June 20, 1944. C. P. BOUCHER ET AL 2,351,914

LUMINESCENT TUBE SYSTEM AND APPARATUS

Filed July 14, 1941

Fig. 2.

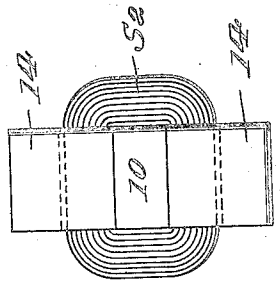


Fig. 1.

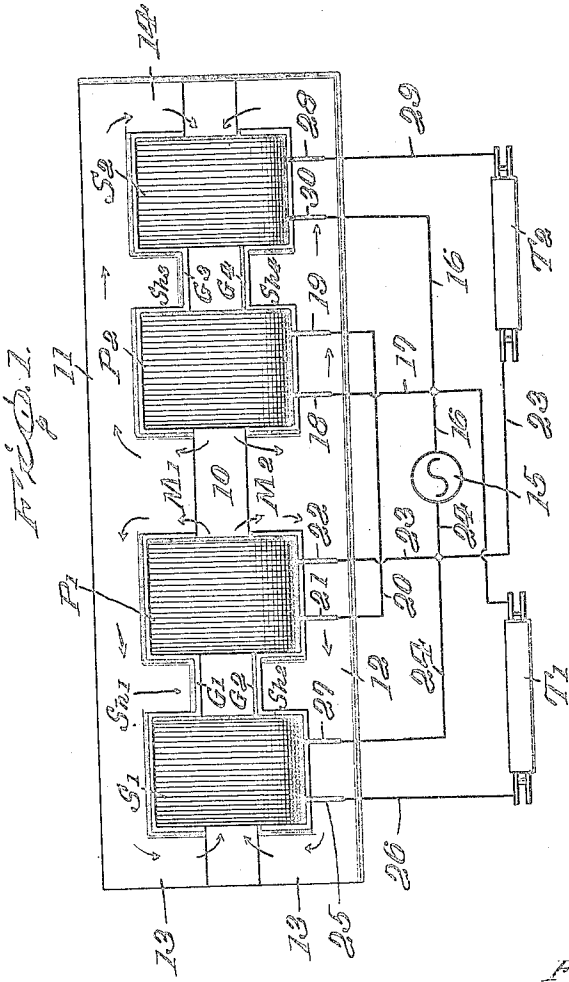
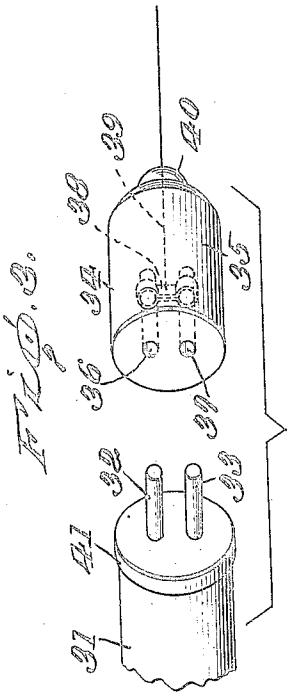


Fig. 3.



INVENTORS
Charles P. Boucher and
Frederick A. Kufel
By
John Howard Jaquet
THEIR ATTORNEY

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LUMINESCENT TUBE SYSTEM AND APPARATUS

Charles Philippe Boucher, Paterson, and Frederick August Kuhl, Ridgewood, N. J., assignors to Boucher Inventions, Ltd., Washington, D. C., a corporation of Delaware

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5 Claims. (Cl. 315—257)

Our invention relates to fluorescent tube lighting, and more particularly concerns a method and manner of operating the present-day hot cathode fluorescent gas discharge tubes, which are now widely available on the market, on cold cathode operation.

The advantages which are attendant upon the operation of fluorescent gas discharge tubes on cold-cathode operation, with energy provided by high leakage reactance transformers which automatically provide the voltages required for satisfactory operation, including both the required high starting voltage and the lower operating voltage necessary once the arc is struck, have already been touched upon in our two co-pending applications, Serial No. 402,410, filed July 14, 1941, and Serial No. 402,411, filed July 14, 1941, and now Patent No. 2,317,844, granted April 27, 1943. Only casual mention is made there, however, as to the feasibility of the satisfactory use in such cold systems of tubes which are readily available on the market but which are initially designed for hot-cathode operation, and the consequent achievement of material saving in initial investment. No manner of connecting nor mode or operating the hot-cathode tubes is described in either said application.

An important object of our invention, therefore, is to provide for the satisfactory employment of hot-cathode fluorescent gas discharge tubes on cold-cathode operation. Another object is to produce a socket for the reception of a hot-cathode fluorescent gas discharge tube in such manner that the tube will perform satisfactorily on cold-cathode operation. A still further object is to produce an electrical energizing system for the satisfactory employment of fluorescent gas discharge tubes on cold-cathode operation, whereby the tubes have a long life, are, quick starting, will both start readily and operate steadily under cold weather conditions, will function satisfactorily with dimmer operation, and which system involves a lighting unit characterized by its simplicity, compactness, low fixture cost, and low assembly and operating costs, and in which system filament-breakage where hot-cathode tubes are employed is a matter of no importance, and which is characterized by its sturdiness and reliability under all operating conditions.

Other objects and advantages in part will be obvious and in part pointed out hereinafter.

Our invention accordingly resides in the several elements, features of construction, and operational steps, and in the combination of each of the same with one or more of the others, all as pointed out hereinafter, and the scope of the application of which is set forth in the appended claims.

In the drawing,

Figures 1 and 2 are front and side elevations, respectively, of a high leakage reactance autotransformer which can be employed in connection with our new system.

Figure 3 is an exploded perspective view showing one form of socket which may be employed according to our invention, as well as the manner in which the same is associated with the terminals of a typical hot-cathode fluorescent gas discharge tube which can now be readily purchased on the market.

As conducive to a more thorough understanding of our invention, we may say at this time that the use of fluorescent gas discharge tube lighting has sprung into considerable prominence during the last few years in various industrial and commercial fields, as well as in household lighting. Such fluorescent tube lighting in fact shows evidence of substantially replacing the more conventional incandescent filament lighting in many fields of illumination.

Many reasons may be marshaled for this somewhat phenomenonal success of fluorescent lighting. Among the more important of these may be listed the high luminous efficiency of fluorescent tubes, whereby they produce the same or even greater light output than do incandescent bulbs, for a materially decreased wattage input. Additionally, the fluorescent tubes are readily adapted to the direct emission of light possessing desired spectral composition over a wide range of the visible spectrum. The tubes employed in such fluorescent lighting systems are found to have a useful life far in excess of that of known incandescent bulbs, and this longevity, coupled with low operating costs, makes the use of such lighting highly attractive from a purely economic standpoint. Such tube lighting is found to be admirably adapted to either indoor or outdoor floodlighting, and is of particular value, for example, in afterdark illumination in factories and the like. Because of the much greater conversion of the energy input into visible light, and because of the greater light-emitting surface of such tubes, as compared to incandescent light bulbs, fluorescent tubes are found to operate at much cooler temperatures, and such heat as is emitted, consisting in but small part of radiant heat, can more readily be accommodated by persons in the neighborhood of such tubes. Addi-

tionally, many other important reasons can be advanced, explaining the deserved popularity of fluorescent light systems.

We may with safety venture the prediction that as soon as certain technical problems now inherent in such fluorescent tubes have been solved, they will have a useful life several times that of incandescent bulbs, nevertheless their life span is very sharply limited to between 2000 and 2500 hours service under normal operation. If the tubes be operated under extreme conditions, such as continuously cold weather, or frequent starting and stopping, this life period is materially decreased. The presence of the oxide-coated filamentary cathode relied upon in the operation of such tubes to provide the electron emission necessary to prepare such tubes to support the arc discharge, and for aiding in the maintenance of the arc once it is struck, represents a source of weakness. As the tube ages, the electron-emitting properties of the coating diminishes, and the coating tends to volatilize off, or to chip off under ionic bombardment. Both starting and maintenance of the arc discharge at prevailing voltages becomes increasingly difficult, and the arc becomes unstable in its characteristics. Blackening of the tube in the region of the electrodes is found to occur, due to the depositing thereon of the coating material volatilized from the cathodes.

Although the preliminary heating of the filamentary cathodes prepares the arc discharge path for striking an arc thereacross at comparatively low potential gradient between the electrodes, with consequent comparatively high power-factor and minimum sputtering of the cathode metal, it is apparent that once the arc strikes, the arc tends to follow the path of the maximum ionization and to settle on the hottest point of the filament. Since sputtering inevitably follows that phenomenon, the filament becomes thinner at this point, increasing in resistance. Because of the potential drop in the region of the filament, therefore, this point of weakness becomes the hottest point along the cathode. Repeated settling of the arc thereon eventually causes failure of the filament at that point. This of course ends the useful life of a tube where used on hot cathode operation. These filamentary cathodes are formed of small diameter tungsten wire, and consequently are somewhat fragile. Although the tungsten metal possesses strong molecular cohesion at high temperatures, the positive ionization bombardment which takes place during arc discharge is such that after about 2500 hours of operation, the filament wire is broken through and the lamp becomes normally inoperative. An important object of our invention therefore is to remove in large measure the difficulties and disadvantages set forth in the foregoing, and to produce a system for operating known fluorescent gas discharge tubes on cold-cathode operation, in which the tubes have stable operating characteristics over a useful life span substantially in excess of that hitherto possible of achievement.

One of the few disadvantages of the present-day fluorescent lighting as compared to the conventional incandescent filament bulbs, is that while the filamentary bulbs emit useful light as soon as they are energized, it requires at a minimum, some 6 or 7 seconds in which to strike an arc across hot cathode tubes in fluorescent lighting systems. This represents an appreciable time lag, and in many installations and uses is found to be a highly objectionable source of annoyance. Further, because such hot-cathode tubes as are currently in use are designed to operate on low voltage input, it is impossible to reduce the impressed voltage to any material extent or to start or operate the tubes satisfactorily on what may be termed dimmer operation

A further object of our invention, therefore, is to produce a system of operating hot-cathode tubes on cold-cathode operation in such manner that they have extremely satisfactory starting characteristics and are susceptible to satisfactory performance under dimmer operation, and in which system the occurrence of a broken filament in the fluorescent tube interposes no problem. A still further important object of our invention is to produce a fluorescent light system employing in satisfactory cold-cathode operation, the known hot-cathode tubes readily available on the market, and in which system, the size and physical shape of the electrodes of the tube are unimportant, and which is characterized by the small number of parts in the electrical unit comprising the tube energy transforming means, wiring and reflector.

Referring now more specifically to Figures 1 and 2, wherein is disclosed a preferred embodiment of our invention, the system which we employ consists basically of a high leakage reactance transformer, a source of energy for said transformer, tubes operated by the transformer, and sockets for receiving said tubes.

The transformer may be either the autotransformer or regular type, i. e., in which the primary and secondary coils are electrically independent of each other. In the instance under discussion and purely for purposes of illustration, we elect to show and describe the construction and use of an autotransformer. Additionally, the transformer may optionally be of either the single or double secondary type. Again for illustrative purposes, we disclose and describe a transformer having double secondary circuits with a tube operated in each secondary circuit. The essential feature of this portion of our invention is that the transformer be of the high leakage reactance type, so that no additional auxiliary will be required in the lamp unit referred to hereinbefore.

With this preliminary explanation, it will be seen that the transformer core is comprised of a longitudinally extending central leg **10**, and outer legs **11** and **12** extending in parallel, spaced relation to said central leg, one on each side thereof. These legs preferably have the same length and are closed on each other at their ends and adjacent their mid-points by end pieces **13**, **13** and **14**, **14** and mid-core portions M1M2, respectively, extending from said outer legs to said central leg.

The mid-core portions M1M2 together with that portion of central leg disposed therebetween, divide the core into two groups of parallel metallic magnetic paths. In the first group of parallel magnetic paths a first path may be traced from the middle of central leg **10** through mid-core portion M1, to the left in Figure 1 along leg **11**, down first end piece **13**, to the right across central leg **10**, back to M1. In the same group, a second parallel path is traced from M2 to the left along leg **12**, up core portion **13**, and across central leg **10**, back to M2. Similarly, in the second group, a first magnetic path may be traced from central leg **10**, up through core portion M1, to the right along leg **11**, down

first end piece 14, across central leg 10, back to M1. In the same group of second parallel magnetic path is traced from M2 to the right along leg 12, up through core portion 14, across leg 10 to M2.

In each group of parallel magnetic paths, a pair of spaces is formed between the outer legs, end pieces, mid core portions and the central core portion. Each pair of spaces is disposed, one on each side of central leg 10.

Paired primary and secondary coils P1, S1 and P2, S2, respectively, are disposed one pair in each group of parallel magnetic paths. The coils are disposed in said spaces, and are positioned around said central leg, with the primary coils on opposite sides of and adjacent the common leg.

Pairs of intermediate high leakage reactance magnetic shunts extend from outer legs 11, 12 between each pair of primary and secondary coils, toward but short of said central leg 10, forming air-gaps therebetween of high reluctance calibrated according to the particular load for which the transformer is designed. The purpose of these shunts will be described hereinafter. Thus shunts Sh1 and Sh2 extend between primary coils P1, S1, from outer legs 11, 12, respectively, towards but short of central leg 10, providing therebetween respective air-gaps G1, G2. In like manner, shunts Sh3, Sh4 extend between primary and secondary coils P2, S2 from outer legs 11, 12, respectively, towards but short of central leg 10. Air-gaps G3, G4 are thus formed between shunts and central leg 10.

While as stated, our present invention includes the use of but a single primary coil, where desired, we here disclose the use of two primary coils. These primary coils may be connected across a source 15 of alternating-current electrical energy in either series or parallel connection, and in either adding relation, or opposed or bucking relationship. Where the primary coils are series-connected the primary voltage, assuming symmetrically-constructed coils, drops in equal steps through the two coils, so that the potential drop across each coil is but half of the total primary voltage. Thus for a given number of turns of wire in the secondary coils, parallel-connected primary coils must contain twice as many turns as series-connected primaries, so that the volt per turn will be the same in either hook-up.

In the illustrative embodiment under discussion, we elect to connect the primary coil in series-connection across the source of primary energy. Bucking relationship of the primary coils may result in slightly higher efficiency inasmuch as when the electrical load across one secondary coil increases, there will occur with opposed relationship of the primary coils a shift in the primary flux from one parallel magnetic path to the other with attendant increase in the voltage induced in the other secondary coil. In the instance under discussion, we elect to connect the primary coils in opposed relationship.

With the following in mind, let us assume that the current for the given half-cycle under discussion is flowing to the right from source 15. Then a primary charging current may be traced through leads 16 and 17 to terminal 18, thence to the right through primary coil P2, terminal 19, lead 20, to terminal 21 thence to the right through primary coil P1, terminal 22, and through leads 23, 24 back to the left side of the source 15. Of course, during the next alternate half-cycle of current flow, the direction of the flow of the charging current through the primary circuit will be exactly opposite that just traced. The directions in which the primary coils P1 and P2 are wound are opposed to each other, to give rise to the bucking relationship referred to.

We have already suggested that it is within the compass of our invention to employ a transformer having but a single secondary coil, energizing but a single fluorescent tube. Illustratively, however, we here employ a transformer having two secondary coils, each operating in separate circuit a fluorescent gas discharge tube. We have also suggested hereinbefore that we can employ our transformer in either regular or autotransformer connection. Again for illustrative purposes we have elected to illustrate and describe an autotransformer connection for voltages within the range of which the use of autotransformers is permitted by the fire underwriters, and which range includes the operating potentials of practically all known hot-cathode fluorescent tube equipment. The use of autotransformer connections gives rise to certain advantages in low first cost and compactness of equipment.

Inasmuch as the primary coils are series-connected across source 15, and since the primary and secondary coils are autotransformer-connected, we take advantage of this situation to increase the terminal voltage induced across the secondary circuits to values substantially the same as those which would maintain were the primary coils parallel-connected, by series-connecting each secondary coil with both primary coils.

Accordingly, each secondary coil is connected in series, first with that primary coil positioned in the opposite magnetic path, and then with the primary coil in its own magnetic path. Thus, a secondary circuit may be traced from secondary coil S1 through terminal 25, lead 26, through fluorescent gas discharge tube T1, and lead 17 to terminal 18 of primary coil P2, thence to the right through said primary coil, through terminal 19 thereof to lead 20, thence to terminal 21, to the right through primary coil P1, down through terminal 22, leads 23 and 24, to terminal 27 and back to the left through secondary coil S1, to the starting point. Similarly, a circuit may be traced from the secondary coil S2, from terminal 28 thereof down through lead 29 to fluorescent gas discharge tube T2, then through lead 23 and terminal 22 to primary coil P1 in the opposite magnetic circuit, to the left through said primary coil, across terminal 21, lead 20 and terminal 19 to primary coil P2 in the same magnetic circuit, then to the left through that primary coil, and through terminal 18 and leads 17 and 16 to terminal 30 and thence to the right through secondary coil S2 to the starting point. It will be seen that each secondary coil contains a corresponding fluorescent gas discharge tube in circuit therewith and that additionally, each secondary coil is in series, first with the opposite primary coil and then with its adjacent primary coil. During the next subsequent half-cycle the direction of current flows through the two circuits of course would be the reverse of that just described.

The tubes T1, T2 are each of the hot-cathode type, having filamentary electrodes led out to pairs of exteriorly extending terminals, which terminals are short-circuited for our desired cold-cathode operation. The tubes are lined with suit-

able fluorescent salts, to give rise to the desired secondary visible radiation.

While it is not necessary, we prefer to design the two tubes of the same electrical characteristics. By such construction it is possible for the electrical constants of the several primary and secondary coils, respectively, to be the same, as is also true of the two parallel magnetic paths.

It will be interesting at this point to trace the passage of the primary magnetic flux through the two parallel magnetic paths for an assumed half-cycle of charging current flow. Let us assume that the direction of charging current is such that the primary flux courses in the directions of the arrows shown in Figure 1. Then the primary flux from coil P1 courses to the right along central leg 10. At the common magnetic leg comprised of mid core oprtions M1, M2 and central leg 10, the primary flux from coil P1 encounters and is bucked by flux from primary coil P2 tending to flow along central leg 10 in the opposite direction.

Choosing the paths of least reluctance, and splitting into two approximately equal streams because of the symmetry of the parts of the parallel magnetic paths under discussion, one stream passes up core portion M1, and courses to the left along leg 11. Choosing the path of least reluctance, practically all of this primary flux avoids shunt Sh1, and continuing to the left along leg 11, courses down end piece 13 to leg 10 at the left of secondary coil S1.

At the same time the other stream of flux courses down core portion M2 and passes to the left along leg 12, and up through end piece 13 to central leg 10. The two streams of flux there re-uniting, the combined stream courses along central leg 10, across and interlinking secondary coil S1, back to primary coil P1. A high voltage is induced in secondary coil S1, which is under open-circuit conditions because the arc is not yet struck across tube T1, so that no back magnetomotive force is developed by this coil.

At the same time, primary flux from primary coil P2 courses the second group of parallel magnetic paths in the following manner: The flux courses along leg 10 to the left of coil P1. In the mid core legs which are in common to the two groups of parallel magnetic paths the stream of flux bucks the primary flux from coil P1, and splitting into two streams which are substantially equal because of the symmetry of the paths comprising this magnetic path, one stream courses upward through core portion M1 and to the right along leg 11. Choosing the path of least reluctance, by far the larger part of this stream of flux avoids shunt Sh3 and courses down end piece 14 to central leg 10. At the same time the second stream of flux courses down through core portion M2, to the right along leg 12, and up leg 14 to central leg 10. The two streams of flux there re-uniting, the combined stream courses along leg 10 back to primary coil P2, and interlinking the secondary coil S2, induces therein a potential of high value. Since the arc across the tube in circuit with this coil is not yet struck, the coil has open circuit, so that no back magnetomotive force is developed therein.

During the next half-cycle of primary current flow, the direction of coursing of the primary flux is opposite of that described. For example, the flux from primary coil P1 courses to the left along leg 10, interlinking secondary coil S1 and inducing a high secondary voltage therein. Splitting into two substantial equal streams, one stream course upwardly opposite the arrows through end piece 13, to the right along leg 11, down core portion M1, to leg 10. The other stream courses down end piece 13, to the right along leg 12, and up core portion M2. The two streams re-uniting at central leg 10, the combined stream courses back to primary coil P1. Similarly, the primary flux from coil P2 courses the second group of magnetic paths to the right along leg 10, interlinking secondary coil S2 and inducing high secondary voltage therein. The flux splitting into two substantially equal streams, one stream courses upwardly through end piece 14, to the left along leg 11, and down through core portion M1. The other stream continues down through end piece 14, to the left along leg 12, and up through core portion M2. The two streams of flux reunite at leg 10 and course back to primary coil P2.

As stated at an earlier point herein, we prefer to design the transformer, where double secondary circuits are provided for, to operate with secondary loads of the same electrical characteristics. While this is preferable, from the standpoint of manufacturing simplicity and hence low first cost, it is not essential, and where it is desired to handle asymmetrical loads, this involves simply a question of proper design of the intermediate shunts, the selection of the proper wire sizes, etc., to achieve highest efficiency.

Even though the tubes T1, T2 are selected as supposedly having the same electrical characteristics, however, it almost invariably proves that the impedance of one tube-containing secondary circuit is slightly less than that of the other secondary circuit. Accordingly, after the passage of but a comparatively few current cycles, the high potential secondary current impressed across the terminals of the tube excites the gas molecules therein to a condition where they are ready to support an arc discharge. The arc immediately strikes, whereupon a back magnetomotive force is induced in the corresponding secondary coil. This induces a secondary flux which opposes the coursing of the primary flux.

Let us assume that it is the tube T2, which forming part of the secondary circuit of lower impedance, strikes first. Secondary flux developed in secondary coil S2 opposes the interlinking of primary flux therethrough. The primary flux from coil P2 therefore seeks the paths of least reluctance. The design of the transformer core with respect to its associated windings, i. e. the proper design of the intermediate shunts, is such that as soon as the load across the secondary coil increases, only sufficient primary flux continues to interlink the corresponding secondary coil as is necessary to induce therein a voltage sufficient to energize the increased secondary load. Inasmuch as the shunts Sh3, Sh4 and their associated air-gaps G3, G4 now have a reluctance which is less than that of the path through secondary coil S2, some part of the primary flux from primary coil P2 is shunted through these elements and courses back to the primary coil.

When an arc strikes across tube T2, appreciable current flow takes place, which courses not only through the secondary coil S2, but as well through the primary coils P1 and P2 electrically connected thereto. This means that increased flux is developed at such times by these primary coils, inasmuch as the flux development is a function of the ampere-turns. This greatly increased stream of primary flux induces a sec-

ondary potential in coil S1 of such high value that the arc across tube T1 strikes almost immediately. Promptly, then, a secondary flux is developed in coil S1, opposing the flow of the primary flux.

Steady operating conditions now maintain, and the shunts Sh1—Sh4 and associated air-gaps G1—G4 are designed to permit just enough primary flux to interlink the secondary coils S1 and S2 to induce therein the voltages required to maintain the arc discharge across tubes T1, T2. It is of course to be understood that less voltage is required to maintain the arc discharge than is needed to strike the arc.

The primary flux may now be traced as follows, assuming the charging current half-cycle to be such that the flux courses generally in the direction of the arrows. From coil P1 the flux splits into two equal streams. One stream courses up along mid core portion M1, to the left along leg 11, and a small measured proportion passes along, down first end piece 13 and back along leg 10 to primary coil P1, interlinking secondary coil S1 as it goes. The major part, however, choosing the path of least reluctance, passes down through shunt Sh1 and across air-gap G1, back to primary coil P1, completely by-passing secondary coil S1. As to this part of the flux the only energy losses are represented in the primary coil energizing current. The other stream courses down through mid core portion M2, to the left along leg 12, and a small quantity of the flux courses up second end piece 13 and back along central leg 10 to primary coil P1, interlinking secondary coil S1. It is these interlinking flux streams which induce in the secondary coil S1, the potential required to maintain the arc discharge across tube T1. The greater part of the flux, however, courses up through shunt Sh2, across air-gaps G2, and back to the primary coil P1, completely by-passing secondary coil S1.

During the next alternate half-cycle of charging current, of course, the direction of coursing of flux is exactly the reverse of that described.

At that time flux will course to the left from primary coil P1, along leg 10. The required small quantity will continue along leg 10, interlinking secondary coil S1, and splitting, part will course up first end piece 13, to the right along leg 11, down core portion M1, and back to primary coil P1. Simultaneously, the other stream will flow down second end piece 13, to the right along leg 12, and up through core portion M2 to primary coil P1. The major part of the flux, however, before it reaches coil S1, splits into two equal streams, one of which courses up across air-gap G1, through shunt Sh1, to the right along leg 11, and down through mid core portion M1, back to primary coil P1. The other stream courses down across air-gap G2, through shunt Sh2, to the right along leg 12, and up mid core portion M2, to primary coil P1.

Similarly, during the first-mentioned charging half-cycle, primary flux courses to the left along leg 10 from primary coil P2. Bucking the primary flux from coil P1, in the leg common to the two parallel magnetic paths, part of the flux courses upwardly through mid core portion M1, to the right along leg 11, and a small quantity continues down through first end piece 14, and to the left along leg 10, back to the primary coil P2, interlinking secondary coil S2 during its passage. The greater part of this stream of flux, however, courses down through shunt Sh3, and across air-gap G3, back to central leg 10 and coil P2, completely by-passing coil S2. At the same time the second stream of flux courses down through core portion M2 to the right along leg 12, and a small part continues up through second end piece 14, to central leg 10, and back to the left therealong to coil P2, interlinking secondary coil S2, during its passage. It is these two bodies of flux which serve to energize secondary coil S2 during normal operation of the tube T2. The larger part of this stream, however, courses up through shunt Sh4, across air-gap G4, and back to primary coil P2, completely shunting coil S2.

During the next alternate half-cycle of charging current flow, the paths of the stream of primary flux are the reverse of those traced, in a manner similar to that already described herein with reference to the first parallel magnetic path.

While we may employ a fluorescent gas discharge tube designed especially for cold-cathode operation and in which the incandescible filaments are omitted, and in which but a single terminal is led out of the tube at each electrode, these tubes are not available on the market, and can be obtained only at considerable expense, on special order. On the other hand the known hot-cathode type of fluorescent tube, having one or more filamentary electrodes, each with a pair of terminals projecting exteriorly of the tube, are readily available on the market, at comparatively low cost.

Accordingly, we have evolved an ingenious method of operating these known hot-cathode tubes on cold-cathode operation, which will now be elaborated upon, having reference to Figure 3. Here the tube consisis of a glass cylinder 31 interiorly lined with a suitable fluorescent salt. Filamentary-electrodes, not shown, are disposed one at each end of the tube, and these electrodes are each connected at their ends to a pair of terminals 32, 33 which extend exteriorly through a base 41. This base, usually of metal, may be formed of suitable plastic, hard rubber, or the like.

The socket for receiving these terminals may follow any one of a variety of possible constructional embodiments. The essential point to be realized, however, is the short-circuiting of these filaments.

To illustrate, the socket may be somewhat of the bayonet type, in which the lamp terminals and base are inserted into the socket and are locked in place by a slight rotary twist. The socket in such case is designed to short-circuit the terminals of the lamp. The design may be such that at the same time, a connection of the primary coil across the source of energy is established. This last feature is developed in our copending application Serial No. 402,413 filed July 14, 1941, and will not be enlarged upon here. A special jumper may be designed for dropping into the base of the ordinary socket, and is held in place, short-circuiting the tube terminals, by the base of the tube when the latter is positioned in the socket.

For purposes of illustration, however, we disclose a socket indicated generally at 34 and comprising a shell 35 of metal or suitable plastic. Within this shell and disposed in insulated relation thereto are metallic conduits 36, 37 for receiving the prongs 32, 33, respectively, of the tube 31. A metal jumper 38 is disposed within the shell, electrically connecting together the conduits 36, 37, and thereby short-circuiting them. A lead 39 to the associated secondary coil extends

from the unit consisting of the two conduits and the jumper to the exterior through a cap 40 on the shell 35. In this manner the unit consisting of the prongs 32, 33 and the filamentary electrodes are electrically connected together and form a single electrode. The base 41 of the tube may consist either of metal or suitable plastic, just as the tube is found on the market. Since, however, this base is insulated from the prongs 32, 33, the question of whether it is formed of metal or of a plastic is a matter of but small moment. Short-circuiting the terminals adapts the tube for cold-cathode operation, and permits obtaining the manifold advantages referred to hereinbefore.

It will be readily appreciated that the invention described herein gives rise to many practical advantages not hitherto possible of achievement with the equipment at hand. Our invention makes it possible to adapt tubes already available on the market for service in our new electrical system, with increased tube life, much quicker starting characteristics, and with highly stable arc discharge, even with prevailing cold weather.

The new system, employing hot-cathode tubes for cold-cathode operation according to the teachings of this application, is materially simplified as contrasted with known tube lighting systems. Complicated and fragile auxiliaries such as starter switches, starter circuits, starting compensators, and simple ballasts are avoided, with attendant simplification of the lighting unit, decrease in assembly costs, and increase in sturdiness. We intentionally short-circuit the tube filament and take it out of participation as a filament in the operation of the tube. This failure of this filament has not effect on the operation of the tube itself.

Further to demonstrate the material simplification which may be achieved by the employment of our new system using hot-cathode tubes on cold-cathode operations is the fact that the transformer and any power-factor regulating condenser which we may elect to use can be mounted, as one single unit, directly upon the reflector which houses the tubes.

We find that, especially under steady operating conditions, the tubes employed in accordance with our present teachings, give a much larger saving in power demand in the tubes, for the same light output. For example, we find that under similar conditions, and with the same brilliance in light output, our system requires only 380 milliamperes, whereas the known hot-cathode tube systems require 420 milliamperes.

We claim:

1. In a fluorescent gas discharge tube lighting system, the combination of a standard hot-cathode fluorescent gas discharge tube having incandescible filamentary electrodes spaced apart from each other, and having pairs of terminals for each said electrode extending therefrom; and a cooperating socket receiving each pair of terminals and presenting shunt means thereacross, thereby adapting the tube for initial cold-cathode operation.

2. In a fluorescent gas discharge tube lighting system, the combination of a hot-cathode fluorescent gas discharge tube having incandescible filamentary electrodes spaced apart from each other, and having pairs of terminals for each said electrode extending therefrom; means for energizing said tube at a potential substantially exceeding the hot-cathode potential; and two sockets connected therewith receiving said pairs of terminals and containing means for short-circuiting the same thereby converting both the filament terminals and the filament cooperating therewith into a single terminal and adapting the tube for cold-cathode operation.

3. A fluorescent gas discharge tube lighting system, comprising two hot-cathode fluorescent gas discharge tubes, each having two spaced filamentary electrodes, and a pair of terminals for each electrode extending therefrom; and a high leakage reactance transformer having a primary coil and two secondary coils capable of impressing across the electrodes of said tubes a potential substantially in excess of that for hot-tube operation to give satisfactory cold-cathode operation; and two pairs of shunt sockets connected with the transformer secondary coils and receiving the electrode terminals of said tubes and short-circuiting the same, thus adapting the tubes for cold-cathode operation.

4. An electrical system comprising a high leakage reactance transformer having a primary and a secondary coil therein and shunt means for by-passing a portion of the primary flux about the secondary coil when the load on the latter increases; a source of alternating-current electrical supply connected across said primary coil; a hot-cathode fluorescent gas discharge tube having filamentary electrodes spaced apart from each other and a pair of terminals for each said electrode extending through said tube and exteriorly thereof; and shunt sockets connected with said secondary coils, each socket receiving a pair of filament terminals and short-circuiting them, to adapt the tube for cold-cathode operation.

5. A fluorescent gas discharge tube lighting system comprising: two fluorescent gas discharge tubes of the hot-cathode type each having two spaced filamentary electrodes, and terminals extending therefrom corresponding in pairs to the electrodes; means impressing across the electrodes of said tubes a potential substantially exceeding the hot-cathode potential of the tubes and sufficient for instantaneous starting and cold-cathode operation; and means receiving and electrically short-circuiting the individual pairs of terminals externally of the tube, thus adapting the hot-cathode tubes for cold-cathode operation.

CHARLES PHILIPPE BOUCHER.
FREDERICK AUGUST KUHL.