

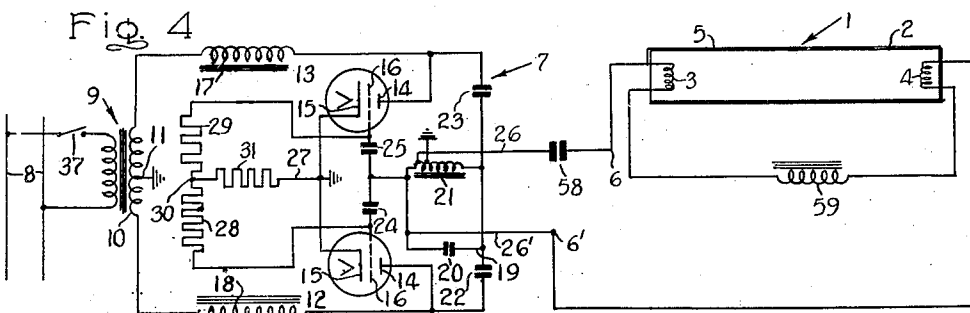
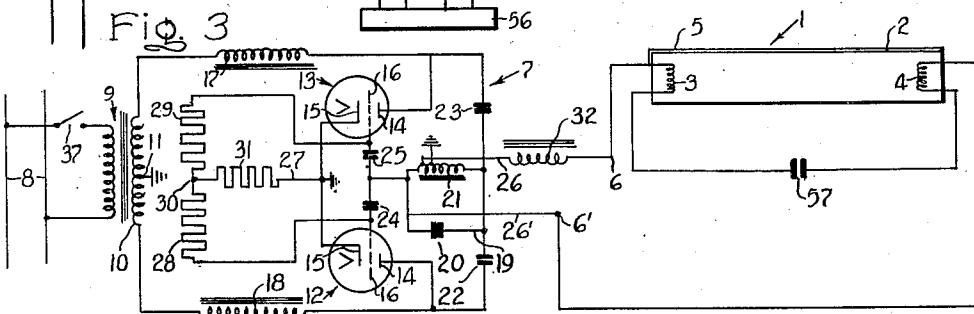
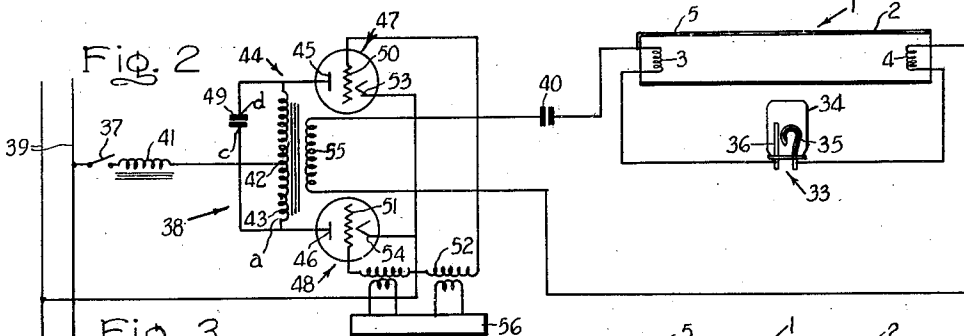
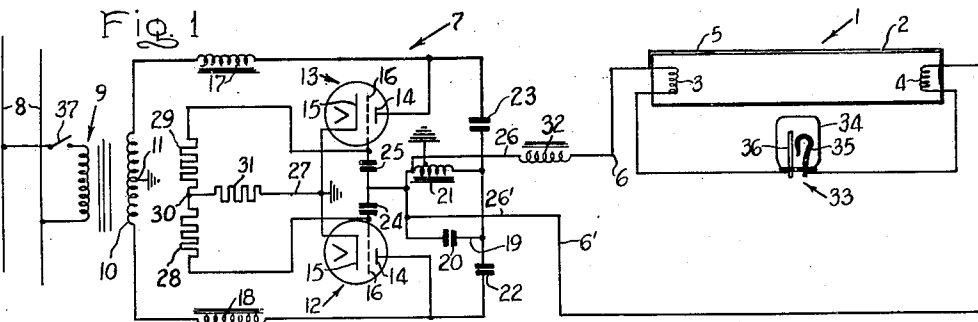
Feb. 14, 1950

J. H. CAMPBELL
CIRCUITS FOR HIGH-FREQUENCY OPERATION
OF FLUORESCENT LAMPS

2,497,534

Filed Sept. 13, 1947

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

Fig 5

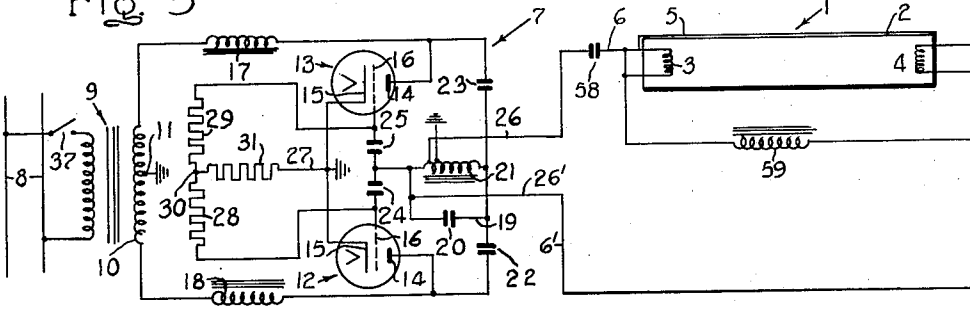
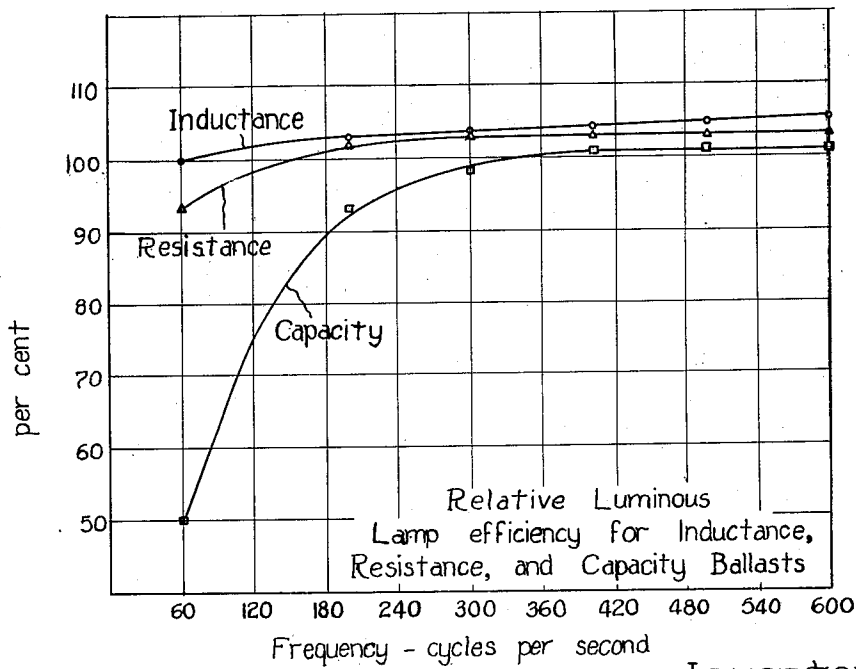


Fig 6



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4 Sheets-Sheet 3

Fig 7

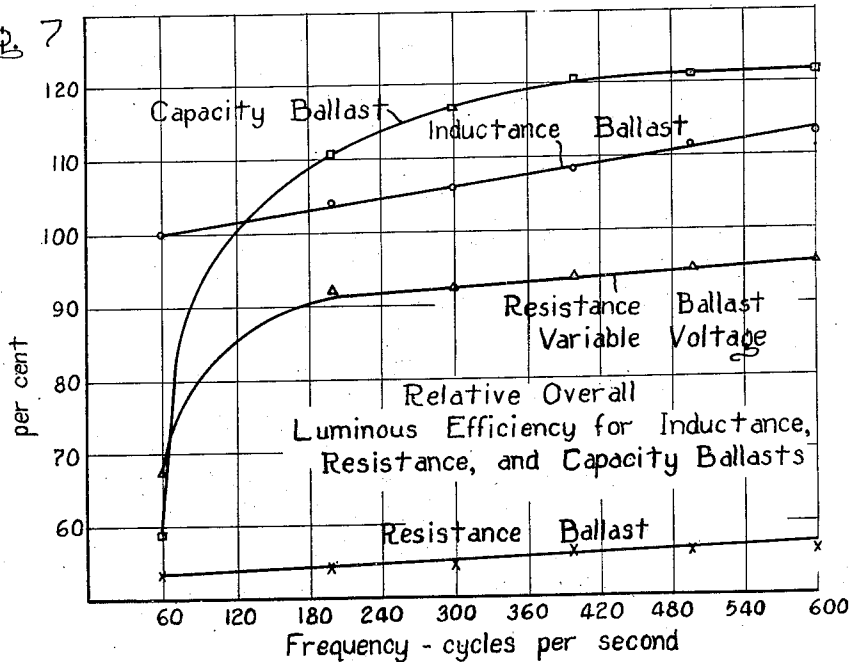
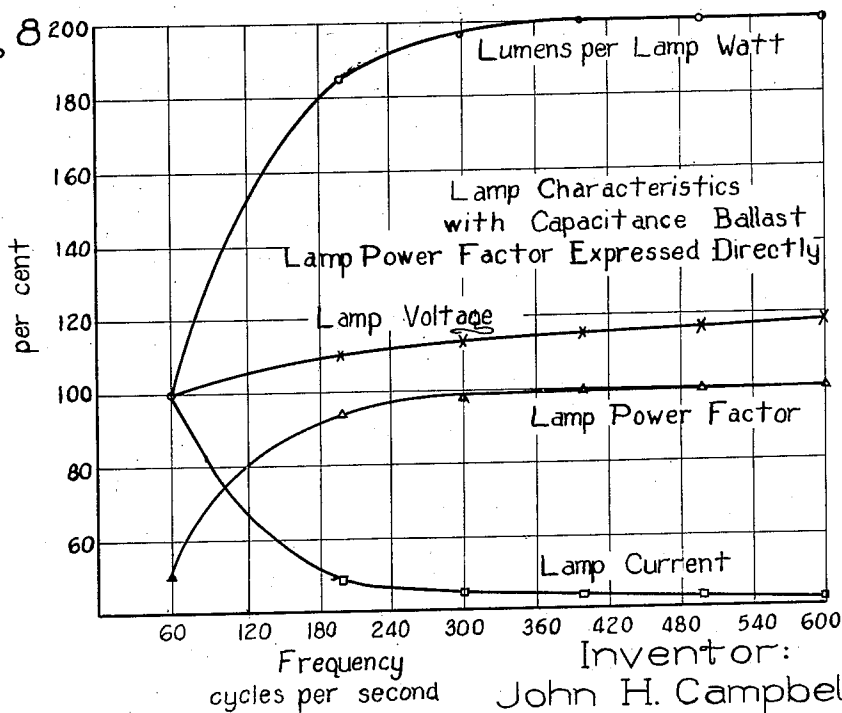


Fig 8



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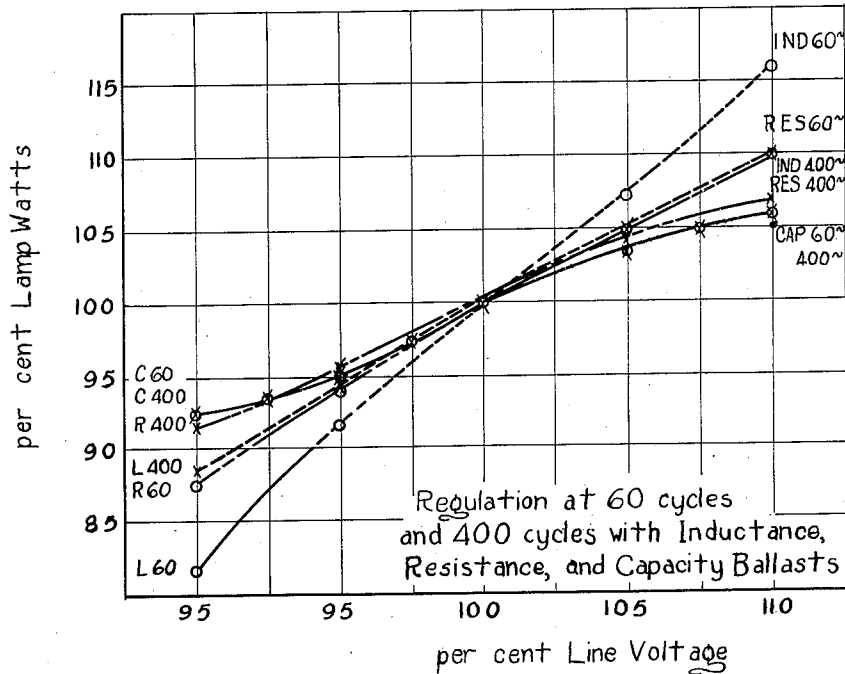
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4 Sheets-Sheet 4

Fig. 9



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UNITED STATES PATENT OFFICE

2,497,534

CIRCUITS FOR HIGH-FREQUENCY OPERATION OF FLUORESCENT LAMPS

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Application September 13, 1947, Serial No. 773,825

6 Claims. (Cl. 315-233)

1

This invention relates to electric discharge devices of the type employing ionizable mediums such as gases or vapors, and more particularly to high frequency circuits for fluorescent lamps.

Circuits now in wide use with fluorescent lamps are designed to operate at a frequency of 60 cycles per second or less. At this range of frequencies the component parts of the control circuit such as transformers, reactors and capacitors are heavy, bulky and inefficient. Higher frequency control devices such as are used for fluorescent lamps, however, become smaller in size as the frequency increases, lighter in weight, lower in watt loss, and cost less in comparable production quantities.

An object of my invention is to provide new and improved starting and operating circuits for an electric discharge device.

Another object of my invention is to provide new and improved starting and operating circuits for a fluorescent lamp suitable for lightweight and more readily portable equipment.

A further object of my invention is to provide new and improved starting and operating circuits for fluorescent lamps for operation within a range of frequencies between 300 and 600 cycles per second, inclusive.

Further features and advantages of my invention will appear from the following description of species thereof.

For a better understanding of my invention, reference may be had to the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims. Fig. 1 is a diagrammatic view of an electric discharge device, a frequency changer, and a starting and operating circuit therefore incorporating my invention. Fig. 2 illustrates diagrammatically an electric discharge device, an inverter and a starting and operating circuit incorporating my invention. Figs. 3 and 4 illustrate diagrammatically an electric discharge device, a frequency changer and a modification of the starting and operating circuits of Figs. 1 and 2 incorporating my invention. Fig. 5 illustrates diagrammatically an electric discharge device with its filamentary electrodes short circuited, an inverter and a starting and operating circuit incorporating my invention. Figs. 6, 7, 8 and 9 illustrate graphically the operating characteristics of a 40 watt fluorescent lamp in a circuit incorporating my invention.

Referring to Fig. 1, I have there illustrated one embodiment of my invention as applied to an electric discharge device 1. The electric discharge de-

2

vice 1, such as a fluorescent lamp, therein illustrated comprises an elongated tubular or cylindrical envelope 2 having sealed into the ends thereof filamentary electrodes 3 and 4, each herein illustrated as comprising a coil, preferably in the form of a coiled coil of tungsten wire activated with oxides of alkaline earth metals such as a mixture of barium or strontium oxides. The envelope 2 contains a gaseous atmosphere such as a rare gas-like neon, argon or mixtures thereof at a pressure of a few millimeters and a small quantity of mercury which, during the operation of the lamps, has a low pressure of the order of 10 microns. The device 1 may be a low pressure positive column lamp of a fluorescent type provided with a suitable phosphor or fluorescent coating. This fluorescent coating upon excitation by the radiation produced by an electric discharge between the electrodes, transforms a shorter wave radiation due to the discharge into longer wave radiation such as radiation within the visible range. For ease of starting a stripe or strip 5 of conductive material which, for example, may be a metallic paint or graphite mixed with potassium silicate, may be applied to the surface of device 1. The starting strip 5 may be connected to one or both of the electrodes.

In accordance with my invention, device 1 is connected across a suitable high frequency power supply circuit 6, 6' which, for example, may be supplied from an electronic frequency changer 7. This electronic frequency changer 7 as disclosed and described in United States Patent 2,288,363, filed by E. D. McArthur and assigned to assignee of this application may be supplied from a single phase alternating current supply circuit 8 which may be of commercial frequency such as 60 cycles. The frequency changer system comprises a transformer 9 having a secondary winding 10 provided with an intermediate or neutral connection 11 connected to ground or connected to a point of reference potential. A pair of electronic discharge devices 12 and 13 are arranged to operate with a pull relationship and each is provided with an anode 14, and cathode 15 and a control member or control grid 16. Filtering inductances 17 and 18 are connected in series relation with the associated portions of the secondary winding 10 and electronic discharge device 12 and 13 to prevent the transmission of high frequency current to transformer 9. Electronic discharge device 12 and 13 are of the high vacuum type and corresponding principal electrodes, such as cathodes 15 are connected to the point of reference potential or to the ground. An oscillatory circuit 19

comprising a capacitance 20 and an inductance 21 is coupled to the anodes 14 of electronic discharge device 12 and 13 through capacitances 22 and 23. The oscillatory circuit 19 is also coupled to control grids 16 of discharge device 12 and 13 through capacitances 24 and 25. The load circuit 26, 26', that is the starting and operating circuit for the electric discharge device 1 may be energized from the inductance 21 of the oscillatory circuit 19, for instance, by tapping across a portion thereof.

As a means for selectively increasing the biasing potential impressed on control grids 16 during the negative or inverse half cycles of the anode-cathode voltage of discharge device 12 and 13, a control circuit 27 comprising resistances 28 and 29 and a common connection or injunction 30 is provided. The common injunction 30 is connected to cathodes 15 of electronic discharge devices 12 and 13 through another resistance 31 which is common to the grid circuits for both discharge devices. The control circuit 27 is energized exclusively by grid currents since capacitances 24 and 25 by-pass the high frequency components of current to ground through the upper portion of inductance 21.

This frequency changer operates to transform the alternating current of commercial frequency derived from circuit 8 into alternating current of a higher frequency. For example, this system may be employed to supply power at frequencies within the range of 300 to 600 cycles per second, which range I have found to be optimum for circuit and lamp performance, as well as circuit economy. Electronic discharge devices 12 and 13 conduct low frequency alternating current alternately during the periods, or intervals of conduction, of low frequency current determined by the voltage of circuit 8. High frequency excitation is derived from the oscillatory circuit 19 through capacitances 24 and 25 and capacitances 22 and 23.

The starting and operating circuit 26, 26' for device 1 comprises a ballast 32 which serves as a starting inductance in series with filamentary electrode 3 of discharge device 1, a switch which, for example, may be a glow switch 33, and filamentary electrode 4 of discharge device 1.

The glow switch 33 comprises a glass bulb 34 filled with a rare gas such as neon or argon, a U-shaped bimetallic strip 35, and a fixed contact or center electrode 36. When current flows through the starting and operating circuit 26, 26' a glow is produced in switch 33 which actuates the bimetallic strip 35 until it contacts the fixed contact or center electrode 36 allowing filament preheating to begin. The glow discharge is extinguished by the bimetallic strip contacting the center electrode 36 and thus the bimetal cools and in a very short time the contacts formed by bimetallic strip 35 and center electrode 36 disengage each other. The reduction in current flow through the ballast 32 produces an inductive voltage kick therefrom which is sufficient in conjunction with the heated electrodes to cause an arc discharge to occur between electrodes 3 and 4. During normal operation, there is not enough voltage across the electric discharge device 1 to produce further starter switch glow so the contacts of the switch remain open and the starter consumes no energy.

When the entire installation is energized by closing a normal make-and-break control switch 37 used to connect the electronic frequency changer 7 to the source of current 8, the desired

frequency, namely 300 to 600 cycles per second is supplied to the starting and operating circuit 26, 26'. Current at this frequency then flows through ballast 32, filamentary electrode 3, glow switch 33, and filamentary electrode 4. After a predetermined interval of time the glow switch 33 interrupts the current flow and the inductive ballast produces a voltage surge or kick and an arc discharge occurs between the electrodes of discharge device 1.

Fig. 2 illustrates diagrammatically a thyatron inverter for supplying frequencies within the range of 300 to 600 cycles per second to a starting and operating circuit therein illustrated embodying a substantially exclusive capacitance ballasting arrangement for discharge device 1. Fig. 2 embodies the same corresponding parts of Fig. 1 except electronic frequency converter 7 of Fig. 1 is replaced by a thyatron inverter 38 supplied by a source of direct current potential 39, and the inductive ballast 32 is replaced by a capacitance ballast 40. The thyatron inverter 38 comprises an inductance 41 connected to one side of the direct-current source 39 and to a center tap 42 of a primary winding 43 of a transformer 44. The primary winding 43 of transformer 44 is connected in shunt with anodes 45 and 46 of thyatron tubes 47 and 48. A condenser 49 shunts the grids 50 and 51 of thyatron tubes 47 and 48, respectively, are connected in series with an oscillator coupling 52 and with each other. Cathodes 53 and 54 are connected in series with each other and to the other side of the direct current supply 39. Secondary winding 55 of transformer 44 supplies the starting and operating circuit 26, 26' with the desired alternating current at the required frequency.

The fundamental principle of operation for the thyatron inverter 38 is as follows: With both anodes 45 and 46 of thyatron tubes 47 and 48 positive with reference to potential polarity, the grid 51 of thyatron tube 48 may be assumed a positive polarity and the grid of tube 47 a negative polarity. Upon the closing of the manual make and break switch 37 current flows through the thyatron tube 48, the primary winding 43, and to the negative polarity side of the direct current supply. During this instant of operation the grid of thyatron tube 47 is negative and, therefore, will allow no current to pass therethrough. Since current is flowing in a section *a* of the primary winding 43 of transformer 44, capacitor 49 is charged with the potential drop. Terminal *c* of capacitor 49 is charged with a negative polarity and terminal *d* with a positive polarity. Near the end of this cycle, the potential to the grids 51 and 50 is reversed by means of an external frequency determining circuit 56 coupled to the control windings or oscillator coupling 52. This change has no immediate effect on the current flow through thyatron tube 48, but allows current to flow through thyatron tube 47, which in effect connects side *d* of the capacitor to the negative polarity lead. This results in a negative potential on the anode 46 of tube 48, thus allowing the grid 51 of tube 48 to regain control and end the first half cycle of alternating current output. The same operation repeats in reverse order producing the next half cycle. The frequency of alternating current output is determined by the external frequency determining circuit 56 coupled to the grid control windings or oscillator coupling 52. The maximum frequency obtainable by equipment of this type is limited to the rate of

deionization of the thyatron tubes which is approximately 900 cycles per second.

Although the above described thyatron inverter functions properly for this type of service other forms of inverters or converters may be used, for example, a magnetic type frequency converter supplied from either a single phase or three phase 60 cycle supply.

Fig. 3 incorporates the same corresponding parts as described with reference to Fig. 1 except the glow switch 33 is replaced by a condenser 57. The impedance of condenser 57 equals the impedance of ballast 32, thus creating a resonant type circuit for high frequencies. The voltage created by the resonant condition is of such a value that an arc discharge will not occur between the electrodes of discharge device 1 until the electrodes are sufficiently preheated. This starting and operating circuit thus eliminates the need of a starting switch.

Fig. 4 incorporates the same corresponding parts as described in Fig. 3 except the inductive ballast 32 is replaced with a capacitive ballast 58 and the capacitance 57 shunting the electrodes of discharge device 1 is replaced with an inductance 59. The impedance of the capacitive ballast 58 equals the impedance of the inductance 59.

Fig. 5 incorporates the same corresponding parts as described in Fig. 4 except the electrodes 3 and 4 of discharge device 1 are short circuited. In this particular case the resonant starting and operating circuit 26, 26' must provide a voltage high enough to produce an arc discharge between electrodes 3 and 4 without preheating the electrodes.

Figs. 6, 7, 8 and 9 illustrate graphically the operating characteristics of a 40 watt fluorescent lamp in a circuit incorporating my invention. The 40 watt lamp was chosen as an example in plotting the above curves because it is produced in large quantities and is in general use for industrial lighting where large high frequency converters would offer the greatest advantage. When similarly plotted, data taken on lamps of other sizes show approximately the same curve shapes as do those taken on the 40 watt lamp.

Lamp characteristics are considerably affected by the type of ballast employed to control the arc discharge in an electric device. In order to point out these differences, the three fundamental types of ballasts, namely, inductance, capacitance and resistance, are used. Curves giving the luminous lamp efficiency and overall circuit efficiency for each type of ballast is shown in Figures 6 and 7. All curves are plotted in percentage of 60 cycle characteristics.

Fig. 6 shows graphically the relationship of the efficiency of a 40 watt lamp with varying frequency for the three types of ballasts. The percentage lamp efficiency is plotted against frequency using efficiency of a lamp operated on an inductive ballast at 60 cycles as 100%.

Inductive ballasts can be made smaller as frequency increases, but as the frequency rises, it may be necessary to use a higher grade iron for the core in order to avoid excessive losses due to core saturation. This results in a relatively expensive design and therefore the reduction in size does not necessarily mean a proportional reduction in cost. The use of pure resistance as a ballast for A. C. operation of fluorescent lamps has not found wide-scale application because of the relatively high loss and resulting low overall efficiency. The capacitance ballast does not

appear to be practical for frequencies much below 300 cycles because of the adverse effect on lamp characteristics at lower frequencies. However, at frequencies above 300 cycles, this method of control has many advantages among which are the relatively small size, light weight, low cost and low losses. The small capacitance required to ballast a 40 watt lamp at high frequency makes possible the design of a single lamp ballast of comparatively small dimensions and weights ranging in ounces instead of pounds.

In any economic consideration, the overall efficiency of the circuit must be taken into account to determine actual operating costs. The curves in Fig. 7 show the overall efficiency for inductance, capacitance and resistance ballasts. Since inductance is the most commonly used, this method of ballasting at 60 cycles is indicated to represent the 100% point. All other curves are therefore in percentage of this base. The rapid rise of overall efficiency in the case of the capacitor ballast is accounted for in the improvement of wave shape and the low loss of this method of ballasting at higher frequencies. The inductance is fundamentally higher in loss and therefore remains less efficient over the frequency range shown. The lower resistance curve shows little improvement in overall efficiency when design for the same line voltage (200 volts) as the two other types of ballasts. The change from 53% to 56% over the range of 60 to 600 cycles is due entirely to the gain in lamp efficiency. The upper resistance curve indicates the overall efficiency with the ballast design for lower line voltage at points where good regulation and lower lamp operating voltage is permitted.

Fig. 8 shows the lamp characteristics for a capacitance type ballast. At the lower frequencies such as 60 cycles, this method of control is impractical due to the delay of the capacitor in allowing current to flow through the lamp. The lamp conducts current for a relatively short period each half cycle, resulting in low lamp efficiency and pronounced stroboscopic effect. At the higher frequencies the current wave shape improves and lamp efficiency approaches that of an inductive ballast. At approximately 300 cycles the lamp efficiency using a capacitor ballast is the same as that of an inductively ballasted lamp operating at 60 cycles. More important than lamp efficiency is the gain in overall efficiency of the circuit when a capacitor ballast is used. Fig. 7 shows this relationship. It will be noted that a capacitor ballast operating in the range of 300 to 600 cycles provides an overall efficiency from 17% to 22% greater than that provided by an inductive ballast at 60 cycles.

The regulation of lamp watts and light output with changes in line voltage is shown in Fig. 9. The curves show percentage lamp watts with a 10% change in line voltage for the three types of ballasts on both 60 and 400 cycle power. It will be noted that regulation improves with frequency for inductance and resistance type ballasts. However, since series capacitance provides more nearly constant current with changes in voltage the regulation of the capacitance curve is superior to inductance or resistance at both frequencies. Thus, the capacitance ballast operating between the frequency range of from 300 to 600 cycles per second has a regulation superior to inductance or resistance ballasts. Although I have described my invention with reference to single electric discharge device circuits, it may be readily ap-

plied to circuits employing a plurality of devices.
What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, an electric discharge device of the type employing an ionizable medium and comprising a plurality of filamentary electrodes and ballast means consisting of a substantially exclusively capacitive reactance in series with said device across a source of current having a frequency of the order of several hundred cycles per second but greater than about 300 cycles per second.

2. In combination, an electric discharge device of the type employing an ionizable medium and comprising a plurality of electrodes and ballast means consisting of a substantially exclusively capacitive reactance in series with said device across a source of current having a frequency within the range of 300 to 600 cycles per second, inclusive.

3. In combination, an electric discharge device of the type employing an ionizable medium and comprising a plurality of filamentary electrodes, an alternating current supply circuit, a frequency changer across said supply circuit for converting the supply to current having a frequency in the range of about 300 to 600 cycles per second, and ballast means consisting of a substantially exclusively capacitive reactance, said capacitive reactance being connected in series with said device and across said frequency changer.

4. In combination, an electric discharge device of the type employing an ionizable medium and comprising a plurality of electrodes at least one of which is of the filamentary type, ballast means consisting of a substantially exclusively capacitive reactance in series with said discharge device across a source of current having a frequency within the range of 300 to 600 cycles per second, and a starting means in series with

said electrodes and shunting said device for providing starting current.

5. In combination, a gaseous electric discharge device having at least one filamentary electrode and a cooperating electrode, ballast means consisting of a substantially exclusively capacitive reactance in series with said discharge device across a source of current having a frequency within the range of 300 to 600 cycles per second, and an inductive reactance in series with said electrodes and shunting said device for providing optimum starting voltage.

6. In combination, an electric discharge device of the type employing an ionizable medium and comprising a plurality of electrodes, ballast means consisting of a substantially exclusively capacitive reactance in series with said discharge device across a source of current having a frequency within the range of 300 to 600 cycles per second, and an inductive reactance connected across said electrodes and constituting with said capacitive reactance a resonant circuit for providing optimum starting voltage.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,050,135	Tour	Aug. 4, 1936
2,056,629	Uyterhoeven et al.	Oct. 6, 1936
2,086,668	Fodor	July 13, 1937
2,133,494	Waters	Oct. 18, 1938
2,170,447	Edwards	Aug. 22, 1939
2,284,407	Edwards	May 26, 1942
2,301,671	Abadie	Nov. 10, 1942
2,368,090	Abernathy	Jan. 30, 1945
2,423,031	Kurtz et al.	June 24, 1947