith, the other end of each reactance element being connected to said first conductor of the supply circuit; means including an inductive reactance element and a resistance element connected in series between said first and second conductor, said reactance element being connected at one end to said first conductor, and the reactance and resistance, respectively, of said last named reactance and resistance elements being approximately equal in magnitude; a single starting means having a pair of input terminals adapted to start any of said discharge devices in response to a substantial potential impressed across its input terminals, one of said input terminals being connected to said third conductor of the supply circuit; a plurality of relays, one for each discharge device, each relay comprising a high impedance actuating winding and a pair of normally open contacts which are closed in response to application of a substantial potential to the actuating winding, one contact of each of said relays being connected to the other terminal of said starting device, and the other contact of each relay being connected to the circuit junction of said reactance and resistance element connected in series across said first and second conductors; a connection between one end of the actuating circuit of each relay and the last mentioned circuit junction; and a connection between the other end of the actuating winding of each relay and the circuit junction of the dis-

charge device and reactance element associated with that relay.

14. In combination; an electrical discharge device having a high impedance when not conducting current and a lower impedance when conducting current; a source of alternating current of low potential for operating said device; a transformer having a primary winding connected to said source, a secondary winding connected to said device, a magnetic shunt core section providing leakage reactance effectively in series with said primary and secondary windings, and a tertiary winding on said shunt core section; starting means having a pair of input terminals for starting said device in response to potential applied to said terminals; means for deriving a potential of predetermined substantially constant value from said source and applying said potential to one of said terminals, said other terminal being connected through said tertiary winding to one side of said source and said tertiary winding being so poled and proportioned as to develop a potential at said other terminal substantially equal to said predetermined value when said electrical discharge device is drawing operating current from said secondary winding; said tertiary winding developing substantially no potential when said device is not drawing operating current from said secondary winding, whereby a substantial potential exists across said input terminals of said starting means to actuate the latter when, and only when, said source is supplying potential and said device is not operating.

15. In combination; a plurality of electrical discharge devices having high impedances when not conducting current and lower impedances when conducting current, one at least of said devices requiring a substantially greater operating potential than another of said devices; a source of alternating current of low potential for operating said devices; a transformer having a primary winding connected to said source, having a secondary winding connected to said first device requiring a high operating potential, having a magnetic shunt core section for providing leakage reactance effectively in series with said primary and said secondary windings, and having a tertiary winding on said shunt core section, starting means having a pair of input terminals for starting any of said devices in response to potential applied to said terminals; means for deriving a potential of predetermined substantially constant value from said source and applying said potential to one of said input terminals, a regulating reactance element connected in series with said other electrical discharge device requiring low operating potential directly across said source, said regulating reactance being so proportioned as to produce a potential at the circuit junction of said reactance with said device, when the device is conducting current, substantially equal to said predetermined potential; means connecting said junction point to the other input terminal of said starting means; means for also connecting said other input terminal through said tertiary winding to one side of said source, said tertiary winding being so poled and proportioned as to develop a potential for maintaining said other terminal at a potential substantially equal to said predetermined value when said first device is drawing operating current from said secondary winding, and said tertiary winding developing substantially no potential when said device is not drawing operat-

ing current from said secondary winding; whereby a substantial potential exists across said input terminals of said starting means to actuate the latter, when, and only when; said source is supplying potential and one of said devices is not operating.

16. In combination; a plurality of electrical discharge devices having high impedances when not conducting current and lower impedances when conducting current, one of said devices requiring a substantially greater operating potential than a second of said devices; a source of alternating current of low potential for operating said devices; a transformer having a primary winding connected to said source, having a secondary winding connected to the first of said devices, having a magnetic shunt core section for providing leakage reactance effectively in series with said primary and secondary windings, and having a tertiary winding on said shunt core section; starting means for starting any of said devices in response to potential applied thereto; a terminal; means for deriving a potential of predetermined substantially constant value intermediate the potentials of the two sides of said source, from said source, and applying said predetermined potential to said terminal; a regulating reactance connected in series with said second device across the two sides of said source, said regulating reactance being of such value as to produce a potential at the junction of the reactance with the device substantially equal to said predetermined potential when said second device is operating; a plurality of relays, one for each electrical discharge device, each relay having a pair of normally open contacts connected in the operating circuit of said starting means for controlling the energization of said starting means and each relay having an actuating winding one side of which is connected to said terminal of constant, predetermined potential, the other side of the actuating winding of one relay being connected to the circuit junction of said regulating reactance and said second device and the other side of the actuating winding of the other of said relays being connected through said tertiary winding to one side of said source, said tertiary winding being so poled and proportioned as to develop a potential for maintaining the end of the relay winding to which it is connected at a potential substantially equal to said predetermined potential when said first device is drawing operating current from said secondary winding, and said tertiary winding developing substantially no potential when said first device is not drawing operating current from said secondary winding; whereby a substantial potential is impressed across one of said relays to close the actuating circuit of said starting device when, and only when, said source is supplying potential and one of said devices is not operating.

17. In combination; a plurality of electrical discharge devices having high impedances when not conducting current and lower impedances when conducting current, each of said devices having a pair of electrodes adapted to be heated by passing electric current therethrough, and one of said devices requiring a higher operating potential than another of said devices; an alternating current supply system comprising three conductors, the first and second of said conductors supplying predetermined potentials, and the third conductor supplying a potential intermediate the potentials of the first and second

conductors; a transformer having a primary winding connected across said first and third conductors, having a secondary winding connected to said device requiring a high operating

potential, having a magnetic shunt core section providing leakage reactance effectively in series with said primary and secondary windings, having a tertiary winding on said shunt core section, and having a pair of auxiliary windings closely coupled to said primary winding for supplying heating current to the respective electrodes of said first device; starting means having a pair of input terminals for starting said devices in response to potential applied to said terminals, one of said terminals being connected to said third conductor of said supply circuit; a regulating reactance connected in series with said second device across said first and second conductors of said supply circuits; said regulating reactance having a reactance comparable in magnitude to the resistance of said second device when the latter is operating; a second transformer having a pair of secondary windings connected to the respective electrodes of said second device for heating said electrodes, said transformer having a primary winding; a reactance element connected in series with said primary winding between said first and second conductors of said source, the reactance of said last mentioned reactance element bearing a ratio to the working input impedance of said second transformer substantially the same as the ratio of the reactance of said regulating reactance to the operating resistance of said second device; a plurality of relays, each having a pair of contacts connected in series between the other terminal of said starting device and the circuit junction of said last mentioned reactance element and the primary winding of said second transformer and each relay also having a contact-actuating circuit, one end of each of which is connected to the circuit junction of said reactance and primary winding, the other end of one of said actuating circuits being connected to the circuit junction of said regulating reactance and second device and the other end of the other actuating circuit being connected through said tertiary winding to the first conductor of said source the tertiary winding being so poled and proportioned as to develop a potential for maintaining said other end of said other actuating circuit at a potential substantially equal to the potential of said circuit junction of the last mentioned reactance element and primary winding when said device is drawing operating current from said secondary winding; said tertiary winding developing substantially no potential when said device is not drawing operating current from said secondary winding; whereby a substantial potential is applied to the actuating winding of one of said relays to close the contacts of that relay and energize the starting device when, and only when, said source is supplying potential and one of said devices is not operating.

18. In combination, a transformer having primary and secondary windings, core means for magnetically linking said windings with a magnetic circuit of low reluctance said core means also including means providing a shunt magnetic circuit of higher reluctance, a device having widely different impedances when operating and not operating, respectively, connected to said secondary winding, means for energizing said primary winding, and means for controlling the

starting of said device in response to predetermined variations in the average intensity of the flux in said shunt magnetic circuit of said transformer.

19. In combination, a gaseous discharge tube, a source of alternating current, and means for applying a potential derived from said source to said tube, said means supplying a potential to said tube sufficient to maintain the tube in operation but insufficient to positively start the tube unaided and having substantial inductive reactance effectively in series with said source and tube, whereby the potential across said tube, when the tube is operating, lags the potential of said source, starting means for initially ionizing the gas in said tube comprising a spark coil, a pair of impedance elements connected in series across said source and having impedances that are substantially resistive and inductively reactive, respectively, and means for connecting said spark coil in shunt to said resistive element in response to a substantial change in the potential drop across said tube, said two impedance elements being so proportioned that the potential across said resistive element is approximately equal to half the potential of said source.

20. In combination, a gaseous discharge tube, a source of alternating current, and means for applying a potential derived from said source to said tube, said means supplying a potential to said tube sufficient to maintain the tube in operation but insufficient to positively start the tube unaided and having substantial inductive reactance effectively in series with said source and tube, whereby the potential across said tube, when the tube is operating, lags the potential of said source, starting means for initially ionizing the gas in said tube comprising a spark coil, a pair of impedance elements connected in series across said source and having impedances that are substantially resistive and inductively reactive, respectively, and means operative in response to a substantial change in the potential drop across said tube for connecting said spark coil in shunt across a portion of said inductively reactive impedance element whereby the potential impressed upon said spark coil may be made substantially equal to half the potential of said source and leads operating potential across said tube by a substantial phase angle.

21. In combination, a gaseous discharge tube, a source of alternating current, and means for applying a potential derived from said source to said tube, said means supplying a potential to said tube sufficient to maintain the tube in operation but insufficient to positively start the tube unaided and having substantial inductive reactance effectively in series with said source and tube, whereby the potential across said tube, when the tube is operating, lags the potential of said source, starting means for initially ionizing the gas in said tube comprising a spark coil, said source of alternating current comprising a pair of main conductors supplying a predetermined potential therebetween and a neutral conductor at potential intermediate the potentials of said main conductors, a pair of impedance elements connected in series across said main conductors and having impedances that are substantially resistive and inductively reactive, respectively, for deriving a first substantially constant potential of predetermined magnitude and phase from said source, means

including said tube for deriving a second potential from said source, which second potential varies according to the impedance of said tube from a value approximately equal to said constant potential when the tube is operating, to a value substantially different from said constant potential when the tube is not operating, and means for connecting said spark coil between said neutral conductor and the circuit junction of said pair of impedance elements in response to a substantial difference between said first and second potentials.

22. In combination, a plurality of electrical discharge devices having high impedances when not conducting current and lower impedances when conducting current; one of said devices requiring a substantially greater operating potential than a second of said devices; a source of alternating current of low potential for operating said devices; a transformer having a primary winding connected to said source, having a secondary winding connected between one side of said source and one end of said one device, having a magnetic shunt core section for providing leakage reactance effectively in series with said primary and secondary windings, and having a tertiary winding on said shunt core section; starting means for starting any of said devices in response to potential applied thereto; a terminal; means for deriving a potential of predetermined substantially constant value intermediate the potentials of the two sides of said source, from said source, and applying said predetermined potential to said terminal; said second device being connected between the other end of said one device and the other side of said source; a regulating reactance connected between the circuit junction of said first and second devices and said one side of said source; said starting means being connected between said terminal of constant predetermined potential and one end of said tertiary winding, the other end of said tertiary winding being connected to said one side of said source and said tertiary winding being so poled and proportioned as to develop a potential at its one end substantially equal to said predetermined potential when said first device is drawing operating current from said secondary winding; and said tertiary winding developing substantially no potential when said first device is not drawing operating current from said secondary winding; whereby a substantial potential is impressed across said starting device when said source is supplying potential and said first device is not operating.

23. In combination, an electrical discharge device having a high impedance when not conducting current and a lower impedance when conducting current; a source of current; starting means having a pair of input terminals for producing a starting effect on said device in response to potential applied to said input terminals; means for applying a potential of predetermined substantially constant value derived from said source to one of said input terminals; circuit means for supplying operating potential to said device, said circuit including a terminal, and means responsive to current flow in said device for maintaining said terminal approximately at said predetermined potential when, and only when, said device is conducting current, the other input terminal of said starting means being connected to said last mentioned terminal, whereby actuating potential is applied to said starting means when, and only when,

said source is supplying current and said device is not conducting current.

24. In combination, an electrical discharge device having a high impedance when not conducting current and a lower substantially resistive impedance when conducting current; a source of current; starting means having a pair of input terminals for producing a starting effect on said device in response to potential applied to said input terminals, a pair of elements having impedances substantially inductively reactive and resistive, respectively, connected in series across said source, a current transformer having a primary winding in series with said device and having a secondary winding connected in series with the input terminals of said starting means across the inductively reactive element of said pair of elements, said transformer being so proportioned and connected as to develop in its secondary winding a potential substantially equal in magnitude and phase to the potential across said inductively reactive element when, and only when, said device is conducting current.

25. In combination, an electrical discharge device having a high impedance when not conducting current and a lower substantially resistive impedance when conducting current; a source of current; starting means having a pair of input terminals for producing a starting effect on said device in response to potential applied to said input terminals, a pair of elements having impedances substantially inductively reactive and resistive, respectively, connected in series across said source; means including a reactor having a winding in series with said device and having a second winding closely coupled to said first winding, said second winding being connected in series with the input terminals of said starting means across the inductively reactive element of said pair of elements, said second winding on said reactor being so proportioned and poled as to develop a potential substantially equal in magnitude and phase to the potential across said inductively reactive element when, and only when, said device is conducting current.

26. In combination, an electrical discharge device having a high impedance when not conducting current and a lower impedance when conducting current; a source of current; starting means having a pair of input terminals for producing a starting effect on said device in response to potential applied to said input terminals; circuit means for supplying operating potential to said device, said circuit including a terminal and means responsive to current flow in said device for maintaining said terminal at a predetermined potential when, and only when, said device is conducting current; a transformer having a primary winding connected to said source and a secondary winding, said transformer being so designed and connected as to provide at one end of said secondary winding a substantially constant potential approximately equal to said predetermined potential; and the input terminals of said starting means being connected between said first mentioned terminal and said one end of said secondary winding.

27. In combination, an electrical discharge device having a high impedance when not conducting current and a lower, substantially resistive impedance when conducting current; a source of current; starting means having a pair of input terminals for producing a starting effect

fect on said device in response to potential applied to said input terminals, means for supplying operating potential to said device from said source including a regulating reactance in series with said device and a terminal connected to the circuit junction between said regulating reactance and said device, said terminal being maintained at a predetermined potential due to the potential drop in said regulating reactance when said device is conducting current and being at a substantially different potential when said source is supplying potential to said device but the device is not operating; a transformer having a primary winding connected to said source, having a secondary winding, core means magnetically coupling said primary and secondary windings and including a shunt core section of relatively high reluctance, a tertiary winding on said shunt core section connected in series with the input terminals of said starting device across said regulating reactance; a load of substantially constant impedance connected to said secondary winding; said tertiary winding being so proportioned and poled as to develop a potential at the input terminal of said starting device substantially equal to said predetermined potential whereby energizing potential is applied to said input terminals when, and only when, said source is supplying potential and said device is not conducting current.

28. A system as described in claim 27 in which said electrical discharge device comprises an electrode adapted to be heated by the passage of current therethrough independent of the discharge current through said device and in which said electrode constitutes said load of substantially constant impedance connected to said secondary winding.

29. In combination, a gaseous discharge device having a pair of electrodes at least one of which is adapted to be heated, said device having high impedance when not conducting current and a lower impedance when conducting current; a transformer having three sections of paramagnetic material in a closed magnetic circuit of low reluctance, a primary winding on a first of said sections connected to a source of supply, a secondary winding on a second of said sections connected to the two electrodes of said device, a tertiary winding on said third section connected to an electrode of said device for heating the same, said transformer also comprising a pair of legs constituting magnetic paths of relatively high reluctance in shunt with said second and third core sections, respectively, and control windings on the respective legs of said pair; starting means for said discharge device operable in response to potential applied thereto and connected in series with said two control windings, the latter being so poled and proportioned as to develop substantially equal potentials in opposition to each other when said device is conducting current whereby substantially no current flows in said starting means, and one of said control windings developing substantially less potential than the other when said discharge device is not drawing current from said secondary winding whereby said starting means is energized from said other control winding to start said discharge device.

30. In combination, a first and a second discharge device, each having high impedance when not conducting current and a lower impedance when conducting current, at least one of said devices having an electrode adapted to be

heated; a transformer having three sections of paramagnetic material in a closed magnetic circuit of low reluctance, a primary winding on a first of said sections connected to a source of supply a secondary winding on a second of said sections connected to the electrodes of said first device; a third winding on said third section connected to said electrode of one of said discharge devices for heating the electrode, said transformer also comprising fourth and fifth legs constituting paths of relatively high reluctance in shunt with said second and third core sections, respectively, and fourth and fifth control windings on the fourth and fifth legs, respectively, starting means having a pair of input circuits and operating in response to potential applied to either input circuit for starting said discharge devices, one of said input circuits being connected in series with said fourth and fifth control windings, the windings being so poled and proportioned as to develop substantially equal potentials in opposition to each other when said first discharge device is conducting current whereby substantially no current flows in said starting means, and said fourth winding developing substantially less potential than said fifth winding when said first discharge device is not drawing current from said secondary winding whereby said starting means is energized from said fourth winding to start said discharge device; a source of potential in phase with the potential applied to the primary winding of said transformer for energizing said second discharge device; a regulating reactance connected in series with said second device across said source; and means for connecting said fifth winding in series with the other input circuit of said starting means across said regulating reactance, said second device and regulating reactance being so proportioned as to their impedances that the potential drop across said regulating reactance is substantially equal in phase and magnitude to the potential developed in said fifth winding when said second device is operating, whereby an increase in the potential drop across said regulating reactance caused by failure of said second device to operate applies operating potential to the other input circuit of said starting means.

31. A system as described in claim 30 in which said device comprises a plurality of electrodes adapted to be heated by passage of current therethrough and a plurality of auxiliary windings on said transformer for energizing said electrodes, said auxiliary windings being closely coupled to said primary winding, whereby they have low leakage reactance.

32. In combination, a gaseous discharge tube, a source of alternating current, and means for applying a potential derived from said source to said tube, said means supplying a potential to said tube sufficient to maintain the tube in operation but insufficient to positively start the tube unaided and having substantial inductive reactance effectively in series with said tube, whereby the potential across said tube when the tube is operating lags the potential of said source, starting means for initially ionizing the gas in said tube comprising a spark coil, a pair of impedance elements connected in series across said source and having impedances that are substantially resistive and inductively reactive, respectively, for producing at the circuit junction of said pair of impedance elements a first substantially constant potential of predeter-

mined magnitude and phase, and also producing in one of said impedance elements a potential drop of predetermined phase relative to the phase of the operating potential across said tube, means including said tube for deriving a second potential from said source, which second potential varies according to the impedance of said tube from a value approximately equal to said first constant potential when the tube is

operating to a value substantially different from said first constant potential when the tube is not operating, and means operable in response to a substantial difference between said first and second potentials for applying at least a portion of said potential drop of predetermined phase produced in said one impedance element to said spark coil to actuate the latter.

ELLIS OSMON ERICKSON.

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15	90
20	95
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35	110
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45	120
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55	130
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65	140
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75	150