

Jan. 21, 1936.

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2,028,538

STARTING CIRCUIT FOR GASEOUS DISCHARGE LAMPS

Filed Feb. 20, 1933

2 Sheets-Sheet 1

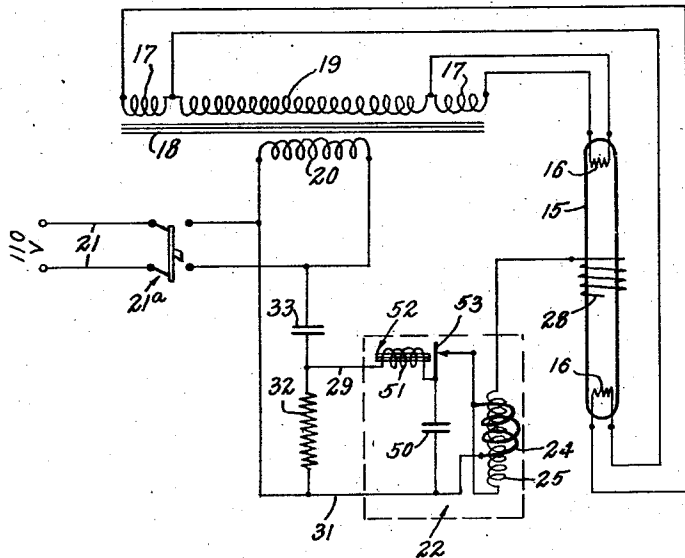


Fig. 1.

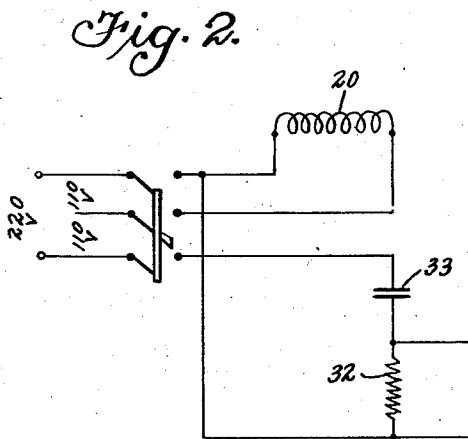


Fig. 2.

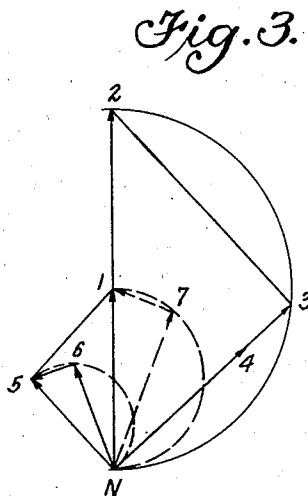


Fig. 3.

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2 Sheets-Sheet 2

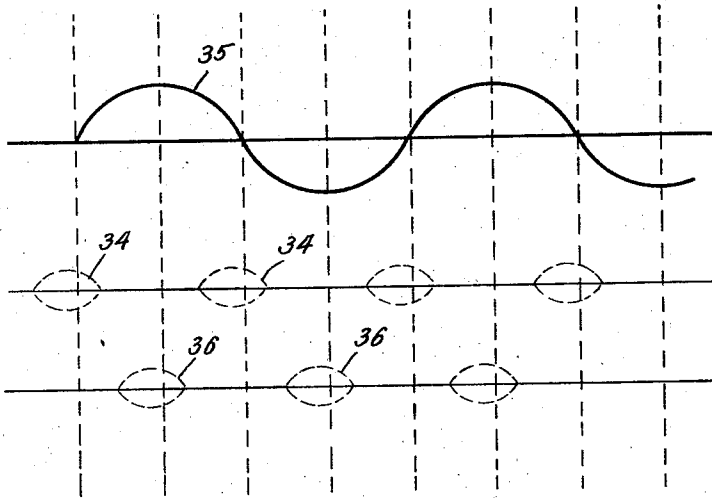


Fig. 4.

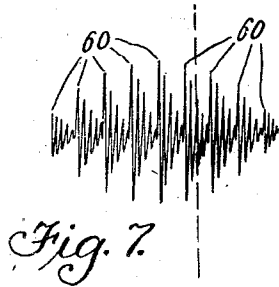


Fig. 7.

Fig. 6.

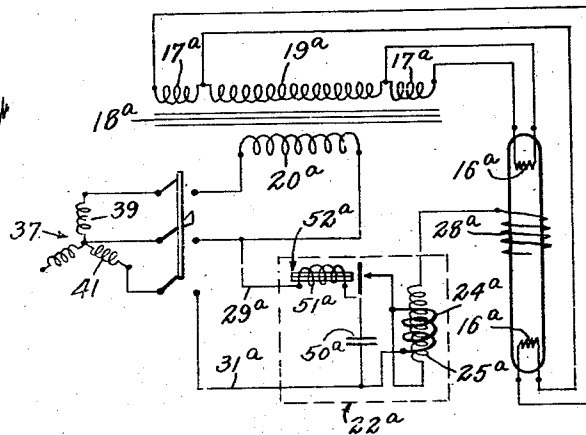
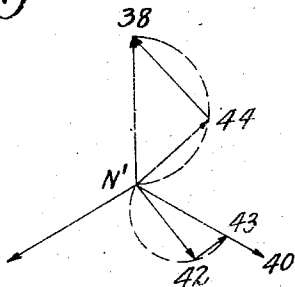


Fig. 5.

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2,028,538

STARTING CIRCUIT FOR GASEOUS
DISCHARGE LAMPS

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Application February 20, 1933, Serial No. 657,486

9 Claims. (Cl. 176—124)

This invention relates broadly to the operation of gaseous discharge tubes, and more specifically to methods of starting gaseous discharge lamps energized with alternating current.

5 An object of the invention is to positively start a. c. operated gaseous discharge lamps with relatively simple and inexpensive apparatus.

As is well-known, gaseous discharge lamps using mercury vapor, neon, or other gases, are widely used, particularly for advertising signs. Many of these lamps are energized from trans-
formers providing relatively high secondary potentials of several thousand volts. Because of the high potentials employed, these tubes start automatically as soon as the potential is applied, and no separate starting means is required. However, there have recently been developed gaseous discharge lamps having hot electron-emitting electrodes as terminals, which tubes
10 operate at relatively low potentials, in many instances less than 1,000 volts. Unfortunately, these lamps are not always capable of starting automatically in response to application of normal operating potential and special starting
15 means must be provided.

A commonly employed method of starting is to initially ionize the gas in the tube by high frequency radiation produced by a spark coil energized from the same source of alternating current as is the transformer supplying the normal operating potential to the tube. This method is not always effective, as it has previously been applied, and I have discovered the reason to lie in the fact that with the conventional starting circuits, the high frequency starting impulses are out of phase with the normal operating potential existing across the tube terminals when the latter is functioning, so that the initial ionization of the gas produced by the spark coil does not always occur at a time when the normal potential, as delivered by the source of tube current across the tube terminals, is sufficient to sustain the discharge.

Throughout this description, wherever reference is made to "the operating potential across the tube terminals", I mean the potential across the tube when the latter is functioning. This potential is less than and is out of phase with the open circuit potential of the transformer because of the resistance and leakage reactance of the transformer.

In accordance with the present invention, I shift the phase of the potential applied to the spark coil by an amount and in a direction to cause the high frequency starting impulses pro-

duced thereby to occur substantially in phase with the normal operating potential across the tube terminals. There are several ways in which the desired phase shift may be obtained and some practical methods are disclosed in the following detailed description, which refers to the drawings. 5

In the drawings:

Figure 1 is a schematic circuit diagram illustrating one method in accordance with my invention for starting a gaseous discharge tube from a source of single-phase alternating current.

Figure 2 is a diagram illustrating a modified form of the circuit shown in Figure 1. 15

Figure 3 is a vector diagram illustrating the operation of the circuit shown in Figure 1.

Figure 4 is a diagram containing curves illustrating the time of occurrence of the starting impulses relative to the times of maximum amplitude of the operating potential in a conventional circuit and in my circuit. 20

Figure 5 is a schematic circuit diagram illustrating a circuit in accordance with my invention, energized from a source of three-phase alternating current. 25

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

Figure 7 is a curve showing the characteristics of the starting impulses produced by a spark coil of a type employed for starting gaseous discharge lamps. 30

Referring to the drawings, I have shown in Figure 1 a gaseous discharge tube 15 having a pair of hot cathodes 16 positioned at the respective ends of the tube and energized from low potential secondary windings 17 of a transformer 18. The cathodes 16 are also connected to the respective opposite ends of a high potential secondary winding 19. The transformer 18 is provided with a primary winding 20 which is shown connected through a switch 21a across a pair of 110-volt alternating current mains 21. 35

In practice, the gaseous discharge tube 15 may approximate ten feet in length, and may have an internal diameter of approximately one inch, under which condition the tube, after being once started, will operate very satisfactorily with the primary and secondary windings 20 and 19, respectively, of the transformer 18, so proportioned as to deliver a secondary potential of approximately 400 volts. Ordinarily, however, the tube would not start automatically upon closure of the circuit described. To start the tube, I provide a spark coil 22, which is essentially a Tesla 40 45 50 55

coil comprising a secondary winding 25 of a great many turns, and a primary winding 24 of a few turns energized by the discharge from a condenser 50. The latter is connected in series with the winding 51 of a buzzer 52 across conductors 29 and 31 supplying energizing potential for the device. Buzzer contacts 53 make and break the operating circuit of the buzzer winding 51 and simultaneously discharge the condenser 50 through the primary winding 24 of the Tesla coil in a manner well-known in the art. One end of the secondary winding 25 is connected to one end of the primary winding 23, as shown, and the other end is connected to an electrode 28 positioned substantially adjacent the middle of the tube 15. Electrode 28 may comprise a few turns of fine wire wrapped about the tube, or it may merely comprise a plate positioned adjacent the tube.

When a spark coil of the type disclosed in Figure 1 is excited from a source of alternating current connected across the input leads 29-31, the buzzer vibrates during a portion of each half cycle of the applied alternating current (while the amplitude of the a. c. wave is sufficient to pull the buzzer armature away from its contact) to produce a series of trains of high frequency impulses at half cycle intervals. The envelope of each train is of the general shape shown in curves 34 and 36 in Figure 4, and, as shown in Figure 7, each of these trains comprises a series of damped trains 60 of high frequency oscillation. Each damped train 60 of high frequency oscillation is started by the closure of the buzzer contacts and the interval between the starting of successive train 60 is governed by the vibration period of the buzzer armature. The period of the high frequency oscillation is determined by the capacity of the condenser 50 and the constants of the Tesla coil windings 24 and 25; it is usually 100,000 cycles or more per second. The starting effect of each train of impulses is proportional to the amplitude of the high frequency oscillation and is, therefore, at its maximum at the center of each train.

In accordance with prior practices, the spark coil leads 29 and 31 would merely be shunted across the alternating current mains 21 supplying current to the primary winding 20 of the transformer 18.

In accordance with the present invention, however, the spark coil leads are not connected directly across the mains 21 but across a resistance 32 which, in turn, is connected in series with a condenser 33 across the mains 21. The operation of the conventional circuit and my preferred circuit described, will now be explained in connection with the vector diagram shown in Figure 3 and the curves of Figure 4.

Referring to Figures 1 and 3, the phase of the potential across the mains 21, which is the potential applied to primary winding 20, is represented by the vector N-1. Under open circuit conditions, the potential developed in the secondary winding 19 will be substantially in phase with the potential applied to the primary winding; the open circuit secondary potential is therefore represented by the vector N-2 which extends in the same direction as vector N-1, but is of greater magnitude. The exact relative magnitudes are not shown in Figure 3.

The transformer 18 is preferably designed, as are most neon tube transformers, to have a relatively high leakage reactance for regulation purposes. This leakage reactance is usually ap-

proximately equal in value to the total resistance of the secondary winding and the tube. Therefore, under operating conditions, the potential developed by the secondary winding 19 will comprise a resistance-component represented by the vector N-3 and a reactance component represented by the vector 3-2. Of the resistance component N-3, N-4 represents the voltage drop in the tube and 4-3 the voltage drop due to the resistance of the transformer. It will be observed that the potential across the tube represented by the vector N-4 lags the potential N-1 of the mains 21 by a phase angle in the neighborhood of 45°.

It is to be understood that the potential across the tube 15 when the tube is operating, is not actually a sine wave. Because of the peculiar impedance characteristic of such tubes 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 wave by that sine wave which is most nearly equivalent in phase and amplitude to the actual wave. Curve 35 (Fig. 4) is this equivalent sine wave, and its phase is represented approximately correctly by vector N-4 in Fig. 3. Wherever reference is made in the specification and claims to "operating potential" across the tube, or to the potential across the tube when the tube is operating, it is to be understood I am referring to the sine wave equivalent of the actual potential across the tube.

Referring now to the starting circuit in Fig. 1, comprising the spark coil, 22, I have discovered by experiment that the potential impressed across such a coil (the potential across the leads 29 and 31) when the buzzer is vibrating is consumed mainly by the resistance of the device and the potential consumed by the reactance is relatively small. Thus, assuming the conventional circuit connection in which the leads 29 and 31 would be connected directly across the mains 21, the potential applied to the spark coil 22 would be the potential represented by vector N-1. Of this potential, the component consumed by the resistance of the coil is relatively large and its phase and relative magnitude are indicated approximately correctly by the dotted vector N-7.

The component of the applied voltage consumed in the reactance of the spark coil, is therefore represented by the dotted vector 7-1 displaced 90° from the dotted vector N-7.

I have discovered that the intensity or amplitude of the high frequency discharge produced by the secondary winding 25 of the spark coil 22 is a periodically variable quantity passing through its maximum and minimum values substantially in a manner equivalent to being in phase with the reactance component (dotted vector 7-1) of the potential applied to the spark coil. Furthermore, the tube starting ability of the spark coil at any instant is measured by the intensity or amplitude of the reactance component of the potential applied to the spark coil at that instant. Therefore the time of occurrence of the starting effect produced on the tube 15 by the spark coil relative to the time of occurrence of operating potential between the tube electrodes 16, is approximately indicated by the phase displacement between the vectors N-4 and 7-1.

It will be observed from Figure 3 that vector 7-1 leads vector N-4 by an angle slightly in excess of 90°. In other words, referring to Figure 4, the high frequency starting impulses represented by the dotted curves 34 occur substantially at

a time when the operating potential across the tube 15, represented by curve 35, is reversing its direction of flow and is of very low amplitude. The result of the circuit operating in the manner described is that unless the spark coil is designed to produce a starting effect over an extremely large portion of the half cycle, the starting effect cannot be of sufficient magnitude to start the tube at a time when the operating potential represented by curve 35 is of amplitude sufficient to sustain a discharge in the tube. As has been previously stated, to be most effective, the starting impulses should reach maximum amplitude at the same instant as the normal operating tube potential, the latter being in the process of being established as the tube begins to light and having to be successfully established if the tube is to remain lighted.

In accordance with the present invention, I connect the input circuit (leads 29 and 31) of the spark coil 22 to the mains 21 through a phase-shifting circuit instead of connecting them directly thereto. A suitable phase-shifting circuit comprises a condenser 33 and a resistance 32 connected in series across the mains 21 with the input terminals of the spark coil 22 shunted across the resistance 32, the circuit connection referred to being shown in Figure 1.

Referring now to the vector diagram of Figure 3, the potential applied to the condenser 33 and resistance 32 in series is the potential of the mains 21 and, as has been previously indicated, is represented by vector N—1. This potential represented by vector N—1, is the vector sum of the potentials across resistance 32 and condenser 33, respectively. The potential across condenser 33 is determined by the reactance of the condenser and the current flowing therethrough. The potential across resistance 32 is determined both by resistance 32, the impedance of the input circuit of the spark coil 22 in shunt thereto, and the current flowing through the resistance 32 and the input circuit of the spark coil.

As has been previously indicated, the input impedance of the spark coil 22 is largely resistance, and it has been found that by suitably proportioning the condenser 33, and the resistance 32 relative to the input impedance of the spark coil 22, the potential across the spark coil and resistance 32 can be made to lead the potential of the mains 21 and therefore to lead the tube operating potential by an amount greater than that which would obtain if the leads 29 and 31 were connected directly across the main 21. Therefore the potential across resistance 32 may be represented by vector N—5 and the potential across condenser 33 by vector 5—1.

Varying the value of condenser 33 and resistance 32 varies the relative lengths of vectors N—5 and 5—1 and by properly choosing the condenser and resistance the potential represented by vector N—5 may be made equal to that required by the particular spark coil used. The vector diagram of Fig. 3 is approximately correct for a system actually tested and is sufficiently accurate to explain the operation of the system.

Since the terminals of the spark coil 22 are connected directly across resistance 32, the potential across resistance 32, represented by vector N—5. Furthermore, as previously described in connection with vectors N—1 and 1—1, the component of the potential N—5 consumed by the resistance of the spark coil may be represented by the vector N—6 and the component consumed in the reactance of the spark coil by the

vector 6—5. It was previously pointed out that the high frequency impulses produced in the secondary of the spark coil are substantially in phase with the reactance component of the potential applied to the input terminals of the coil. Therefore, with the circuit shown in Figure 1 the high frequency starting impulses applied to tube 15 through electrode 28 are substantially in phase with the vector 6—5 which, it will be observed, is displaced approximately 180° from the vector N—4 representing the operating potential across the tube terminals 16.

It will be apparent that since the operating potential applied to the electrodes 16 of tube 15 reaches a maximum value twice during each cycle and that since the starting impulses applied to the tube 15 over the electrode 28 also occur twice during each cycle, it makes no difference, in so far as their starting effect is concerned, whether the starting impulses are in phase with the operating potential across the electrodes 16 or 180° out of phase therewith.

Thus, referring to Figure 4, the high frequency discharges, represented by curve 36, which is drawn in the same phase relation to curve 35 as vector 6—5 bears to vector N—4 Figure 3, occur substantially at the times when the operating potential represented by curve 35 attains its maximum amplitude.

It may be mentioned that although the currents flowing in the tube 15 and in the spark coil circuit are not strictly sine-wave in shape (vector diagrams apply to sine-wave functions) and although the resistance of a hot cathode discharge tube of the type described is far from being a pure resistance, the use of vector diagrams do actually result in deductions in very close agreement with actual observations and their use in analysis is therefore fully justified.

The actual angle of lag between the effective component of the potential applied to the terminals of tube 15 (vector N—4) with respect to the potential of the mains 21 (vector N—1) may differ slightly from that shown in Figure 3, but good engineering practice results in vector relations quite close to those therein shown. The variation seldom exceeds a few degrees and does not vary enough to alter the effectiveness of the phase shifting circuit described.

In the embodiment of the invention described in connection with Figure 1, the terminals of the phase shifting circuit comprising condenser 33 and resistance 32 are shown connected directly across the same 110-volt lighting mains from which the primary winding 20 of the transformer 18 is energized. By properly designing the spark coil 22 it can be made to deliver the necessary high potential impulses on the reduced voltage available across the resistance 32. However, standard spark coils of the type used are designed for operation from 110-volt circuits and where a three-wire 220-volt circuit is available, it is desirable to connect the condenser 33 and resistance 32 across the 220-volt circuit as shown in Figure 2, the primary winding 20 of the transformer 18 being connected between one side of the 220-volt main and the neutral conductor. Since in a three-wire 220-volt circuit the potential across the 110-volt mains is in phase with the potential across the 220-volt mains, the operation of the circuit modified as shown in Figure 2 is identical with that of the circuit shown in Figure 1, except that the potential applied to the spark coil is greater.

It is practicable, when using the circuit of Fig-

ure 2, to so proportion the condenser 33 and the resistor 32 as to make the potential applied to the spark coil (the potential across resistor 32) substantially 110 volts. Under these conditions the potential across the resistance 32 is smaller, relative to the potential across the condenser 33, than as represented by vectors N—5 and 5—1, respectively, in Figure 3, thus bringing the reactance component of the potential consumed in the spark coil more nearly 180° out of phase with the operating potential (vector N—4) across the tube. This result is of course to be desired.

Where a polyphase power circuit is available, approximately the desired phase shift between the potentials applied to the power transformer and the spark coil may be obtained by connecting them to different phases of the circuit. Thus I have shown, in Figure 5, a gaseous discharge tube circuit similar to that of Figure 1, but energized from a three-phase source. In Figure 5 all of the elements corresponding to those in Figure 1 bear the same reference numeral with the suffix *a*. Thus the primary winding 20*a* of the transformer 18*a* is connected across one leg 39 of the secondary of a three-phase star connected transformer 37, the primary winding of which is not shown, and the conductors 29*a* and 31*a* leading from the spark coil 22*a* are connected across one of the other legs 41 of the three-phase transformer secondary 37.

Referring to Figure 6, which is a vector diagram illustrating the operation of the circuit shown in Figure 5, the vector N'—38 represents the potential developed in the leg 39 of the three-phase winding 37 and the vector N'—40 represents the relative phase of the potential developed in the leg 41 connected to the spark coil 22*a*.

As previously described in connection with Figure 3, the operating potential across the tube terminals 16*a* lags the potential applied to the primary winding 20*a* of transformer 18*a* and may be represented by the vector N'—44. Likewise the potential effective in the spark coil 22*a* for developing the starting tendency, leads the potential developed in winding 41 and may be represented by the vector 42—43, bearing the same relation to vector N'—40 as vector 5—6 to vector N—5 in Figure 3. It will be observed from an inspection of Figure 6 that as a result of the 120° displacement between the vectors N'—38 and N'—40, the vector 42—43 is approximately parallel to the vector N'—44. Therefore the starting impulses applied to the starting electrode 18*a* will be substantially in phase with the operating potential between electrodes 16*a*, and will be fully effective for starting the tube.

Obviously several different tubes may be operated from different legs of the same polyphase circuit, the starting coil associated with each tube being connected to a different phase than is the operating transformer associated with that tube.

Having fully described the preferred embodiment 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:

70 1. 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 un-

aided 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, means for starting said tube adapted to be energized from alternating current to produce a starting effect during a portion only of each half cycle of the energizing alternating current and phase-shifting means connecting said starting means to said source of alternating current for causing said starting means to function at a time during the cycle of said operating current when, under normal operation conditions of said tube, the potential across said tube would be sufficient to sustain said tube in operation.

2. 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 said tube comprising a spark coil energized from said source of alternating current, and phase-shifting means connected between said source and said spark coil for causing the potential applied to said spark coil to differ substantially in phase from the potential of said source.

3. 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 said tube comprising a spark coil energized from said source of alternating current, and phase-shifting means connected between said source and said spark coil to cause the potential applied to said spark coil to lead, in phase, the potential of said source.

4. 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 and a second source of alternating current of the same frequency but displaced approximately from 90° to 120° in phase from said first source for energizing said spark coil.

5. In combination, a gaseous discharge tube, a source of polyphase alternating current, means for applying a potential derived from one phase of said source to said tube for operating the tube, said means having substantial inductive reactance effectively in series with said source and tube whereby the normal operating potential applied to said tube lags the potential of said one phase of said source and starting means for ionizing said tube comprising a spark coil energized from

another phase of said source of alternating current.

5 6. In combination, a gaseous discharge tube, a source of alternating current, means for applying a potential derived from said source to said tube for operating the tube, said means having substantial inductive reactance effectively in series with said source whereby the normal operating potential across said tube lags the potential of said source, starting means for initially ionizing said tube comprising a spark coil, and a condenser and a resistance connected in series across said source of alternating current, said spark coil being shunted across said resistance whereby the potential applied thereto leads the potential of said source.

10 7. In combination with an alternating current supply system supplying a low potential and a high potential substantially double the low potential; a gaseous discharge lamp comprising a discharge tube and means energized from the low potential leads of said source for 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 said tube comprising a spark coil adapted to normally operate on a potential equal to the low potential of said source; and phase-shifting means connected to the high potential leads of

said source for supplying potential approximately equal in magnitude to said low potential, but differing in phase therefrom, to said spark coil.

8. In combination, an electric circuit, a gaseous discharge tube in said circuit, a gas in said tube, a source of a. c. power, means for applying a potential from said source to said circuit of magnitude sufficient to maintain said tube in operation but insufficient to start the tube unaided, inductive reactance in said circuit, separate means to ionize the gas in said tube, and means for energizing said ionizing means in such phase relation with respect to the potential applied to said circuit and to the magnitude of said inductive reactance as to ionize the gas in said tube at a time when, if the tube were operating, the potential across the tube would be substantially at maximum amplitude.

9. In combination, an electric circuit, a gaseous discharge tube in said circuit, a gas in said tube, a source of a. c. power, means for applying a potential from said source to said circuit of magnitude sufficient to maintain said tube in operation but insufficient to start the tube unaided, inductive reactance in said circuit, separate means energized from said source to ionize the gas in said tube, and means for applying current from said source to said ionizing means in such phase relation as to energize the latter at times when, if the tube were operating, the potential across the tube would be substantially at maximum amplitude.

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