

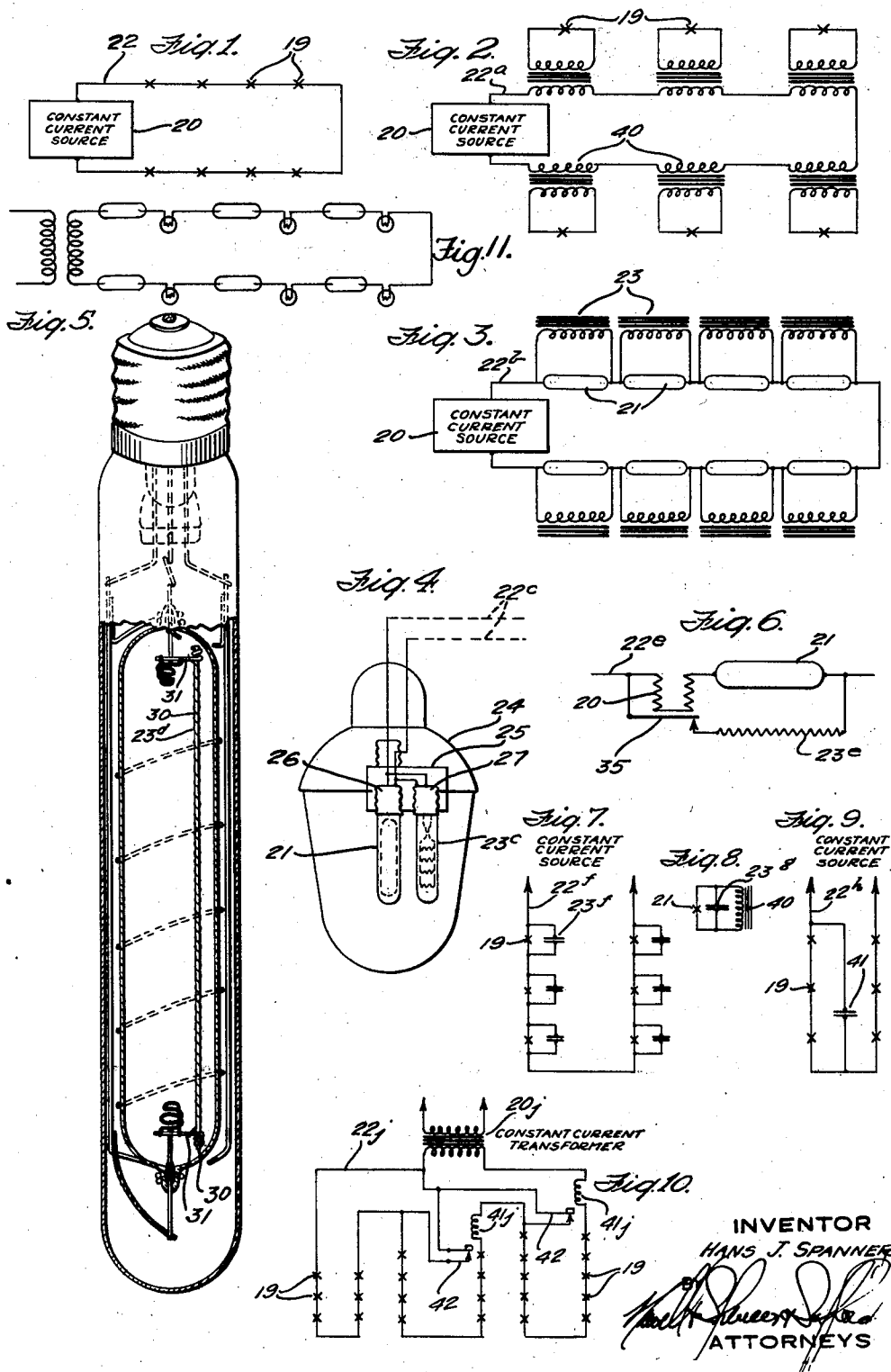
Sept. 29, 1942.

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2,297,258

DISCHARGE DEVICE

Filed April 22, 1938



UNITED STATES PATENT OFFICE

2,297,258

DISCHARGE DEVICE

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Application April 22, 1938, Serial No. 203,557

9 Claims. (Cl. 176—124)

This invention relates to a gaseous discharge device and circuits therefor. More particularly the invention relates to circuits including gaseous discharge devices of the type in which the re-starting voltage is greatly increased due to in-crease in temperature or pressure during opera-tion.

I have described in my previous applications Serial Nos. 558,148, filed August 19, 1931, and 744,-206, filed September 15, 1934, lamps in which a supply of mercury or other vaporizable material is vaporized during operation. The increase in density of the atmosphere between the electrodes resulting from vaporization in such lamps may be so great that the lamps when deionized can-not be restarted until they have cooled for sev-eral minutes after they have ceased to operate, such lamps I refer to herein as "high pressure vapor lamps." In series lighting circuits, where-in the failure of one lamp will extinguish the en-tire series, this may be particularly annoying be-cause it prevents the use of the ordinary "film cut-outs" to short circuit any lamp which fails to operate.

One object of my invention, therefore, is to provide a series circuit for discharge lamps or other devices of the type specified.

Another object of my invention is to provide an illuminating system adapted to use such dis-charge lamps with existing street lighting equip-ment, and in circuits of types which are familiar to the personnel responsible for street lighting installation and operation.

Another object of my invention is to provide a series circuit for gaseous discharge lamps in which the failure of any lamp will not prevent the others from operation.

Another object of my invention is to provide a circuit in which a vapor discharge lamp will restart automatically as soon as its break-down voltage is sufficiently reduced by condensation of its vapor filling.

Another object of my invention is to provide a lighting circuit in which a gaseous discharge lamp is operated in conjunction with an incan-descent filament lamp so that when both are properly operating they complement one another to give a color-corrected light and which, in the event of failure or temporary outage of the dis-charge lamp, will provide adequate lighting from the incandescent filament lamp.

Another object of the invention is to provide a device suitable for street lighting or similar situations in which a color-corrected light is de-sired at the edge of the road where pedestrians

pass while the more efficient colored light of the gaseous discharge is used toward the center of the road for illumination of the vehicular high-ways.

5 Another object of the invention is to provide a device which is adapted to start and operate a high pressure vapor arc lamp of the type men-tioned even in the coldest weather and even when the usual fixed gases are omitted.

10 The series circuits in use today have been de-signed for incandescent lamps or for contacting carbon arc lamps. The peculiarities of the high pressure vapor lamps having fixed electrodes have been thought to make them unsuitable for use in series circuits. Among these character-15 istics are (1) that although they ordinarily are designed to start at a voltage a little above their operating voltage they may, while otherwise good, start only at higher voltage, and in any case under extreme weather conditions they may require much higher voltage; (2) that the ini-tial discharge occurs at a low voltage only a frac-20 tion of the final operating voltage, and that dur-ing this low voltage discharge the lamp must be heated sufficiently to evaporate the vaporizable filling material; (3) that after they have at-tained their full operating voltage, if they are once extinguished, they cannot be restarted until after a delay of several minutes or at a voltage 30 many times that of the original starting voltage.

I have now discovered that these vapor lamps can be used in series circuits very similar to those already in use for incandescent and carbon arc lamps; and in the accompanying drawing I have 35 shown a number of illustrative circuits by ref-erence to which I shall show how this can in fact be done.

In the accompanying drawing I have shown several preferred embodiments of my invention 40 and I have suggested various modifications thereof. These I have chosen with a view to illus-trating and explaining the invention and in-structing others in the best manner of embody-ing the same in practice. These are not intended to be exhaustive or limiting of the invention; 45 but, on the contrary, it is my intention thus to enable others to embody the invention in numer-ous other forms and with numerous other modi-fications, each as may be best adapted to the particular use for which it is intended. 50

In the accompanying drawing:

Figs. 1, 2 and 3 are diagrammatic views show-ing circuits for use of discharge lamps accord-ing to my invention;

Fig. 4 is a diagrammatic view showing the ar-

rangement of parallel lamps in a fixture according to my invention;

Fig. 5 is a view partly in perspective, partly in longitudinal section of a combination lamp with which my invention may be embodied;

Fig. 6 is a diagrammatic view of a portion of a circuit according to my invention;

Figs. 7, 9, 10 and 11 are circuit diagrams of modified forms of my invention; and

Fig. 8 is a fragmentary circuit diagram illustrating a modification of the circuit shown, for example, in Fig. 2.

In Fig. 1, I have shown a very simple series circuit which may be suitable for operation of the high pressure vapor lamps. (By "high pressure" I mean, throughout this application, that the pressure is so far increased after starting as to raise the voltage of the discharge above its initial discharge voltage by an important amount, e. g., double or more and, as a consequence, to raise likewise the voltage at which the lamp can be restarted.) A constant current transformer 20 supplies through the line 22 current of the amperage required for normal operation of lamps at the several stations 19 and adjusts its output voltage automatically to the requirements of the circuit.

This circuit is suitable for the operation of high pressure vapor lamps if the number of lamps is reduced or the voltage capacity of the transformer increased so that the sum of the break-down or starting voltages of all the lamps is substantially less than the open circuit voltage of the transformer; and provided secondly, that the transformer is designed to adjust itself to the low voltage reached by the series of lamps just after starting, or, better yet, if it and the circuit connections are designed for an overload current during this period of low voltage, e. g., at least double the normal operating current; and provided thirdly, that the usual film cut-outs are removed; and fourthly, provided that the lamps themselves are designed to withstand the imposition of very high voltages when they are hot. The design of the lamps, however, to protect them against high voltages, and especially the use of mica insulation between the glass envelope and the circuit connections to protect against electrolysis effects which result from such high voltages, is disclosed and claimed in my copending application, Serial No. 744,206, filed September 15, 1934, and forms no part of this invention.

The design of these transformers to the desired maximum and minimum voltages to which it will react in its operating responses is common engineering practice well known in connection with the present manufacture of constant current transformers, the limits to which the transformer adjusts itself are, however, different according to my invention than according to prior practice, especially in the provision for reduction of voltage to a fraction, e. g., $\frac{1}{4}$ to $\frac{1}{10}$ of the maximum voltage utilized in the circuit; and if the transformer is designed to give an increased current instead of fully adjusting itself to the low voltage, the circuits should be designed to carry this greater current for a period of a few minutes.

Such changes obviously require differently designed transformers and/or circuits than those heretofore in use. In some cases, however, it will be desirable to use existing transformers and circuits with substitution of vapor lamps for incandescent lamps. This I have found can be

done safely if a substantial portion of incandescent lamps remain in the series e. g., as shown in Fig. 11. In this combination the incandescent lamps act as a ballasting load to protect transformer and circuit when the voltage of the vapor lamps is low.

It is advantageous in this also to have the current increase during starting, which may be accomplished by replacing incandescent lamps in the series with vapor lamps to an extent which reduces the initial operating voltage sufficiently below that at which the transformer reaches the mechanical limit of its response and until the current is increased, but only to the extent that such increased current can be safely carried by the circuit and transformer windings and by the incandescent lamps themselves. With such proportioning of incandescent and vapor lamps with regard to the transformer circuit (e. g., to give a twenty-five percent increase in current at the minimum voltage), the vaporization is hastened and at the same time the light output of the incandescent lamps is increased during the period while the vapor lamps give relatively little light. If the incandescent lamps are positioned adjacent or combined with the vapor lamps the result will be to give adequate illumination even during this warming up period. If the vapor lamps are filled with mercury vapor, they and the incandescent lamps will each supply deficiencies in the other so that this adjacent location of the lamps will in that case give a very desirable "synthetic white light."

The incandescent lamps, since they draw no current until the vapor lamps are started, allow their share of the operating voltage to be imposed upon the vapor lamps as excess voltage for starting, and thus permit more efficient use of the capacity of the transformer.

Even at best, however, this simple circuit is subject to some disadvantage, particularly in that a failure of one lamp may cause an outage of the whole series, and that if the starting voltage of the lamps is substantially higher than their operating voltage and unless incandescent lamps are also used, the circuit may not be used efficiently, only relatively few lamps being operated from the expensive constant current transformer station.

In Fig. 2, I have shown a circuit very similar to existing "isolation transformer" or so-called "IL" circuits. This has the usual advantages which have led to its adoption in existing lighting circuits. In addition to these, however, I have found that it has special advantages when combined with high pressure vapor lamps according to my invention, and especially offers a simple means for avoiding outage of the entire series upon failure of a single lamp. If the isolation transformers are made to saturate a little above the starting voltage of their respective vapor lamps, e. g., 15-25% above the maximum expected starting voltage, each lamp may be continuously subjected to a starting potential until it does actually start. With all lamps out, the impedance of the IL transformers will be such that little or no current flows in their primary circuit and the maximum potential of the constant current transformer will be imposed upon the circuit and divided among the primaries of the IL transformers, thus imposing a starting voltage on the secondaries, i. e., upon the respective lamps.

As soon as one or more of the lamps start, a current flows in the secondary and allows a cur-

rent to flow in the primary. With only a few lamps remaining inoperative, their transformers become saturated and the full current flows in the primary circuit, thereby maintaining the other lamps in normal operation.

The isolation transformer which saturates at a moderate voltage when one lamp goes out or fails to start, avoids the imposition on the lamp of excessive voltages which might cause electrolysis or puncture of the glass.

In this case again, it is advantageous to design the "tub" transformer and primary circuit for a substantial overload, e. g., twice to three times normal operating current, during the short period while it is at minimum voltage when the vapor lamps are first beginning to heat up. In this case also the combination of vapor lamps and incandescent lamps will have the advantages discussed above and will make practicable the use of vapor lamps in existing circuits. In such conversion, however, it may be necessary to substitute an IL transformer having a different ratio of number of turns in primary and secondary coils respectively, to assure the proper voltages for the vapor lamps.

In Fig. 3, is shown a circuit having similar advantages but with the lamps connected directly in series. Each lamp 21 has in parallel therewith a choke coil 23 similar to the known so-called "socket adaptors," which is adapted normally to offer high impedance so that only a small part (e. g., 2%) of the current will pass through it. At a voltage above the starting voltage of the lamp the choke becomes saturated and carries the full current necessary to operate other lamps of the series.

The operation of this circuit is substantially identical with that described in connection with Fig. 2, and in this circuit also it is advantageous to design for overload during the initial heating up period and, especially when using existing circuits, to use incandescent lamps in the series.

The inductances in this circuit may be replaced by other impedances, resistance or capacitance, or any combination of two or all designed to impose the starting voltage on the lamps. When capacitance is used it may not be practicable to design condensers to carry the full discharge current, and with any such impedance shunt circuit, the impedance may be so high as to allow only less than full operating current until all the lamps are started.

In Fig. 4, I have shown one unit of a similar combination in which a resistance replaces the inductive impedance of Fig. 3, the resistance in the case illustrated being an incandescent lamp 23c. Although it is primarily intended that this unit would replace some or all of the units shown in the series circuits of the preceding figures, it should be understood that this arrangement of lamp and impedance in parallel may be used in other types of circuits; and, particularly where the parallel impedance is an incandescent lamp, the arrangement has advantage even in multiple circuits with each unit individually ballasted.

The current leads from the current supplying circuit 22c pass into the illumination fixture shown diagrammatically at 24, in which is a double socket 25, having its outlets 26-27 connected in parallel to the current leads 22. In the center socket 26 is screwed a typical high pressure mercury vapor lamp 21, e. g., of the type described in my prior applications, Serial Nos. 558,148, of August 19, 1931, 744,206, of September 15, 1934, 51,390, of November 25, 1935; and in the eccen-

tric socket 27 beside it is screwed a typical incandescent filament lamp 23c.

The filament lamp 23c is designed, according to well known principles so that, operating in this circuit with the mercury vapor lamp extinguished, the voltage drop across the filament lamp is greater than the normal break-down voltage of the mercury vapor lamp 21 and the filament, moreover, is designed so as to operate at maximum efficiency or even overloaded when it is operating thus alone in the circuit, but so that, when operating together with the mercury vapor lamp, it will give a substantial light output at a lower temperature of incandescence, whereby its radiation is rich in the red portion of the spectrum. Operating normally in parallel with the vapor lamp, therefore, its life will be very greatly increased over that of an ordinary commercial incandescent lamp whereas the higher temperature attained when it operates alone may be one at which the filament would have only a few hundred hours or less of life.

In the use of this device, turning on of the current immediately lights the incandescent lamp; and, if the mercury vapor lamp is in condition for starting, a discharge will start therein at the same time, since the voltage drop across the filament when carrying the full current of the circuit rises above its normal operating voltage sufficiently high to start the discharge in the mercury vapor lamp. After several minutes of operation, the pressure in the mercury vapor lamp is so far increased that if there should be a temporary failure in the line or if the lamp should be extinguished for any other reason it would not be possible to restart the lamp until it has been allowed to cool for several minutes. With this combination, however, as soon as the current is again turned on, the incandescent lamp 23c is immediately lighted; and, so long as the mercury vapor lamp 21 remains extinguished, the entire current of the line will pass through the filament lamp, thereby keeping it at maximum light output and efficiency and producing adequate temporary lighting. Due to the high voltage of the filament lamp during this stage of operation, the starting voltage is continually imposed upon the mercury vapor lamp 21 and as soon as it has cooled to such a point that the breakdown voltage is no greater than the imposed voltage its discharge is immediately started.

When this combination is used in a constant potential circuit its operation will be substantially similar to that described in connection with Fig. 4, except that the current loading imposed on the incandescent lamp will be much less increased when the vapor lamp is out.

Although I have shown only one fixture it will be understood that any number of such fixtures may be connected in multiple or in series in the same circuit. It is an advantage of the arrangement, when connected in series, that the circuit remains closed at each fixture through the incandescent filament regardless of the condition of the vapor lamp and ordinary film cut-outs may be used with the incandescent lamp to protect the circuit against burning out of those lamps. Thus the failure of any one lamp will not result in extinguishing the other lamps of the circuit or imposing excessive voltages on the circuit. Likewise, after a temporary failure of current or shutting off of the circuit, immediate illumination may be had from the filament lamps, and the vapor lamps will be relighted as

fast as they are cooled, each one lighting as soon as its break-down voltage is reduced to the voltage imposed on its filament lamp.

It is an advantage of this arrangement also that the placing of the incandescent and vapor lamp side by side results in throwing a higher percentage of red light in one direction than in another. Thus, for example in street lighting, the filament lamp may be placed toward the sidewalk or the side of the road where pedestrians walk or on which residences or stores are located. Thus, the red light from the filament lamp will supplement the greenish-blue light of the mercury vapor lamp and produce a pleasing light approximating white light and avoid any objectionable emphasis on greens or blues; whereas, on the highway side of the fixture, where the corrected color is less important, the efficient mercury vapor light will predominate.

If the lamp is to be used in a location where uniform color correction is desired the socket may have several outlets for incandescent lamps spaced around the vapor lamp and several incandescent lamps of lower wattage may be used in place of the one shown in Fig. 1. Another important advantage of the closely adjacent mounting is that the vapor lamp is heated by the incandescent lamp. This makes its starting certain even in the coldest weather and even allows the vapor lamps to be made and to start and operate satisfactorily without the usual starting gas.

The simplicity of this arrangement is also an advantage since it permits the use of the invention by the simple expedient of screwing an ordinary double socket into any existing type of fixture.

Although I have shown the incandescent lamp and the vapor lamp in separate tubes mounted in the same fixture, it should be understood that this arrangement is not necessary to my invention. Both may be included in the same tube as illustrated in Fig. 5 or in concentric tubes as more fully described and claimed in my copending application, Serial No. 115,685, filed December 14, 1936, or the respective lamps may be mounted in separate fixtures. The lamp shown in Fig. 5 may be similar to the lamp 21, except that a filament 23d is supported on the thin quartz rod 30 supported on the extensions 31 of the electrode supporting frame. These extensions also carry the current to the filament 23d. Other features of the lamp shown are described more fully and claimed in my copending application, Serial No. 124,183, filed February 5, 1937, and in Serial No. 115,685, filed December 14, 1936.

Mounting in separate fixtures may be particularly desirable on highways passing through shopping districts or the more densely populated areas where a whiter light than that of the mercury arc is desirable on the sidewalks and adjacent yards or building fronts. In such cases, the high pressure mercury vapor lamps may be mounted more or less centrally over the highway and preferably at greater height above the ground, while the incandescent lamps at the side of the highway predominate on the sidewalks. The effect may be improved also by using two incandescent fixtures (preferably series connected with one another) in parallel with a single vapor lamp fixture.

This modification will give quicker restarting because the overloaded filament causes ionization by its thermionic discharge to start at a much higher temperature than otherwise would be pos-

sible. To aid in this effect, a thoriated tungsten or otherwise activated filament may be used. This is partly offset, however, by the heating from the filament slowing the condensation of the vapor filling; and this must be taken care of by the design of the tube to give heat dissipation which will assure restarting.

The parallel connected incandescent lamp, however arranged, aids also in shortening the heating-up period of the vapor lamp. In the constant current circuits the drop in voltage when the arc is first started results in a serious drop in voltage, which greatly lengthens the heating-up period as compared with the period for the same lamp operating with a suitable ballast from a constant voltage circuit. When the incandescent lamp is connected in parallel, the current which it normally consumes is diverted into the discharge during the starting period, thereby hastening the heating-up and vaporization.

This circuit will be particularly advantageous where the constant current transformer is designed to carry a substantial overload and to react to maintain constant current only for a safe margin of variations from normal operating conditions. Thus, we may assume, for example, a constant current transformer capable of varying the voltage 50% above or below the normal requirements of the circuit to maintain constant current within those limits, and beyond those limits to act merely as a reactance transformer. When this circuit is first closed, the current all flows through the incandescent filament. This filament, however, cannot carry the full constant current load except at a very much higher voltage. Consequently, the constant current transformer reacts to raise the voltage to or above the normal starting voltage of the discharge lamp. If the lamps are not a 50% over-voltage will be imposed by the transformer, but it cannot go higher. As soon as the discharge starts, however, it immediately drops its voltage to a fraction of the starting voltage, and at this low voltage only a very small current will pass through the filament, so that almost the entire current of the circuit passes through the discharge, thereby causing more rapid heating and vaporization. As the voltage of the discharge increases, due to the vaporization, the voltage on the filament is correspondingly increased until, at the normal operating voltage it is receiving the current necessary to give it an orange or yellow incandescence designed for best color correction of the mercury arc light.

If the filament or filaments are in separate tubes or bulbs from the vapor arc, they should be designed to carry the full current of the circuit at least for a few minutes without serious disintegration. For this reason a relatively high proportion of the current should normally pass through the incandescent filament, e. g., at least 2/3. If a higher proportion of light is desired from the vapor lamp, it and its incandescent shunt may be connected into the secondary of an IL transformer which saturates at a voltage before that which would put the full normal secondary current through the incandescent lamp. With such an arrangement any desired proportion may be attained, but, of course, the normal operating temperature of the incandescent filament would ordinarily be lowered to get a higher proportion of light from the vapor lamp. For this latter reason it is desirable to have the filament and discharge in close heat-exchange relation.

If the filament is in the same atmosphere as he discharge, its thermionic emission will ordinarily start the arc before the filament itself is damaged by overheating. Such a lamp may, therefore, have the incandescent filament designed normally to take a current equal to or even less than that of the vapor arc, and the filament may operate nearer to a white incandescence.

The incandescent lamps or other impedance may be connected in parallel with lamp 21 in the secondary circuit of IL transformers having their primaries in series in the constant current circuit 12. When these transformers are designed to saturate when the secondary reaches a given voltage above the normal starting voltage of the lamp, this will protect the incandescent lamp against excessive over-voltage and allow it to operate alone at any desired loading less than the sum of the normal operating currents of both lamps 21 and 23a. With such an arrangement the lamp 23a may be burned during normal operation at a higher temperature of incandescence than if it were not thus protected.

Although it is an advantage of the arrangements shown in Figs. 4 and 5 that they provide illumination of the fixture during the period when the vapor lamp is not in operation, in some cases this may not be necessary or desired. Where light from the incandescent lamp is not desired, the shunt may be disconnected during operation of the lamp.

For this purpose one may provide a relay, magnetic or thermal, or other device for breaking the parallel shunt circuit while the discharge lamp is operating. In Fig. 6, I have shown one example of such a device. In this case the lamp 21 has connected across its terminals an impedance shunt 23e equivalent to that shown at 23 in Fig. 2, or to the incandescent lamp 23c of Fig. 4. This is connected, however, through the relay 35, the magnetic coil of which is in series with the discharge lamp 21 and in parallel with the shunt 23e. So long as the lamp 21 remains extinguished, the shunt circuit 23e is connected through the relay 35; but, as soon as the discharge path breaks down in the lamp 21 and the lamp, therefore, begins to operate, the current passing through the coils of the relay 20 picks up the armature and breaks the shunt circuit through 23e. This is an advantage also in connection with an incandescent lamp shunt when color correction is not required, and with such an arrangement the incandescent lamp will burn only when the discharge lamp is inoperative.

In Fig. 7 is shown circuits similar to that of Fig. 3, but with capacitance in parallel with the lamp instead of inductance as in Fig. 3 or resistance as in Fig. 4.

If these condensers are made with progressively varying capacity from one to another along the series one of the lamps may be made to receive more than its proportionate share of the voltage when the circuit is first closed and the other lamps to be started in turn each as the break-down of the preceding lamp imposes a greater voltage upon it, the striking of the discharge progressing down the line of lamps one at a time until the entire line is burning.

A similar result can be obtained with other types of impedance and, as already stated, this arrangement may be used in the secondary of an IL transformer as well as directly connected into the constant current circuit as shown in Fig. 8. 75

In the latter case, if the capacity of the condenser is proportioned to the inductance of the IL transformer so that a condition approaching resonance is attained (in this case to the extent that the capacity of the condensers 23g and the inductance of the IL transformer 40 approach a condition of resonance) at least in the transients, the voltage actually imposed upon the lamp for starting may be in excess of the normal open circuit voltage of the IL transformer. In this way the constant current transformer can be used more efficiently and the spread between maximum and minimum voltage to which it is required to react can be reduced.

The use of an impedance shunt across each lamp, e. g., as shown and described in connection with Figs. 2 to 8 inclusive, where the impedance is sufficiently high to maintain a high starting potential upon any lamp which is out of operation, and sufficiently low to allow the passage through the shunt of a current sufficient to maintain the discharge in any lamps which have started or which have not extinguished, is particularly advantageous because it permits the imposition of a very high voltage upon one or a few lamps which may have become extinguished, while the others continue to burn, and will give restarting after a cooling period only a fraction of what would be required if all of the lamps were extinguished and required to be restarted together. Thus, for example, I have found that lamps which, when directly connected into the constant current circuit as illustrated, for example in Fig. 1, would require 20 minutes for cooling, and restarting may be restarted within two minutes when the lamps are connected to the same constant current transformer through an isolation transformer circuit as shown, for example in Fig. 2, provided, of course, that only one or a few lamps of the series are extinguished at one time. When all of the lamps are extinguished at the same time this advantage of the isolation transformer circuit results primarily from transients which may give high peak voltages due to the inductance in the IL transformer; and a considerably longer period will be required for restarting when all of the lamps of the series have been extinguished than when only one or a few have been extinguished and the others allowed to continue burning.

In Figs. 9 and 10 are shown other circuits designed similarly to impose a greater proportion of the potential of the constant current transformer upon a part of the lamp circuit until the lamps of that part have started, and thereafter to impose a potential upon the remaining lamps so that the lamps of each part may receive a higher starting potential than would be possible if all were connected in a simple series circuit such as that shown in Fig. 1.

In the arrangement of Fig. 9, the high impedance shunt is connected across a part of the line. In this case, however, including a number of lamps in series instead of a single lamp as in the case shown in Fig. 8. The impedance in this case may be resistive, inductive or capacitive and should be of a value sufficiently high so that during operation it does not carry enough current to constitute a serious loss.

In this circuit, as shown, the capacity 41, being in parallel with the capacity imposed by the lamp across which it is connected, allows the greater part of the voltage to be imposed upon the other lamps which are in series with this shunt. As soon as these other lamps are started, however,

the ionization of their filling results in a decrease in the voltage consumption in each of these lamps and consequently the greater part of the voltage will be imposed upon the shunt and the lamps in parallel thereto. As soon as these lamps start, their voltage consumption also drops and they constitute a low resistance path around the impedance 41.

If the impedance 41 is a resistance instead of a condenser, a similar action occurs. When the circuit is first closed, the maximum potential of the constant current transformer is imposed upon the lamps in series with the resistance; and the absence of any current flow at this time will allow the potential to be transmitted through the shunt without drop. As soon as these lamps are ionized, however, a current will flow through the resistance sufficient to result in a voltage drop approaching the full voltage of the constant current source and this voltage, of course, will be imposed upon the lamps in parallel with the resistance. As soon as they are started, they constitute a low resistance path around the impedance 41 and consequently very little current will flow through the impedance.

If the impedance 41 is an inductance the operation will be similar to that just described. However, insofar as the lamps act as capacity in the circuit or have additional capacity connected thereto, e. g., as shown in Fig. 8, there may be an increase in voltage which will become greater as a condition of resonance is approached. Likewise, if in the circuit as shown in Fig. 9 with the impedance 41 a capacity, the lamps are connected into the circuit through IL transformers instead of directly, an increase in voltage may result from the combination of the inductance of the IL transformers with the capacitance of the impedance 41.

The use of the condensers, as shown for example in Figs. 7 to 9, may have also the important advantage of improving the power factor of the circuit.

Although the construction of the lamp itself is not a part of the present invention and is fully described and claimed in other copending applications, the peculiarities of the series type circuit described above make it advantageous to observe certain precautions. The fact that any given lamp may be subjected to a very high voltage, several times its normal starting voltage, requires precaution against arcing across the connections of the lamp and against electrolysis or even puncturing of the glass or other material of which the lamp itself or insulation used within the lamp, may be made. For the latter purpose I may use mica insulation between the lamp tube and any return lead or supporting parts or starting strips connected to such lead on the one hand and the glass of the lamp on the other hand, as described and claimed in my application 744,206, filed December 15, 1934; or, alternatively, these parts may be substantially spaced from the discharge tube wherever they are maintained at a potential different from the discharge or electrodes adjacent thereto within the tube, and the space between preferably filled with a gas at sufficiently high pressure to avoid break-down under the voltages to which it is subjected, e. g., as described and claimed in my copending application Serial No. 51,390, filed November 25, 1935; and likewise the connections for the lamp should be sufficiently spaced and the space between filled with a gas or other insulator adapted

to avoid break-down at the voltages attained, all as described in my said application 51,390.

It must be remembered also that when the lamps are burned on a constant current circuit, the wattage depends on the voltage consumption of the lamp; and, since this in turn depends upon the degree of vaporization within the lamp, it is important that the lamp should be designed to have all of the material which is available for vaporization within the lamp evaporated before the lamps come to their normal operating temperature. This is more particularly described and claimed in my copending application Serial No. 124,183, filed February 5, 1937, and my application Serial No. 744,206, filed September 15, 1934.

In Fig. 10, I have shown a series circuit adapted for a similar operation; but in this case instead of relying upon the electrical characteristics of a mechanically unchanged circuit, a shunt or shunts 42 are mechanically opened or allowed to close by the relays 41j. In this case, as in the other cases, the lamps at the illuminating stations or fixtures 19 may be either directly connected into the circuit or through an IL transformer, as already discussed above in connection with the other figures.

Although, in Fig. 10, I have divided the circuit into three banks and in Fig. 9 into only two banks, it will be understood that these are only exemplary and that a given circuit may be divided into as many groups of lamps as may be convenient with the particular circuit. The extreme case, of course, is illustrated by Figs. 3 to 8 in which each lamp is provided with separate means for shunting the circuit around the lamp so long as it remains inoperative.

Although I have described this arrangement particularly in connection with high pressure vapor lamps it should be understood that the arrangements discussed above for reducing the total voltage required for starting the series of lamps may be even more important with discharge lamps designed to operate at low pressures, e. g., because of the fact that their normal operating voltage is only a small fraction of the starting voltage.

Although I have shown in Fig. 10 a magnetic relay for shorting and subsequently breaking the short across successive portions of the circuit, these magnetic relays are, of course, merely representative of a large number of well known devices which can be used for this purpose including photo-electric devices and heat-responsive devices.

Moreover, although in this application I am particularly concerned with series circuits, both direct connected and IL, some of these devices herein described may be used also in multiple circuits (i. e., where the vapor lamp operates in series with a ballasting device from a constant potential source). Thus, for example, an incandescent lamp in parallel may burn with a red incandescence for color correction during normal operation, but burn with full brightness when the vapor lamp is extinguished. This action is more particularly described in my prior copending application Serial No. 115,685, filed December 14, 1936, or an incandescent lamp in series, e. g., as more fully described and claimed in my prior copending application, Serial No. 107,190, filed October 23, 1936, may be used as a ballast for the vapor lamp and when the vapor lamp is extinguished may nevertheless give light by virtue of the shunt connection. When both of these are combined, the series filament can be designed

to operate at maximum safe efficiency during the starting of the vapor lamp. At this time the parallel filament will be dark, because practically short circuited by the low voltage discharge of the vapor lamp. When the vapor lamp comes to normal operating voltage, the series lamp has less voltage and less current and will, therefore, be at dull incandescence or even dark, whereas, the parallel lamp receives the same high voltage as the vapor lamp and burns at a bright yellow incandescence, at which it gives the best color correction for the high pressure mercury vapor light and at which it also will have very long life. While the vapor lamp is cooling or inoperative for any other reason, the series filament carries only the current of the parallel filament and, therefore, operates at lower voltage, whereby a higher voltage is imposed in the parallel filament so that it burns at full brightness and efficiency with a white light. Thus, good light is assured at all times. If desired the series filament may be adjusted to increase and decrease its resistance at these various stages in order to keep it also at incandescence.

I have described these series circuits as operating from a constant current source because such is the common and accepted method of operating series lamps circuits. The use of a constant current source, however, is not essential to my invention and in fact in many respects such a circuit would be more suitable for operating of the discharge devices and especially high pressure vapor lamps if connected to a constant potential source of suitable high voltage current. If this is done the circuit would, of course, have to be ballasted, e. g., by using a reactance transformer as the source of the desired high voltage current or by using choke coils, reactance IL transformers or resistances, e. g., incandescent lamps in series with the discharge devices. A most advantageous arrangement is to use an insulation transformer circuit, as shown in Fig. 2, except for substitution of a high constant voltage source, with each transformer being designed with sufficient reactance to ballast its discharge device or devices. Such a circuit can be used, for example, on highway lighting where the lighting circuit can be tapped directly from high voltage transmission lines.

Such an arrangement not only eliminates the expensive transformer stations required for constant current circuits, but it makes practicable the use of single wire distribution circuits, one end of such circuit being connected to one wire of the transmission circuit, and the other end of the series lighting circuit being connected to the other wire of the high tension transmission circuit a mile or so farther down the highway at the end of the section of lamps which are fed thereby. Both the use of the single wire and the high voltage result in considerable savings of initial cost.

The present application is a continuation-in-part of my prior applications Serial Nos. 558,148, filed August 19, 1931; 714,949, filed March 10, 1934, and now U. S. Patent No. 2,265,323, Dec. 9, 1941; 744,206, filed September 15, 1934, and now U. S. Patent No. 2,252,474, Aug. 12, 1941; 51,390, filed November 25, 1935; 115,685, filed December 14, 1936, and now U. S. Patent No. 2,205,000, June 18, 1940, and 124,183, filed February 5, 1937.

What I claim is:

1. An illuminating device which comprises a current source, a plurality of high pressure vapor lamps connected in series and a constant cur-

rent transformer which maintains a constant current output through a limited voltage range and adapted to adjust itself to impose upon the circuit when no current is flowing a voltage higher than the sum of the break-down voltages of all the lamps in the series when cold, and to reach the limit of its constant current range above the minimum voltage resulting from starting of the discharge in the vapor lamps, whereby to provide an overload current for rapid vaporization in the vapor lamps.

2. An illuminating device as defined in claim 1, in which the circuit also includes a plurality of incandescent resistance lamps connected into the series circuit each near a vapor lamp whereby both illuminate a common area and whereby the incandescent lamp is overloaded to give relatively high illumination during the initial vaporizing period when the light output of the vapor lamp is low.

3. An illuminating device which comprises a constant current source, a plurality of lamps connected in series to said source, some of said lamps being high pressure vapor lamps and a part being incandescent resistance lamps, the total resistance of the incandescent lamps being sufficient to protect the constant current source against injury due to the drop in voltage of the vapor lamps before the voltage is raised by vaporization, and the ratio of the maximum voltage of the constant current source available for starting the lamps to the normal operating voltage thereof being less than the ratio of the starting voltage of the vapor lamps when at the coldest temperatures to which they may be subjected in use to the normal operating voltage thereof.

4. An illuminating device which comprises a constant current source, a plurality of lamps connected in series to said source, some of said lamps being high pressure mercury vapor lamps and a part being incandescent resistance lamps, the total resistance of the incandescent lamps being sufficient to protect the constant current source against injury due to the drop in voltage of the vapor lamps before the voltage is raised by vaporization, and the ratio of the maximum voltage of the constant current source available for starting the lamps to the normal operating voltage thereof being less than the ratio of the starting voltage of the vapor lamps when at the coldest temperatures to which they may be subjected in use to the normal operating voltage thereof, and at least a part of the incandescent lamps are arranged near the mercury vapor lamps to radiate respectively to a common area whereby each corrects deficiencies in the light of the other.

5. An illuminating device comprising a high pressure vapor lamp, a constant current circuit for energizing said lamp, and means for increasing the heating of said lamp during the initial period of low voltage operation, in which the means for increasing the heating is an impedance heater connected thereto for simultaneous operation and positioned in heat exchange relation thereto.

6. An illuminating device comprising a high pressure vapor lamp, a circuit which maintains a constant current output through a limited voltage range for energizing said lamp, and means for increasing the current loading of said lamp during the initial period of low voltage operation, in which the means for increasing the current loading is an impedance connected in parallel therewith and adapted during normal operation

to draw a current of the same order of magnitude as that of the vapor lamp.

7. A lighting circuit comprising a constant current source and a plurality of vapor discharge lamps having a supply of vaporizable material adapted by increase of vapor pressure to raise the restarting voltage above that which is available to the lamp in said circuit, impedance connections in parallel with said vapor discharge lamps respectively and each having an operating voltage on said constant current greater than the normal starting voltage of its vapor discharge lamp when cold.

8. A lighting circuit comprising a constant current source and a plurality of vapor discharge lamps having a supply of vaporizable material adapted by increase of vapor pressure to raise the restarting voltage above that which is available to the lamp in said circuit, incandescent filament lamps in parallel with said vapor discharge lamps respectively and having an operating voltage on said constant current greater than the normal starting voltage of the vapor discharge lamp when cold.

9. A lighting circuit comprising a constant current source and a plurality of vapor discharge lamps having a supply of vaporizable material

adapted by increase of vapor pressure to raise the starting voltage above that which is available to the lamp in said circuit, impedance connections in parallel with said vapor discharge lamps respectively, and each having an operating voltage on said constant current greater than the normal starting voltage of its vapor discharge lamp when cold, in which the discharge device is a high pressure type lamp provided with a vaporizable filling material adapted to increase the pressure in the lamp during operation to a value at which break down would not occur on the voltage available to the lamp in the circuit, and the impedance shunt is through an incandescent lamp, the voltage drop of which when carrying the entire current of the circuit is greater than the break down voltage of the discharge lamp when cooled, whereby the discharge lamp may start as soon as it has cooled, notwithstanding temporary substitution by the filament lamp in parallel therewith, and the amount of vaporizable material being adapted to increase the operating voltage of the discharge lamp after it is started to a value at which the incandescent lamp is lighted.

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