April 6, 1937. J. W. RYDE ET AL 2,076,278

ELECTRIC DISCHARGE DEVICE

Filed Sept. 7, 1935

FIG. 1.

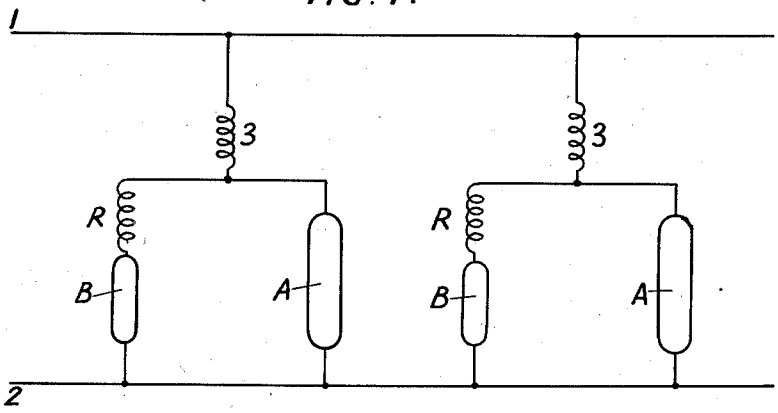


FIG. 2.

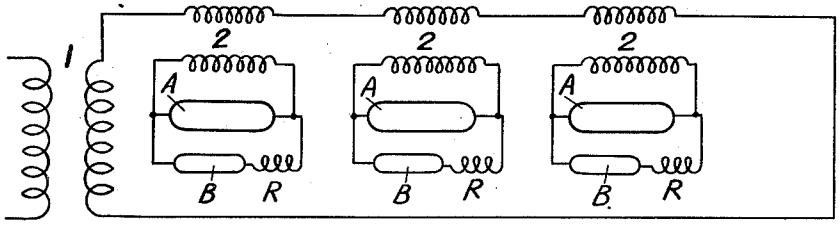
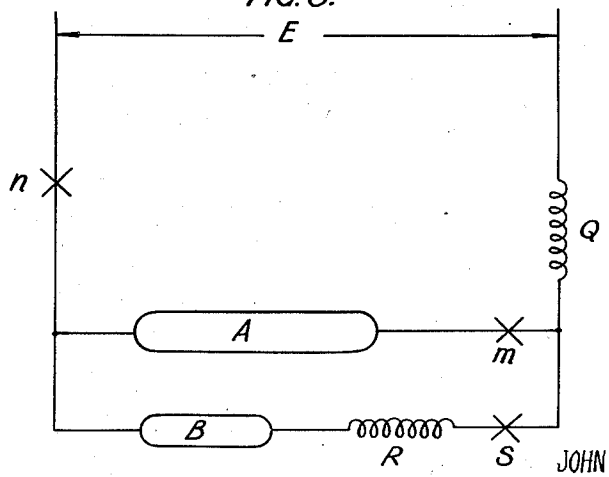


FIG. 3.



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ELECTRIC DISCHARGE DEVICE

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This invention relates to a circuit arrangement for operating electric discharge devices of the high-pressure metal-vapour type. Since it depends on certain operating characteristics of devices of this type, and not on their content, luminous emission, or other features, the type is defined for the purpose of the invention by the following statement:—

Let V_c be the voltage across the device necessary to start a discharge in it when the device is cold (that is to say, first brought into operation); V_h, the voltage necessary to start a discharge when the device is hot (that is to say, when it has been operating for so long that it has reached a state of thermal equilibrium, is then extinguished, and the starting voltage applied to it after an interval just sufficient to allow the ions to disappear); V_1, the voltage across the device immediately after the discharge has been started from cold; V_2, the voltage across it when the device has operated for so long that it is in thermal equilibrium. Then the device is of the high-pressure metal-vapour type if, and only if, both V_c and V_2 are much greater than V_1; and V_h is much greater than V_c.

The voltages mentioned in this definition are not entirely precise. For, if the device is operated (as is usual) on A. C., and the values of the V's are R. M. S. values, they will depend on the waveform of the supply and may be different from the D. C. values; for V_c and V_h depend on the peak rather than on the mean voltage of the supply. Again, even on a D. C. supply, V_c and V_h are not perfectly definite; there is apt to be a range of voltage within which starting is uncertain. Lastly V_1 and V_2 depend on the circuit in which the device is connected, as well as on the device itself.

In what follows we shall have to take account of these complications. But they do not introduce any practical difficulties in deciding whether a device satisfies the definition. For this purpose it is sufficient to take R. M. S. values for an approximately sinusoidal supply, and to estimate V_1 and V_2 when the device is in any circuit by which it is adapted to be normally operated. Thus, on this understanding, a typical device to which the invention relates may have the following values:—

V_1=20 volts.
V_2=150 volts.
V_c=180 volts.
V_h=more than 300 volts.

The difference between V_h and V_c is apt to lead to serious inconvenience if the supply is liable to interruptions or sudden decreases of voltage, even if they are momentary. For, if the normal supply voltage lies between V_c and V_h, the device, extinguished by a lowering of the supply voltage, is not restarted immediately the voltage is restored; it will not start again until the device has cooled down so that the starting voltage again approaches V_c. If the device is a lamp (as it usually is), a momentary interruption of the supply may cause a considerable period of darkness; and, even if its primary purpose is not to supply light, other disadvantages may arise that are of particular importance in connection with the constant current circuits that will be considered more fully later. These disadvantages may arise equally if the device is extinguished by its own (merely temporary) failure, rather than by failure of the supply.

It has been proposed to overcome the difficulty arising from failure of the supply by connecting a pair of similar high-pressure metal-vapour discharge devices in parallel. Only one (say A) will strike when the supply voltage is first applied; for they can never be exactly similar. The other (say B) will remain cool while A operates. If A is extinguished, B will strike as soon as the supply voltage is normal; A will then cool down, so as to be ready to strike if B is extinguished. But in certain conditions, especially in street lighting for which high-pressure metal-vapour lamps are particularly suitable, this solution is not wholly satisfactory. The irregularity in starting voltages makes it difficult to ensure that A, and not B, will always strike when both are cold; and, even if that is achieved, a momentary failure of the supply will mean that, for the rest of the lighting period, the light comes from B and not from A. Accordingly matters have to be arranged so that it is immaterial whether A or B is running normally. This involves either a lighting fixture in which two lamps can be placed in equivalent positions or two separate fixtures similarly related to the street; both these alternatives are often inconvenient.

The same objection applies to another solution of the problem, suggested by a common practice when incandescent lamps are run either in series or from a constant current transformer. This is to make the starting voltage of B not greater than that of A, and to place in series with it an insulator which breaks down and conducts when a sufficient voltage is applied to it. A will then always start from cold in preference to B; but if A is hot, or for some other reason will not start at its normal V_c, the voltage across B and its insulator in series may be sufficient both to break down the insulator and to start B. But here again B continues in operation after A has returned to normality. A further objection is that it is difficult to make this device work with certainty in connection with discharge tubes.

The object of the invention is to overcome this objection and to provide means whereby, when A is extinguished and will not restart at its normal voltage (owing to temporary failure of itself or

the supply), an alternative path is provided for the current normally flowing through A (or for current of approximately the same magnitude), and whereby also, when A is restored to normality, the current will leave the alternative path and A will operate once more. If A is a lamp, it is obviously desirable that the alternative path should produce light, and in some circumstances it is desirable further that this light should be of the same character as that from A, and should therefore come from another lamp of the same type in the alternative path. But it is not essential to the invention that these further objects should always be attained.

We have found that the object of the invention can be attained by constructing the alternative path of a continuous impedance (hereafter termed R) in series with a discharge tube (hereafter called B), this alternative path being connected directly across the terminals of the normally operating high-pressure metal-vapour discharge devices (hereafter termed A), so that both A and the alternative path are in series with the stabilizing impedance (or its equivalent) which is always required in series with high-pressure metal-vapour discharge devices. A "continuous impedance" is one in which the relation between potential and current is continuous throughout the whole relevant range; it thus excludes a discharge tube having a definite starting and stopping potential; but it includes an impedance (such as a metallic resistance with a high temperature coefficient) in which the potential is not proportional to the current. It is to be observed that a discharge tube differs from an insulator subject to break-down (as aforementioned), because the former is, and the latter is not, restored to the non-conducting state when the potential that produced conduction is removed.

Of course there is nothing new in proposing generally to shunt one discharge device (not necessarily a high-pressure metal-vapour device) by another discharge device in series with a continuous impedance. In order that such arrangement should lie within the invention, the elements A, B, R must fulfill certain conditions. The fact on which the invention rests is that, owing to the special properties of high-pressure metal-vapour discharge devices, as defined, it is possible to secure fulfilment of these conditions so as to secure the object of the invention.

We will first state more formally the conditions that have to be fulfilled in operation, in order that the object of the invention shall be attained. They are:

(1) So long as the supply voltage is normal, a discharge must pass either through A or through the alternative path and therefore through B.

(2) When the normal supply voltage is first applied the discharge starts in A within some brief period, but the discharge may start first in B.

(3) If, when the normal voltage is first applied, the discharge starts first in B, then the starting of A will extinguish B.

(4) B cannot start at any time after the starting of A, so long as A remains in operation.

(5) If B is in full operation because A has been extinguished, either by its own failure or that of the supply, A will start again and extinguish B when A is restored to normality.

Sometimes, but not always, another condition is necessary, namely (6) that the impedance of B and R in series, when passing current, is not very different from that of A when passing current. But since this condition is not always imposed, it will be treated apart from the remainder.

We have now to consider what conditions must be satisfied by the characteristics of A, B, R in order that operating conditions (1) to (5) shall be satisfied. We will suppose at the outset that the supply to the circuit arrangement is D. C. Actually it is very seldom desirable to operate high-pressure metal-vapour devices on D. C., because energy has then to be wasted in the stabilizing impedance, which has to be a resistance. But the supposition enables the complications above mentioned, arising from the effect of varying wave-form, to be ignored.

Some further definitions must be introduced. Voltages characteristic of A will be distinguished by the suffix M (for "main"); they denote voltages across the terminals of A, and do not include the voltage across the stabilizing impedance (or its equivalent). The corresponding voltages characteristic of the alternative path will be denoted by the suffix S (for "subsidiary"); they are voltages across the combination consisting of R and B in series. Since no current is flowing when V_c is estimated, $(V_c)_S$ is the cold starting voltage of B alone. $(V_2)_S$ is the voltage across the combination when it has reached thermal equilibrium. $(V_1)_S$ is the voltage across the combination immediately after B starts (or, more accurately, the maximum voltage attained within some inappreciable interval after starting). $(V_m)_S$ is the minimum voltage across the combination which enables a current to pass through it at all when A is passing a discharge. In virtue of the fact that B is a discharge device, there will always be such a minimum voltage in any determinate conditions. E is the normal supply voltage.

In order that the operating conditions (1)–(5) abovementioned should be satisfied, it is sufficient (subject to comments made below) that all of the following statements should be true:—

(1′) $(V_c)_M$ and $(V_c)_S$ are both less than E.

(2′) Either $(V_c)_S$ is greater than $(V_c)_M$, or $(V_1)_S > (V_c)_M$.

(3′) $(V_m)_S$ is greater than $(V_1)_M$.

(4′) $(V_c)_S$ is greater than $(V_2)_M$.

(5′) $(V_2)_S$ is greater than $(V_c)_M$.

The condition that all these statements should be true will be called condition P, when the supply is D. C.

Examination will show that the truth of each of these statements means approximately that the operating condition similarly numbered is satisfied. No proof of this statement will be necessary for those skilled in the art; but it is to be observed that condition (5), as well as condition (3) requires that (3′) should be true.

However, the following comments are necessary. First, (1′) may not ensure that (1) is satisfied if it can happen that both A and B are "hot" at the same moment and therefore have starting voltages higher than the respective V_c. (4′) would not necessarily ensure (4), if the voltage across A, while rising from $(V_1)_M$ to $(V_2)_M$ passed through a value greater than $(V_2)_M$. In one contingency (5′) with (3′) may not ensure that (5) is satisfied. If A has been extinguished by a temporary failure of the supply, it may start again before it has cooled down completely; if it does so, the voltage across it immediately after starting may be greater than $(V_1)_M$ and thus greater than $(V_m)_S$, although $(V_m)_S$ is greater than $(V_1)_M$. None of these possibilities are likely to be troublesome; but it may sometimes be necessary to impose a rather more stringent con-

dition than P. However, condition P must still be fulfilled.

Second, we have to take into account the inconsistency aforementioned in the values of the characteristic voltages and especially in the V_c's. V_c may vary with temperature and with the age of the device. This inconsistency has to be allowed for by means of a "factor of safety"; that is to say, it is necessary in practice (for example in (1')) that $(V_c)_M$ and $(V_c)_S$ should not be merely less than E, but less by some considerable margin. The margins that are suitable will appear from the examples given below. Condition P is to be understood as including a suitable factor of safety.

So far only D. C. operation has been considered. When the supply is A. C., the statements (1') to (5') have no definite meaning; for they may be true (e. g.) if peak values are used and untrue (e. g.) if R. M. S. values are used. In order to produce definite and accurate statements of the same form, it would be necessary to consider the variation of each V through a cycle and to take account of the fact that the waveform of the voltage applied to B (or A) may depend on whether current is or is not passing in A (or B). Accordingly it is desirable to give the statements a different form. But, before the alternative statements are given, it should be pointed out that, if the supply is sinusoidal, and if the factor of safety, necessary on the score of consistency, is allowed, then condition P in the form already given will often secure conditions (1) to (5), when R. M. S. values are used throughout for the V's and for E. Thus in these conditions $(V_c)_M$ may be identified with the R. M. S. value of the least sinusoidal voltage which will start a discharge consistently in A; $(V_1)_S$ with the R. M. S. value of the voltage across the alternative path just after the discharge in B has started, the supply voltage being sinusoidal; and so on.

The alternative statements describe certain tests to be applied to the circuit. These tests will now be described with reference to Figure 3 of the accompanying drawing. As shown in this figure, the components are connected in a main and alternative path across the actual A. C. supply of voltage E to be used, the stabilizing impedance Q being in series with both paths. The main path contains a make-and-break switch *m*, the alternative path a make-and-break switch S; a make-and-break switch *n* is in series with both paths. The following tests are made always starting in each case with all switches open, and the devices A and B cold; if the result indicated in each case is obtained, condition P is satisfied.

Test 1*a*. Close *m*; close *n*. Result: A starts.
1*b*. Close S; close *n*. Result: B starts.
2*a*. Close *m*, S and then *n*. Result: A starts, B does not start or only flickers momentarily and is then extinguished.
2*b*. Almost immediately after B starts in test 1*b*, close *m*. Result: A starts.
3. As in 2*b*. Result: B is extinguished.
4. After A starts in 1*a*, allow A to run until voltage across it reaches a steady value. Close S. Result: B does not start.
5. After B starts in 1*b*, allow B to run until voltage across it reaches a steady value. Close *m*. Result: A starts, and B is extinguished.

Examination will show that the tests 1*a*, 1*b* secure that condition (1) is satisfied; 2*a*, 2*b* that condition (2) is satisfied, and so on. It is to be observed that, if condition P in its earlier form for a D. C. supply is satisfied, the tests would succeed if a D. C. supply were used for them. Condition P, defined by the tests, is therefore sufficient for any supply, whether A. C. or D. C.

According to the invention a circuit arrangement for operating one or more high-pressure metal-vapour electric discharge devices (A) comprises an alternative path connected across the terminals of at least one of the said devices A, the said path consisting of a discharge device (B) in series with a continuous impedance (R), the voltages characteristic of A, B, R being so related to each other and to the normal supply voltage that condition P is satisfied in actual operation.

Condition (6) must now be considered. Here three known circuit arrangements for operating the devices must be distinguished. (*a*) An arrangement in which the devices are connected in parallel across mains of low impedance, (*b*) an arrangement in which they are fed by a common constant current transformer, being connected across the secondaries of separate transformers whose primaries are all in series with the secondary of the constant current transformer, (*c*) an arrangement in which they are connected across the secondaries of transformers (which are usually leaky transformers) whose primaries are all in series with a constant potential supply.

In arrangement (*b*) it is always necessary that condition (6) should be fulfilled; the exact degree to which the impedances of the main and alternative paths must be similar depends on the nature of the constant current transformer. In (*c*) it is usually necessary; but the degree of similarity in the impedances is apt to be less. In (*a*) it is not necessary at all, unless it is required that the alternative path should consume, for the purpose of emitting light, watts not very different from those consumed in the main circuit. The degree of similarity of the impedances will then depend on the amount of light required and on the means in the alternative path for emitting light.

If condition (6) has to be fulfilled, it will, of course, impose additional restrictions on the choice of the components B and R. The nature of these restrictions will be clear to those skilled in the art in the light of the examples given below. But some general observations will be offered here.

If one of the objects of the invention is to provide a source of light alternative to A, when A is out of operation, and emitting light of the same character as A, then B must be another high-pressure metal-vapour discharge device. It is then just possible that the impedance R might be omitted, that is to say, its value might be zero. For it is sometimes possible to find pairs of such discharge devices which will fulfill condition P when suffix S denotes the voltage across B alone. But even in this case it is preferable that impedance R should be finite; for the satisfying of condition P is then much easier and more certain, and the impedance, if it is approximately a pure reactance, need waste no appreciable amount of energy.

If, on the other hand, the alternative path need not provide light similar to that from A, B need not be a high-pressure metal-vapour discharge device. Even if the alternative path has to pro-

vide light, it is usually preferable to make R an incandescent lamp and to obtain the light from this lamp rather than from B. It is then desirable that the voltage across B and the energy consumed in it should be kept as small as possible. B serves merely to control the starting and stopping of the current in the alternative path.

Certain embodiments of the invention will now be described by way of example, each corresponding to a different requirement.

In all cases the supply circuit is 50 cycle A. C. A is a high-pressure mercury-vapour lamp of the known type adapted to consume 400 watts on a main supply of about 230 R. M. S. volts. In the first three examples the supply voltage is drawn from mains of low impedance (arrangement (*a*)). A number of similar lamps A, each with its alternative path, are connected across the mains. This arrangement is shown in Figure 1 of the accompanying drawing. Here 1 and 2 are the mains of voltage E, 3 the stabilizing impedance, usually a choke, A, B, R the components so denoted in the statement of the invention. R is shown as a choke in the figure; but, as will appear below, it may be either a choke, a condenser, or a resistor. The condensers usually placed across the mains for correcting the power factor are not shown; of course they are desirable, but they do not affect the invention.

In the first example nothing is required of the alternative path beyond that it should provide a reasonable amount of light when A is extinguished. The quality of the light is unimportant. Then, as has been explained, it is preferable that R should be an incandescent lamp and that the energy consumed in B should be small. Condition P is now more easily fulfilled than in any of the other examples; considerable departures from the components about to be described are possible without violating condition P; but some limitation will be imposed by condition (6).

A may be characterized by the voltages already given as an example, namely

$(V_c)_M=180; (V_h)_M>300; (V_1)_M=20; (V_2)_M=150;$ E=230 volts

The stabilizing choke 3 has an impedance of 50 ohms. The current passing through A in the state characterized by V_2 is about 2.9A. The power factor of A with its stabilizing choke is about 0.6.

R is a tungsten gas-filled incandenscent lamp designed for 200 watts at 210 volts.

B is a discharge device similar in construction to the inner tube of A; but it is rather smaller and has no outer envelope. V_1 and V_2 for this device are then much more nearly equal than they are in A; for the vapour pressure of the mercury does not rise much in operation. (The same result may be attained by restricting the supply of mercury in B, or by other known means). Such a device can be constructed so that, when it is used in combination with the aforesaid R, the characteristic voltages of the alternative path are

$(V_c)_S=180$; $(V_1)_S=200$; $(V_2)_S=218$; $(V_m)_S=$ 30 to 40

The state characterized by $(V_1)_S=200$ is reached as soon as the tungsten lamp has heated up; the further rise to $(V_2)_S$ occupies only a few seconds. In this equilibrium state, 0.93 amp. passes through the alternative path and of the 218 volts only 14.5 are across B.

Condition P is thus fulfilled. Since $(V_c)_S$ is not greater than $(V_c)_M$, either A or V may strike first from cold; but $(V_1)_S$ is greater than $(V_c)_M$, so that A will strike, even if B strikes first; and, since $(V_m)_S$ is greater than $(V_1)_M$, A will extinguish B when it strikes.

In the second and third examples, it is required that the light from the alternative path should be of the same quality as that from A. B must therefore be a high-pressure mercury discharge lamp, and R is preferably reactive. In the second example it is a choke, in the third it is a condenser; a condenser turns out to be more convenient; for in order to meet the new requirements with a choke for R, it is desirable to give the lamp A slightly different characteristics; moreover the factor of safety is greater with the condenser.

In the second example

$(V_c)_M=150$; $(V_h)_M>300$; $(V_1)_M=20$; $(V_2)_M=150$; E=234 volts

The stabilizing choke 3 has an impedance of 49 ohms.

R is an inductance of 125 ohms impedance.

B is a 100 watt high-pressure mercury-vapour lamp. On starting from cold (with A out) its V_1 is 19 volts; the current through it is 1.35A; 24 watts are consumed in it and the voltage across the choke 3 is 67. When it is hot (with A out), its V_2 is 117 volts; the current about 1A; the watts 100; the volts across choke 3 are 51. With such a lamp we have

$(V_c)_S=200$; $(V_1)_S=169$; $(V_2)_S=191$; $(V_m)_S=$ 30 to 40

In the third example, the characteristics of A and the choke 3 are the same as in the first example, but E is raised to 235 volts.

R is a condenser of 12.8μ f. capacity.

B is a 150 watt high-pressure mercury-vapour lamp. On starting from cold its V_1 is 19 volts; current 1.24A; watts 21; voltage across choke 3 about 62. When it is hot, its V_2 is 140 volts; current 1.4A; watts 159; voltage across choke 3 about 75. With such a lamp we have

$(V_c)_S=180$; $(V_1)_S=299$; $(V_2)_S=302$; $(V_m)_S=$ 30 to 40

It will be observed that the substitution of a condenser for a choke has the advantage of raising $(V_1)_S$; but it will probably decrease the power factor when the alternative path is taking the current. It is here assumed that the power factor is "corrected" when the main path is in operation.

In the fourth and fifth examples, the supply circuit is different; the lamps are fed from a constant current transformer (arrangement (*b*)); the advantages of this form of supply in a street lighting system are well known. The arrangement appropriate to this case is shown in Figure 2 of the accompanying drawing. Here 1 is a transformer designed to provide a constant current I_1=(say) 6.6A. It supplies a plurality of series connected primaries of ordinary transformers 2, whose secondaries feed the lamps A; the current through these secondaries tends to a constant value I_2=(say) 3.1A. No stabilizing impedance is required in series with each A; for the constant current transformer is the equivalent of such an impedance. In the known arrangement, the alternative paths shown are absent. If then one of the secondary circuits is broken owing to the failure of a lamp A, the impedance

of the corresponding primary may become so high that the transformer 1 can no longer maintain the constant current I_1; the remaining lamps may be extinguished or underrun. Even if the transformer 1 can eventually maintain the current I_1, it will need time to adjust itself; and during this time the lamps A may be extinguished, so that they will not start again when the adjustment is complete.

In these circumstances the use of the invention is particularly desirable. The alternative paths B, R are provided across each lamp A. In order to obtain full advantage of it, B must start so quickly after A is extinguished that I_1 has no time to fall. There is usually no difficulty in fulfilling this condition. It is now necessary that the impedances of the main and alternative paths should be closely similar.

In the fourth example, the light provided by the alternative path comes from an incandescent lamp, as in the first example. Then B is required merely to start and stop the current in the alternative path.

The constant current transformer 1 is designed to yield a constant current $I_1=6.6A$ in the primary circuits of the transformers 2 and about 3.1A in their secondary circuits. If the secondary circuits are open, the secondary volts rise to 470; consequently E is not much less than 470. The lamps A are characterized by

$(V_c)_M=180$; $(V_h)_M>300$; $(V_1)_M=20$; $(V_2)_M=140$

R is made up of an incandescent lamp, designed to consume 198 watts with 65 volts across it, in series with a choke having an impedance of 54 ohms. This choke enables a large voltage to be developed across S without a large wattage being consumed in it.

B is a discharge device of the same general kind as in the first example, so that its V_1 and V_2 are nearly equal. Then it can be chosen so that

$(V_c)_S=180V$; $(V_1)_S=198$;
$(V_2)_S=198$; $(V_m)_S=30$ to 40

About 44 watts will be consumed in B and about 198 in the lamp.

In the fifth example, the light from the alternative path is provided by a high-pressure mercury lamp B; R is therefore preferably purely reactive. With the same transformers and the same characteristics of A as in the fourth example, R may be a choke of about 70 ohms impedance and B a 250 watt high-pressure mercury lamp. In this lamp on starting $V_1=19$ volts; the current is 3.11A; the watts 50. When hot, $V_2=100$, the current is 3.09A; the watts 280. Then the following values for S can be obtained

$(V_c)_S=180$; $(V_1)_S=212$; $(V_2)_S=247$; $(V_m)_S$ 30–40

Certain irregularities, not fully explained, have been observed in the operation of the circuit in this fifth example. Thus, after B starts from cold, the current through it may fall and then rise again. They probably arise from the presence of the choke in series with B; for they do not arise in A. But, except in abnormal circumstances, they do not affect the attainment of the object of the invention.

In any circuit arrangement according to the invention, the alternative path is a mere stop-gap, and is not intended to be operated normally. Accordingly if it provides light, there is no need to place the source in a position optically equivalent to that of A. But in a street lighting system it will generally be convenient to place it on the same post as A.

If arrangement (*c*) is used for supplying the devices, the combination of B and R required will in general be more similar to that suitable for arrangement (*b*) than to that suitable for arrangement (*a*).

In any of the arrangements (*a*), (*b*) or (*c*) it is not necessary that if the alternative path provides light, this light should be comparable in amount with that produced in the main path. Thus the alternative path may provide a mere pilot light to indicate to a supervisor that A is extinguished. In this case the watts consumed in the alternative path may be small. Thus R may be purely reactive and B be a discharge lamp consuming few watts, which serves as the pilot light. Alternatively R may be mainly reactive, but includes a small wattage incandescent lamp, which is used as the pilot; then B need not be used to give light at all.

We claim:—

1. In combination, a main electric gaseous discharge device of a type whose starting potential at normal operating temperature is far in excess of its starting potential at room temperature, and whose discharge maintaining potential lies within a fixed range, an impedance between said device and a source of constant potential, and an impedance in parallel with said device consisting at least in part of a second gaseous discharge device whose starting potential is in excess of said range but below the hot starting potential of said main device, the voltage drop attained across the latter impedance when said second discharge device reaches a given temperature in operation being in excess of the room temperature starting potential of said main device, the minimum potential required to maintain current flow through said latter impedance when said second device is at said given temperature being in excess of the maintaining potential of said main device when it restarts, whereby said second device serves as a standby for the main device, functioning for an interval whenever potential is applied thereto after the discharge in the main device has been extinguished after it is appreciably above room temperature and automatically transferring the discharge back to said main device when the latter approaches room temperature provided said main device is in operable condition.

2. In combination, a main electric gaseous discharge device of a type whose starting potential at normal operating temperature is far in excess of its starting potential at room temperature, and whose discharge maintaining potential lies within a fixed range, an impedance between said device and a source of constant potential, and an impedance of substantially the same apparent value as the apparent impedance of said discharge device connected in parallel with said device, said impedance consisting at least in part of a second gaseous discharge device whose starting potential is in excess of said range but below the hot starting potential of said main device, the voltage drop attained across the latter impedance when said second discharge device reaches a given temperature in operation being in excess of the room temperature starting potential of said main device, the minimum potential required to maintain current flow through said latter impedance when said second device is at said given temperature being in excess of the maintaining potential of said main device when

it restarts, whereby said second device serves as a standby for the main device, functioning for an interval whenever potential is applied thereto after the discharge in the main device has been extinguished after it is appreciably above room temperature and automatically transferring the discharge back to said main device when the latter approaches room temperature provided said main device is in operable condition.

3. In combination, a main electric gaseous discharge device of a type whose starting potential at normal operating temperature is far in excess of its starting potential at room temperature, and whose discharge maintaining potential lies within a fixed range, an impedance between said device and a source of constant potential, and an impedance in parallel with said device, said impedance consisting at least in part of a second gaseous discharge device of the same type as said main discharge device but whose starting potential is in excess of said range but below the hot starting potential of said main device, the voltage drop attained across the latter impedance when said second discharge device reaches a given temperature in operation being in excess of the room temperature starting potential of said main device, the minimum potential required to maintain current flow through said latter impedance when said second device is at said given temperature being in excess of the maintaining potential of said main device when it restarts, whereby said second device serves as a standby for the main device, functioning for an interval whenever potential is applied thereto after the discharge in the main device has been extinguished after it is appreciably above room temperature and automatically transferring the discharge back to said main device when the latter approaches room temperature provided said main device is in operable condition.

4. In combination, a main electric gaseous discharge device of a type whose starting potential at normal operating temperature is far in excess of its starting potential at room temperature, and whose discharge maintaining potential lies within a fixed range, an impedance between said device and a source of constant potential, and an impedance in parallel with said device, said impedance consisting of a condenser and a second gaseous discharge device of the same type as said main discharge device in series therewith whose starting potential is in excess of said range but below the hot starting potential of said main device, the voltage drop attained across the latter impedance when said second discharge device reaches a given temperature in operation being in excess of the room temperature starting potential of said main device, the minimum potential required to maintain current flow through said latter impedance when said second device is at said given temperature being in excess of the maintaining potential of said main device when it restarts, whereby said second device serves as a standby for the main device, functioning for an interval whenever potential is applied thereto after the discharge in the main device has been extinguished after it is appreciably above room temperature and automatically transferring the discharge back to said main device when the latter approaches room temperature provided said main device is in operable condition.

5. In combination, a main electric gaseous discharge device of a type whose starting potential at normal operating temperature is far in excess of its starting potential at room temperature, and whose discharge maintaining potential lies within a fixed range, an impedance between said device and a source of constant potential, and an impedance in parallel with said device, said impedance comprising an incandescent lamp in series with a second gaseous discharge device whose starting potential is in excess of said range but below the hot starting potential of said main device, the voltage drop attained across the latter impedance when said second discharge device reaches a given temperature in operation being in excess of the room temperature starting potential of said main device, the minimum potential required to maintain current flow through said latter impedance when said second device is at said given temperature being in excess of the maintaining potential of said main device when it restarts, whereby said second device and the incandescent lamp serve as a standby for the main device, functioning for an interval whenever potential is applied thereto after the discharge in the main device has been extinguished after it is appreciably above room temperature and automatically transferring the discharge back to said main device when the latter approaches room temperature provided said main device is in operable condition.

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