May 26, 1942. H. E. SCHWANEGER 2,284,481

ELECTRIC LIGHTING METHOD AND APPARATUS

Filed Oct. 21, 1939

Fig. 1.

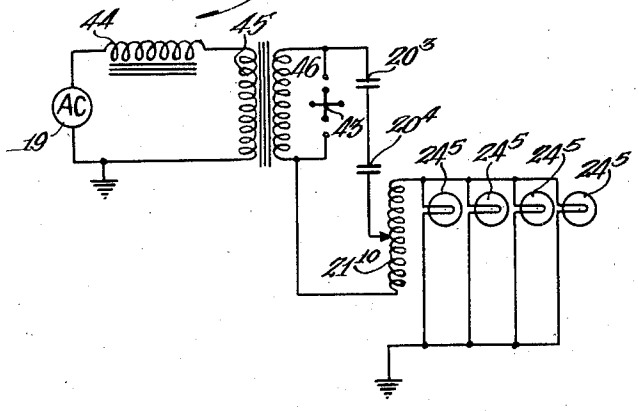


Fig. 2.

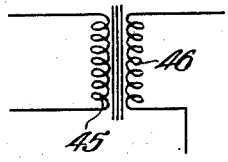
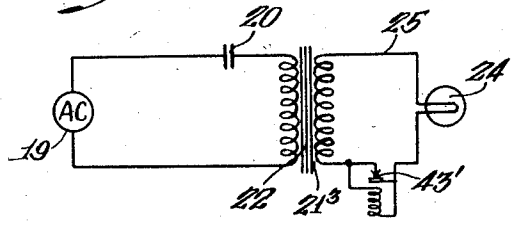


Fig. 3.



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ELECTRIC LIGHTING METHOD AND APPARATUS

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4 Claims. (Cl. 176—8)

The present invention relates to methods and apparatus for electric lighting by means of closed system electric illuminating lamps, such as incandescent lamps, glow lamps, and combined incandescent and glow lamps.

A further purpose is to prolong the lives of closed system lamps, such as incandescent and glow lamps.

A further purpose is to obtain increased intensity on an ordinary electric lamp of the closed system type for photography, theater lighting, street lighting, electric signs, or the like.

A further purpose is to operate closed system lamps, such as incandescent and glow lamps, from a low frequency commercial source on a combination of flow frequency fundamental or carrier wave and higher frequency superimposed harmonics, preferably in excess of one megacycle.

A further purpose is to utilize high frequency harmonics in alternating current incandescent and glow lighting to an extent not heretofore employed.

A further purpose is to operate a closed system illuminating lamp or bank of lamps, preferably an incandescent lamp or bank of lamps, in shunt across a reactance which is in series with an opposite reactance.

A further purpose is to operate a system consisting of a reactance and an opposite reactance in series, and having an illuminating lamp or lamps shunted across one of the reactances, in a condition of "off resonance" and with an excess in the circuit of inductive reactance where inductance is shunted by the lamp or lamps with respect to the condition of series resonance; or an insufficiency in the circuit of inductive reactance where capacity is shunted by the lamp or lamps with respect to the condition for series resonance. The circuit will ordinarily be sufficiently off resonance so that the power consumed is less than 75% of the power peak and most desirably between 30 and 75% of the power peak.

A further purpose is to obtain a given intensity of illumination from a closed system illuminating lamp with a lower current through the lamp measurable upon ordinary instruments, than would flow through the lamp to produce the same intensity of illumination if the lamp were directly connected to a commercial alternating current source. In other words, by the present invention it is possible to obtain a given lumen output with less low frequency energy consumption in the lamp itself using the system of the present invention than with direct lighting connection to the commercial source.

A further purpose is to light an incandescent lamp by a combination of higher frequency gas effect and filament heating.

A further purpose is to insert a current interrupter, such as a vibrator or crystal, locally in the load loop containing the lamp or lamps shunted across a reactance which is in turn in series with an opposite reactance.

Further purposes appear in the specification and in the claims.

Figure 1 is a circuit diagram, useful in explaining the invention.

Figures 2 and 3 are circuit diagrams of variant embodiments of the invention, Figure 2 being fragmentary.

In the drawing, like numerals refer to like parts.

The present invention is concerned with improving the operation of closed system illuminating lamps. This term is intended to include not only incandescent lamps which light by reason of the filament, but also glow lamps which operate by virtue of incandescence of a gas or vapor, such as mercury vapor, sodium vapor, cadmium vapor, zinc vapor, and neon, zenon, krypton, argon, and helium gases. These are designated as glow lamps whether there be substantial pressure or a high vacuum present in the lamps. The present invention is likewise applicable to combined incandescent and glow lamps, such as the nitrogen-filled incandescent lamp, or other inert-gas-filled incandescent lamp.

The present inventor has discovered that if the characteristics of the electrical energy passing through the lamp are altered somewhat, the efficiency of the lamp itself as a light generator may be increased (this may or may not mean that the over-all efficiency of the system will be increased, depending upon the losses in the reactors). Due to this increased efficiency, it is possible to obtain a given intensity of lighting with a lower current through the lamp as measured by the usual ammeter, than would flow through the lamp in producing the same illumination with the lamp directly connected across the line. Convenient change in the intensity of illumination can readily be made without overloading the lamp.

In order to obtain the novel effects of the present invention in the best manner known to me, the lamp (or bank of lamps whether series, parallel or series-parallel connected and whether single phase or multiphase) is placed in shunt

across reactance, preferably inductance, and the reactance is connected in series with opposite reactance, preferably capacity connected to an alternating current source suitably at 110 volts and 60 cycles or 25 cycles, although of course the frequency and voltage may be varied.

Advantage may be obtained by interrupting the circuit or inducing it to oscillate.

Figure 1 illustrates a circuit containing an interrupter **43**, suitably a rotary spark gap. Power is fed to the system through the choke coil **44** to the transformer **45** whose secondary **46** is connected across the gap **43**. The high or ungrounded side of the transformer secondary **46** is connected to series condensers 20^3 and 20^4 which connect to an intermediate tap on an inductor 21^{10}. The low side of the transformer secondary **46** is connected to one extremity of the inductor 21^{10} and the opposite extremity of the inductor is connected to a parallel arrangement of lamps 24^5, the other sides of the lamps being suitably grounded. The condensers 20^3 and 20^4 mutually discharge into one another, cooperating with the gap **43** to produce violent oscillations. When the circuit is adjusted as already described, very intense illumination occurs in the lamps in accordance with the principles referred to.

It will be observed that from an apparatus standpoint the capacitors 20^3 and inductor 21^{10} are connected as in series resonance with the alternating current source **19**, but, as will be later explained, the size of the capacity and inductance need not and ordinarily preferably will not conform to series resonance.

The capacitors 20^3 and 20^4 may be of any suitable type, either a paper, air, vapor, gas (high or low pressure), vacuum (high or low) or electrolytic condenser being suitable. The electrolytic and gas-vacuum condensers have been found to be the most economical and convenient.

The gap **43**, while desirable for extremely high illumination, may be omitted with its connections where less brilliancy is desired. This is shown fragmentarily in Figure 2 where the transformer secondary **46** is illustrated without the connection to the gap **43**.

In Figure 3 a mechanical interrupter or vibrator **43'** is shown, for example an automobile spark coil.

It has been found to be preferable to place the interrupter in the load loop, where it can break the load circuit.

Experiments with variations in the inductance for a given condenser and lamp indicate that as the inductance is increased, the power consumed by the system increases to a maximum, and that with further increase in inductance beyond the power peak a point of abnormally high illumination with lower power consummation is reached. It ordinarily occurs at a point at which the power is between 30% and 75% of the power peak. There is often a peak in voltage across the lamp which is attained between the power peak and the peak in illumination at lower power.

It will be understood that, while I do not base my present application upon the correctness of the theoretical explanation given, it would seem that the peculiar lighting effect obtained when the inductance in the circuit over-balances the capacity sufficiently to carry the system beyond the voltage peak, is due to a fundamental change in the wave characteristics.

It appears that one of the effects of the invention is to superimpose higher frequency harmonics on a low frequency sine curve and that the high frequency harmonics are useful in illumination.

Experiments thus far conducted indicate that it is easier to obtain increased overall efficiency of the system as compared with the efficiency of the lamp directly connected across the line, when operating upon a glow lamp, than when operating upon an incandescent lamp. This difference, however, is evidently not inherent, but merely a function of the electrical vectors of the individual lamps tested.

In comparative tests, measuring the illumination in all cases at the same distance from the lamp, the metallic filament lamp of reasonable wattage, when ordinarily lighted directly across the line, consumed about 0.5 watt per foot candle power. The ordinary glow lamp with its circuit directly connected across the line, consumed approximately 0.25 watt per foot candle power. In experiments made with the ordinary glow lamp circuit connected in the system of the present invention, the energy requirement was 0.1 watt per foot candle power.

It will of course be understood that the efficiency of the low wattage lamp is likely to be lower than the efficiency of the higher wattage lamp.

Additional confirmation of the fact that illuminating effects are produced by the harmonic power has been obtained by experiments conducted with neon lamps. When 4-cycle harmonics were artificially superimposed upon a 60-cycle alternating wave, intermittent glow in the lamp, superimposed upon the steady glow and in time with the harmonic frequency, could be observed. When upon the normal 60-cycle wave continuous harmonics at 5000 cycles were superimposed, the normal illumination of the neon tube was supplemented by greatly increased light intensity, and the supplemental light had a distinctive cherry red color.

It will be evident that the preferable operation of the device is obtained at a position distinctly off resonance, beyond the power peak of the system and beyond the voltage peak of the lamp. At this point the unusual light-giving qualities become evident as before explained. The efficiency of the lamp as a converter of energy into light is increased. In this aspect of the invention, the system may be regarded as one which would be series resonant but for the excessive magnitude of the inductance, with the lamp or lamps operating locally in shunt with the inductance.

Less desirably, the circuit for operation of the lamp may include the inductance and capacity in series but with the lamp shunting the capacity rather than the inductance. It will be understood that this transposition can be made in any of the circuits. With the system in which the lamp shunts the capacity, the adjustment will be the reverse of that described; namely, the capacity, instead of being more than sufficient for series resonance, will be insufficient for series resonance, and the system will be operated beyond in the negative direction (below) the power and voltage peaks.

Thus as a generalization, it may be stated that the reactance and opposite reactance are in series, the lamp shunting one of them, and the circuit being adjusted so that the one shunted includes the reactance proper to series resonance and algebraically added reactance of its own sign. Thus if inductive reactance is shunted,

the algebraically added reactance is positive and the inductive reactance will exceed the value for series resonance with the particular capacity at the particular frequency. If capacitative reactance is shunted, the algebraically added reactance is negative, and the capacitative reactance will be less than the value for series resonance with the particular inductance at the particular frequency, and overbalance the other reactance of the circuit.

Viewed in the light of resonance, the reactance is dimensioned to overcompensate, in the direction of the algebraic sign of the reactance (additively or positively in the case of a shunt of inductive reactance and subtractively (as the reciprocal) or negatively in the case of a shunt of capacitative reactance), for the opposite reactance during normal lamp operation with respect to the condition of series resonance.

Ordinarily heat is the intermediary by which light is produced in an electric lamp, the heat developed being equal to the resistance of the lamp multiplied by the square of the current. Where, however, extremely high frequencies are developed, it would appear that light is produced to some extent by the direct influence of the frequency on moving electrons without the intermediate step of generation of heat. In other words, it appears that part of the light produced in the present instance is due to direct action of the high frequency on electrons to produce waves within the light radiation range. Of course, in the present instance, the high frequency is superimposed upon a basic or carrier low frequency wave and the low frequency to the extent of its presence exerts its usual effect.

Calculations indicate that the peak frequency developed may be ascertained as follows:

$$\text{Peak frequency} = \frac{1}{2\pi fc} \text{ megacycles}$$

where f is the frequency of the low frequency source and c is the capacity of the condenser in farads. This equation is believed to hold only for the conditions of high light intensity beyond the power peak and voltage peak.

Attention is directed to the fact that in designing the reactance and the opposite reactance, the reactance shunted by the lamp is greater or less than its value for series resonance, depending upon whether its character is positive or negative, and produces a peak of light intensity, during normal operation of the lamp. Many systems for starting glow lamps employ series inductance and shunt capacity for starting the glow lamp and, after operation of the lamp has begun, either switch this equipment out of the circuit or render it inoperative. Such systems have either operated at resonance, or, if detuned, have had excess capacity, with the lamp shunting the capacity, a condition just opposite to that desired by the present inventor.

It will be recognized that, wherever the predetermined relation of the reactance and opposite reactance is referred to herein, this relation is intended with respect to the condition of equilibrium during operation of the lamp and not the starting condition.

For the shunt on the inductance, it will be evident that if there is too much inductance with respect to the condition of series resonance, series resonance might again be restored either by lowering the inductance or by lowering the capacity. When the circuit has reached its illumination peak beyond the power peak and the voltage peak of the system, there will be with respect to the condition of series resonance too much inductance and also too much capacity.

With the shunt on the inductance, the actual relation of the inductance and capacity for the illumination peak with respect to series resonance will depend to some extent upon the characteristics of the individual lamp. Excellent results have been obtained when there was approximately 2000 times as much inductance as proper for series resonance at the frequency of the low frequency peak source. With other lamps satisfactory operation has been obtained with 250 times as much inductance as proper for series resonance, and with 70 times as much capacity as proper for series resonance.

In ordinary cases it may be stated that for good results there should be at least 50 times as much inductance as required for series resonance, preferably more than 200 times and for best results more than 1000 times. Some advantage from the invention may however be obtained with as little as 5 times as much inductance as proper for series resonance.

Where the shunt is on the capacity instead of the inductance, excellent results are secured with the capacity $\frac{1}{2000}$ of that for series resonance. In such case, the capacity should be less than $\frac{1}{50}$ of that for series resonance, preferably less than $\frac{1}{200}$, and for best results less than $\frac{1}{1000}$; although some advantage is obtained with capacities less than $\frac{1}{5}$ that for series resonance.

Measurements made of the frequency of the harmonics produced at the illumination peak indicates that they are in excess of one megacycle (million cycles) in the ordinary installation conforming to the invention, when connected to a 60 cycle source. In most cases, the harmonics range between 3 and 65 megacycles. There is also some harmonic power between 1000 cycles and one megacycle. The harmonic range in excess of one megacycle appears to be peculiarly effective for illumination purposes.

One use to which the invention may be put is in obtaining greater uniformity in filament temperature of incandescent and glow lamps through partially eliminating flicker. This renders possible operation of incandescent and glow lamps without flicker at low frequencies such as 25 cycles, and removal of the stroboscopic effect on glow lamps such as sodium and mercury vapor lamps at 60 cycles.

Where reference is made herein to commercial frequency, it is intended to designate frequency below 100 cycles, for example 60 cycles or 25 cycles. Where reference is made herein to high frequency, it is intended to designate a frequency in excess of one thousand cycles. As already explained, the frequency which has been used with success in the harmonics superimposed upon the fundamental or carrier wave is in excess of one megacycle (million cycles). In individual tests the harmonic frequency appears to be between 3 and 65 megacycles, and in some cases higher.

In operation of the device, the circuit may be designed conveniently by calculating the value of the inductance and capacity which should be available for series resonance and then adding or removing inductance, as the case may be (depending upon whether the load loop shunts the inductance or capacity) until the power peak and voltage peak are passed and a peak of illumination intensity is obtained as determined by inspection, or measurement of the light. It will be understood however, that advantage may be

obtained from the invention without this adjustment for dimming or intensifying lights.

It will be evident that if desired special lamps may be designed, having some or all of the auxiliary equipment physically combined with the lamp, for example built into the base of the lamp.

It will be evident that by the present invention the efficiency of the lamp itself as a convertor of electrical energy into light is increased, and, the over-all efficiency of the system will or will not be increased, depending upon the losses in the inductance and capacity. With glow lamps it has been found that increase of the over-all efficiency can be obtained notwithstanding the presence of somewhat high reactance losses. With the incandescent lamp for increase in over-all efficiency the reactance losses must be kept lower. Of the many tests made upon incandescent lamps, an increase in over-all efficiency due to low reactance losses was obtained in some instances, although in many instances the over-all efficiency was less than that of the lamp directly connected across the line.

Where light is referred to herein, it is intended to designate not only the luminous range, but also the adjoining radiation bands, such as the ultra-violet and infra-red rays.

In view of my invention and disclosure, variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of my invention without copying the structure shown, and I, therefore, claim all such in so far as they fall within the reasonable spirit and scope of my invention.

Having thus described my invention what I claim as new and desire to secure by Letters Patent is:

1. The process of operating a closed system illuminating lamp, which consists in passing alternating current through a reactance and an opposite reactance in series, in shunting the reactance by a closed system illuminating lamp, the said lamp shunt forming a load loop, and in rapidly making and breaking the circuit in the load loop containing the lamp.

2. In an electric lighting system, reactance and reactance of opposite electrical character in series, a closed system illuminating lamp shunting the reactance and automatic interrupter means for rapidly making and breaking the circuit in the said shunt.

3. In an electric lighting system, reactance and reactance of opposite electrical character in series, a closed system illuminating lamp shunting the reactance, the reactance and opposite reactance being so related that the reactance over-compensates in the direction of the algebraic sign of the reactance, for the opposite reactance during lamp operation subsequent to the starting period, with respect to the condition for series resonance and automatic interrupter means for rapidly making and breaking the circuit in the said shunt.

4. In an electric lighting system, inductance and a plurality of capacities in series, a closed system electric illuminating lamp shunting the inductance and an interrupter impressing oscillations on the system.

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