

May 16, 1944.

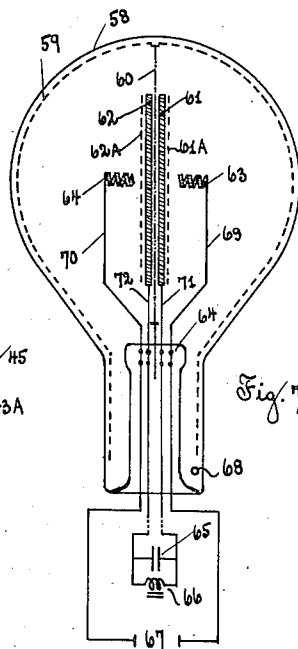
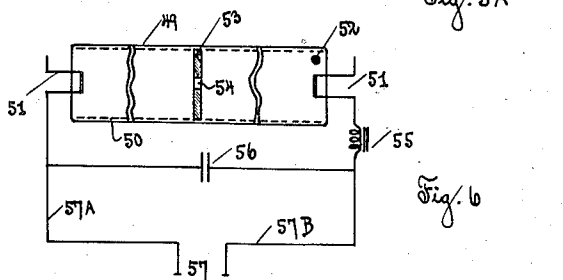
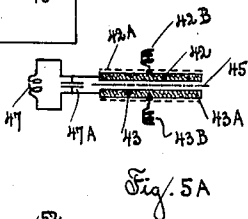
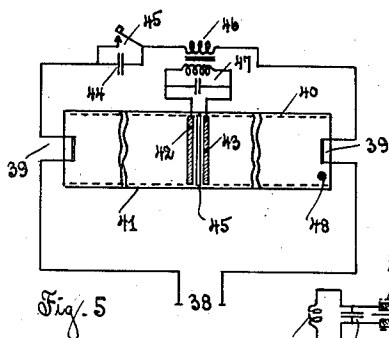
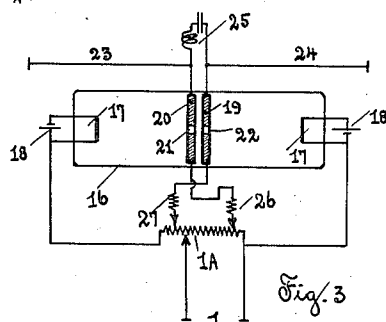
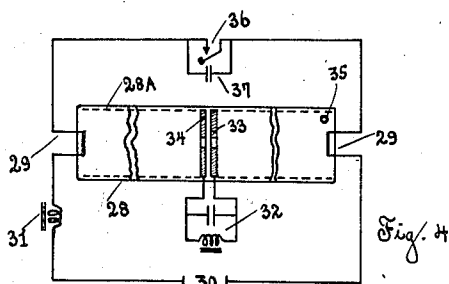
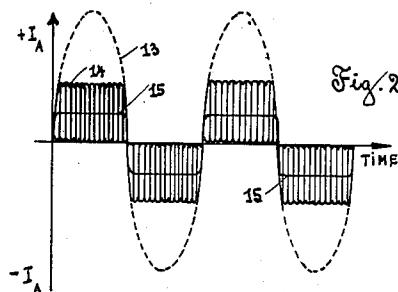
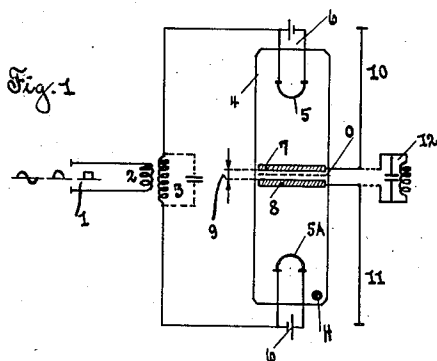
C. SPAETH

2,349,012

MEANS FOR PRODUCING HIGH FREQUENCY OSCILLATIONS IN
ILLUMINATING ELECTRONIC DISCHARGE LAMP DEVICES

Filed June 24, 1941

2 Sheets-Sheet 1



INVENTOR.

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2 Sheets-Sheet 2

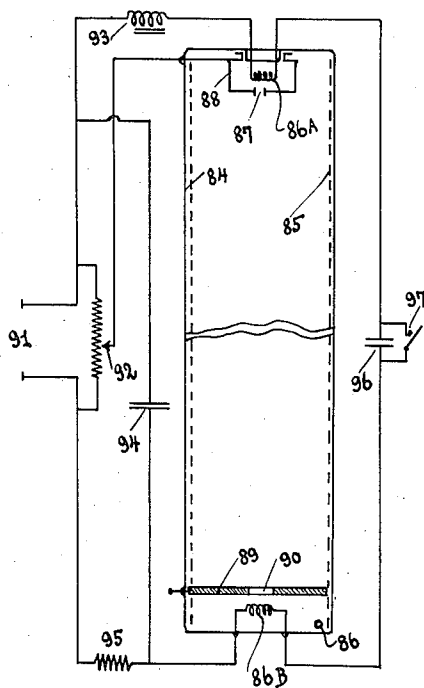
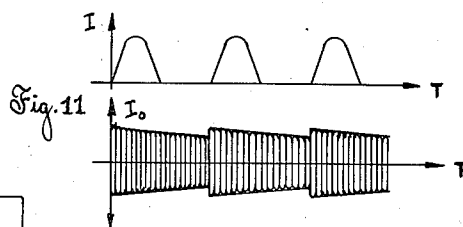
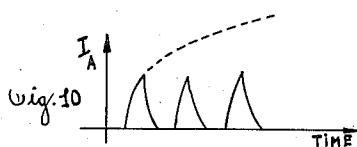
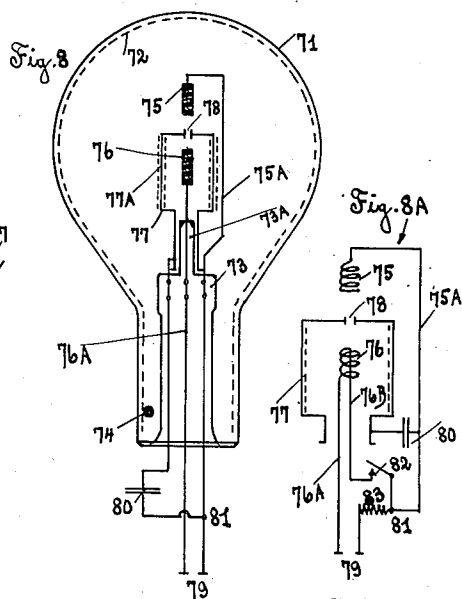


Fig. 9



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UNITED STATES PATENT OFFICE

2,349,012

MEANS FOR PRODUCING HIGH FREQUENCY
OSCILLATIONS IN ILLUMINATING ELECTRONIC
DISCHARGE LAMP DEVICES

Charles Spaeth, Mamaroneck, N. Y.

Application June 24, 1941, Serial No. 398,450

9 Claims. (Cl. 315-246)

This application is a continuation in part as to all common subject matter of my copending application Ser. No. 383,098 filed March 13, 1941 and relating to, "Method of producing and transmitting high frequency oscillations."

The present invention relates to improvements in electronic discharge devices of the high vacuum and/or gas-vapor filled type and to methods of producing low-medium, high and ultra-high frequency oscillations, by means of electronic discharge devices herein disclosed which are suitable for radio, television, wired radio frequency transmission and other related fields.

In one aspect the invention relates to improvements in electronic discharge devices, particularly to devices used for purposes of illumination of the type involving the excitation of luminescent, fluorescent and phosphorescent materials by means of electronic or other discharges produced by new and improved types of oscillating and radiating units as disclosed in my copending application Ser. No. 383,098 filed March 13, 1941.

The present invention in one aspect also includes fluorescent tubes or lamps or other electronic discharge devices used in the illuminating field embodying high frequency producing means for the purpose of increasing the luminous efficiency and to reduce the necessity of ballasting or stabilizing such gaseous discharge devices due to their inherent negative volt-ampere characteristics. Fluorescent tubes, lamps or other light producing electronic discharge lamp devices of the gaseous-vapor filled type will produce visible light radiations of increased luminous efficiency and increased life as compared to present light producing electronic discharge lamps or tubes if energized with high frequency currents.

The increase in luminous efficiency of gaseous conduction tubes of the electronic discharge type is partly due to the fact that the rising and falling current, if plotted in a voltage versus current diagram, describes a loop area for both periods of the supplied alternating current flowing through the lamp similar to the hysteresis curve in the magnetization of iron, representing a loss of energy. Since the static volt-ampere characteristic of a gaseous discharge is of the negative or falling type a large part of the gas hysteresis cycle is of the falling portion as indicated by the curve 1 in Fig. 20, therefore requiring a considerable ballasting or stabilizing means in order to maintain the gaseous discharge besides the fact that the area of the gas hysteresis cycle is considerable, representing a loss of energy. These conditions apply for operation of gaseous con-

duction tubes on low frequencies, around 60 cycles per second alternating current. At higher frequencies the rising and falling current flowing through the tube approaches values closer together and forms a curve similar to curve 2, indicating a smaller area and also a shorter portion of the dynamic negative or falling characteristics, requiring consequently a smaller ballasting device to maintain the gaseous discharge. The curve 2 applies for operation of a gaseous electronic discharge tube with an alternating current of about 1000 cycles per second. If the frequency of the alternating current approaches radio frequency, the rising and falling current flowing through the tube during one cycle approaches values very close together and the curve resembles the line 3, which represents a pure ohmic resistance. If the frequency of the supplied alternating current energizing the fluorescent gaseous conduction tube is sufficiently high, current will flow mostly on the outside of the ionized positive gas-vapor column due to the skin effect, the column representing a current carrying conductor. Because the outside of the ionized positive gas-vapor column in a long fluorescent tube of the conventional structure is next to the fluorescent coating material which is attached to the inside walls of the tube, a very intense ionization of the gas-vapor particles, due to the skin-effect, takes place in the gas-vapor layer touching the fluorescent coating material, thus assuring a maximum energy transfer from the shortwave ultraviolet radiation into the longer wave visible light radiation. Since the ionization density is higher in the gas film next to the tube walls and lower in the center or the core of the positive discharge column, due to the skin-effect, less absorption of shortwave ultraviolet radiation from the core reaching the fluorescent material on the tube walls takes place (by travelling through the gas-vapor atmosphere) thus contributing to an increase in luminous efficiency of the tube.

Light radiating units of the fluorescent tube or lamp type constructed in accordance with the preferred embodiments of this invention have certain important and new advantages in use as compared with fluorescent tubes or lamps of the usual type. Briefly, these advantages are:

1. Increased radiation efficient in lumens per watt in the visible region of the light- and ultraviolet light spectrum.
2. Better lumen maintenance during the useful life of the lamp due to less sputtering and evaporation of the electrode material and blackening of the tube or bulb.

3. Easy starting of the gaseous electronic discharge tube or lamp on low voltage circuits of the conventional 120 volt line voltage type, due to the high frequency oscillations produced within the tube or lamp.

4. Reduction of ballasting devices, necessary in the usual type of gaseous discharge devices, due to their inherent negative volt-ampere characteristics. By interposing into the discharge path of a gaseous electronic discharge device, taking place between two or more electrodes within a tube or bulb, means such as one or more diaphragms having one or more perforations or plates acting as capacity electrodes similar to a condenser, enough positive resistance is introduced into the circuit, containing the negative resistance of the gaseous discharge, to cause stabilization of the device and to reduce the usual necessary ballasting devices. This makes it possible to operate such devices embodying the new means to be operated directly from the usual current supply lines with very little ballasting means well known in the art to operate tubes of the usual type. By energizing electronic discharge tubes or lamps of the fluorescent type, producing visible light radiations, or other light producing gaseous discharge devices with high frequency currents instead of the usual conventional 60 cycles per second alternating current, above mentioned advantages are obtained. A greater energy and frequency conversion from electrical energy into shortwave ultraviolet radiation and into longer wave visible light radiation by means of the fluorescent, phosphorescent or luminescent materials takes place, resulting in a gain of 20% or more in luminous efficiency (lumens per watt), if a given fluorescent tube or lamp is operated, for example, at 500 cycles per second, instead of at a frequency of 60 cycles per second of alternating current or with direct current.

Increasing the frequency of the current energizing the electronic discharge device causes an increase in luminous efficiency as the frequency becomes greater and values of luminous efficiencies much greater than the above mentioned increase of 20% are very easily obtainable if the frequency of the current flowing through the fluorescent tube or lamp is raised to frequencies approaching radio-frequencies. Advantage of these facts is taken by making the fluorescent tubes or lamps self-generating high frequency current oscillators or rapid current interrupters or frequency multipliers while acting at the same time as a light radiating device for illumination purposes.

Interposing into the path of the electronic discharge, taking place between one or more electrodes, means such as one or more diaphragms having one or more perforations or plates acting as capacity electrodes and as a condenser simultaneously, the electronic discharge device may be made a source of self-generating high frequency oscillations. If the tube or electronic device is made self-rectifying at the same time, frequency multiplication may be obtained by impulse excitation of a resonant circuit, consisting of a condenser and an inductance, said resonant circuit being coupled to the tube or lamp in such a manner as to produce such condition. The inherent negative volt-ampere characteristic of gaseous discharge devices favors the production of high frequency oscillations or interrupted pulsating currents. Due to the presence of resonant circuits in combination with the gaseous discharge tubes, high frequency oscillations may be

produced under certain conditions up to several thousand cycles per second, however the high frequency energy obtained is of small power, representing mostly small amplitudes of an alternating sinusoidal current, while in the preferred embodiments of this invention high-frequency alternating or pulsating currents of large amplitudes (even complete extinction of the current between the cycles, if desired) and large power are obtainable besides the fact that frequencies from several hundred cycles per second up to several thousand megacycles per second are easily obtainable. (1 megacycle=one million cycles per second.) Several thousand watts of high frequency energy of the order of several thousand megacycles are easily obtainable in the form of peaked pulses or of the sinusoidal or other shaped half wave or full wave current types.

The presence of a resonant circuit, consisting of a condenser and an inductance, permits also the easy starting of gaseous discharge devices, because high transient voltages are produced in the resonant circuit which easily ionize the gas-vapor mixtures within the tube or lamp.

The voltage across a condenser, being charged, is under certain conditions in connection with an inductance very high compared against the value of the supplied charging voltage, this is desirable especially in the case of fluorescent lamps used for illuminating purposes and energized from the conventional 120 volt line; several hundred volts are about required to start or ionize the positive gas column of the gaseous discharge tube of the conventional fluorescent tube having, for example in the 40 watt size a tube length of 48 inches, a tube diameter of about 1.5 inches and a useful life of about 2000 hours.

Operation of fluorescent gaseous discharge tubes or lamps with high frequency currents reduces also the sputtering of the electrodes, either of the oxide coated hot cathode type or of the thermionic type, thus reducing the deposition of electrode material on the fluorescent coating material (attached to the tube walls) and keeping the tube walls from blackening to a considerable degree with the result of a better and higher lumen-maintenance rate during the useful life of the illuminating tube.

By placing the perforated capacity electrode or electrodes near the electron emitting hot cathodes and/or anodes within the tube, the evaporated and sputtered electrode and oxide coating materials are prevented from reaching the tube walls and are deposited on or near the capacity electrodes, which due to their perforations act simultaneously as a current-interrupter for the ionized gas column as previously disclosed.

The result is that the evaporated and sputtered materials are kept from reaching the fluorescent coating material, attached to the tube walls, and prevents the fluorescent coating material from poisoning which greatly reduces the conversion efficiency of shortwave ultraviolet radiation into the longer wave visible light radiation. Fluorescent materials or so-called phosphors used in the manufacture of fluorescent lamps, such as calcium tungstate, magnesium tungstate, cadmium silicate and others are very sensitive to certain impurities and lose their high conversion efficiency if contaminated with impurities. Since high frequency current operation of fluorescent lamps reduces also the positive ion-bombardment of the electrodes, less sputtering takes place and consequently longer life of the lamps is obtained. The present invention includes also within its

scope the means herein disclosed of producing and radiating high frequency energy in the form of peaked pulses, similar to rectified alternating currents, or producing sinusoidal alternating current waves or other shaped half wave or full wave type radiations by means of gaseous electronic discharge devices or thermionic high vacuum devices having two or more electrodes within a gas filled or high vacuum tube or bulb for the purpose of producing with said electronic discharge devices in suitably connected antenna circuits or wire transmission circuits pulsating or alternating high frequency currents of large power and of low-medium-high and ultra high frequencies. By interposing into the electronic discharge path capacitive and/or inductive means, high-frequency oscillations and frequency multiplications are obtained.

These and other features of the invention will be best understood from the following description of certain preferred means and embodiments thereof, selected for purposes of illustration and shown in the accompanying drawings and in which,

Figure 1 illustrates an electronic discharge device producing high-frequency oscillations and frequency multiplication at the same time.

Figure 2 discloses in diagrammatic form the conversion of the supplied alternating current into pulsating or alternating current of higher frequency by frequency multiplication showing the wave shape before and after conversion.

Fig. 3 shows an electronic discharge device acting as a high-frequency current oscillator or high frequency interrupter producing frequency multiplication simultaneously.

Fig. 4 illustrates a visible light radiation producing electronic discharge tube of the fluorescent lamp type acting as a high frequency current interrupter or oscillator at the same time.

Fig. 5 shows a modified electronic discharge tube producing visible light radiations and high frequency oscillations simultaneously.

Fig. 5A shows an enlarged diagrammatic view of the combination condenser-electrodes acting simultaneously as a resonant circuit for frequency multiplication and as electrodes for the electronic or gaseous discharge.

Fig. 6 illustrates a modified electronic discharge tube acting as a high-frequency current interrupter and a visible light producing lamp device simultaneously.

Fig. 7 illustrates a light producing electronic discharge lamp oscillator acting as a frequency multiplier simultaneously for the purpose of increasing the luminous efficiency by energizing and ionizing the gaseous and fluorescent means of the lamp with high frequency currents.

Fig. 8 discloses a gaseous electronic discharge device capable of generating high frequency oscillations and light radiations of increased luminous efficiency.

Fig. 8A shows a modified structure of the lamp device shown in Figure 8.

Fig. 9 shows an electronic device of the illuminating fluorescent tube type producing current interruptions of a high-frequency in order to raise the luminous efficiency.

Fig. 10 illustrates in graphic form in a current versus time diagram the shape and form of the high-frequency current-interruptions produced by the devices shown in Figs. 8 and 9.

Fig. 11 discloses in a current-time diagram, the shape and form of the high-frequency oscilla-

tions produced within the electronic devices shown in Figs. 1 to 9.

Figure 12 illustrates the gaseous hysteresis cycles taking place in a gaseous conducting electronic discharge tube if energized with alternating currents.

Referring now to Fig. 1, an electronic discharge device producing high frequency oscillations and frequency multiplication at the same time is shown in diagrammatic form. A suitable source 1 of electric current, preferably an alternating current of low-medium or high-frequency is connected to the primary coil 2 which is inductively coupled to the coil 3, both coils representing a transformer. In case of low frequency alternating current, a transformer using an iron core is used while at high-frequencies, the iron core may be dispensed with. Low frequency refers to frequencies from 16 to 60 cycles per second. The alternating current source may in certain instances be replaced by a direct current source of a suitable potential if desired.

The ends of the secondary coil 3 of the transformer are connected to the two electrodes 5 and 5A of the electronic discharge device 4. The electronic discharge device 4 consist of a bulb or tube having two electrodes 5 and 5A placed and separated from each other at a suitable distance. The electrodes may be of the cold or hot cathode type if a gaseous atmosphere is used within the bulb, as for example argon gas at a suitable pressure. The area of the electrodes in this case should be small as compared to the area of the two metal-plate electrodes 7 and 8 in order to insure point to plate rectification of the supplied current. However thermionic electrodes either of the filament type, straight wire, coiled wire or coiled coil type may be used, employing tungsten-wire of the thoriated type or other refractory metals, such as tantalum, molybdenum etc. Oxide coated electrodes or cathodes heated to the proper temperature in order to produce an electron emission using oxides such as barium oxides, strontium oxide, calcium oxide, thorium oxide or other suitable oxide mixtures or carbides or mixtures of both may be used.

If thermionic electrodes or oxide coated electrodes are used a separate source of electric current is required in order to heat the thermionic electrodes or the oxide coated cathodes to the proper temperature, the electric source for heating is indicated by the number 6 in the diagram.

Interposed between the two electrodes 5 and 5A are two metal plates 7 and 8, spaced very closely to each other and acting as a condenser. The spacing 9 between these two metal plates should be less than the mean free path of the gas molecules at a given gas pressure in order to prevent ionization by collision of the gaseous atmosphere between the plates 7 and 8. This enables the two plates to act as a condenser and the shape of the plates should be such that they fit closely to the tube walls in order to prevent the gaseous discharge to leak around. Interposed between these two plates is, if desired, a plate 10 of mica to act as a dielectric for the condenser and also to prevent a discharge between the plates, a quartz crystal plate may also be used instead of a mica plate and by choosing the proper thickness of the quartz plate, it may cause the condenser and a connected circuit consisting of an inductance and capacity to oscillate at a certain frequency. The two condenser electrodes 7 and 8 are connected to the two antenna dipoles 10 and 11 or to a resonant circuit 12, compris-

ing an inductance and a capacity, which may be coupled to any other circuit desired. The bulb or tube 4 is either highly evacuated or gasfilled and may have any suitable gas pressure from a fraction of a micron (one micron equals one thousandth of a millimeter) up to atmosphere pressure or even above. The preferred gases used in a gasfilled bulb are inert gases, such as helium, argon, neon, krypton and xenon; metallic vapors such as those of mercury or sodium or other suitable metals may also be used. A globe of mercury or a mercury alloy or of some other metal may be located within said bulb 4. Of course mixtures of above mentioned gases with or without metallic vapors may also be used within the bulb.

In operation of the electronic discharge device an electric current of a suitable frequency and of a suitable potential is applied between the electrodes 5 and 5A, after a suitable heating current has been passed through the electrodes 5 and 5A, bringing the electrodes up to a temperature to produce electron emission.

The supplied impressed low-medium or high-frequency voltage charges the condenser electrodes 7 and 8 by means of the electron streams and the ionized gas (being highly conductive) and/or metal vapor according to the polarity of the electrodes 5 and 5A acting as anodes and cathodes during a given cycle. While the charging takes place the two metal condenser plates 7 and 8 and the two antenna dipoles 10 and 11 will be caused to oscillate at their own natural frequency, both representing a resonant circuit comprising an inductance and capacity, thus causing the dipoles to radiate electromagnetic waves. When the charging voltage drops to zero, the charged condenser plates will discharge through the ionized gas, back over the electron emitting electrodes 5 and 5A and cause the resonant circuit again to oscillate and radiate. If therefore the supplied alternating current or voltage and frequency is very high it will cause the two condenser plates to be rapidly charged and discharged at the opposite potentials and consequently cause the antenna dipoles 10 and 11 to radiate a large amount of energy at a very high frequency or at a very short wavelength, since the time constant for charging and discharging such a small condenser is extremely short. Since the condenser charging frequency is relatively high and has been predetermined by the frequency of the supplied impressed oscillator high frequency current, coupled to the coil 2 is a high frequency oscillator source 1 in this case, a large amount of energy will be stored in the condenser plate 7 and 8 although the capacity of the plates may be small. For example, if the capacity of the plates 7 and 8 be 50 micro-micro farads and the voltage of the charged condenser 4000 volts and the charging frequency 10 million cycles per second, about 2000 watts of energy will be available for radiation at an extremely short wave length, since the discharge and charge time constant $T=RC$ for 63% values is extremely short. R represents the resistance and C the capacity T represents the time. The fact that the ionized gas-metal vapor medium has a falling or negative volt-ampere characteristic, accelerates the time constant T since the internal ohmic resistance of such an ionized gas-metal vapor atmosphere is extremely small and has a variable value also simultaneously.

A resonant circuit 12 comprising an inductance and a capacity may be connected to the two

condenser plates 7 and 8, if desired, and as indicated by the dotted lines in the circuit diagram to be used as a tank circuit for further frequency multiplication and to reduce harmonics.

Although the preferred shape of the supplied alternating current energizing the electronic device is a sinusoidal shape, other shaped currents may be used, as for example triangular current shaped or rectangular current pulses. Square or rectangular current pulses are very suitable for energizing an electronic discharge device in order to produce frequency multiplication.

If therefore the electronic discharge device shown in Fig. 1 consists of a highly evacuated bulb 4 instead of a gas filled bulb, rectangular or square current pulses for charging and discharging the two condenser plates 7 and 8 are obtained by impressing between the two thermionic filamentary electrodes 5 and 5A a sinusoidal alternating current having a peak voltage which is large compared with the voltage required to produce the saturation current of the two filament electrodes which are operated at a given temperature. The result is that the top of the supplied sinusoidal current is cut off or flattened out. The resultant square or rectangular current pulses, therefore resemble interrupted direct current of changing polarity. By choosing the ratio of the supplied alternating voltage to the voltage, producing the saturation current of the thermionic electrodes operating at a given temperature within an evacuated bulb very large, very steep sides of the square or rectangular current pulses are obtained, thus obtaining very short time intervals in which the voltage reaches the cut off point of saturation, thus permitting to obtain frequency multiplication ratios with suitable resonant circuits up to several millions. Fig. 2 shows a diagram in which the supplied impressed alternating current or voltage and the obtained current or voltage of multiplied frequency are plotted as functions of time. The curve 13 represents the supplied alternating low-medium or high frequency voltage or current.

The line 15 represents the saturation current of the tube electrodes due to electron emission, indicating a conversion from a sinusoidal waveform into a square or trapezoid or rectangular wave or current form, suitable to excite and energize by impulse excitation coupled resonant circuits to oscillate at increased frequencies according to the LC ratios of the resonant circuits. The resulting oscillating current 14 of alternating sinusoidal wave form is superimposed upon the flat top part of the square or rectangular current pulses 15 which change in polarity according to the frequency of the supplied alternating current.

Referring now to Fig. 3 an electronic or thermionic discharge tube is disclosed acting as a high-frequency current interrupter and frequency multiplier at the same time. The discharge tube comprises a tubular bulb 16 having at its opposite ends two electrodes 17 of the type used in the device shown in Fig. 1, both being heated to electron emission temperatures by the electric current sources 18. The tube is filled with a suitable monatomic gas or a mixture of gases at a suitable gas pressure as previously disclosed and the bulb or tube also contains if desired a globe of mercury, mercury alloy or sodium. Interposed between said electrodes are two metal plates 19 and 20, each having a small bore or perforation 21 and 22, the two metal

plates are spaced at such distance from each other, which is less than the mean free path of the gas molecules at a given gas pressure, so as to prevent ionization by collision of the gas molecules in the space between the plates 19 and 20. This enables the two plates to act as a condenser and the size of the plates should be such that they fit very closely to the tube walls in order to prevent the gaseous or electronic discharge to leak around.

The two metal plates acting as condenser and as electrodes are connected to the two antenna dipoles 23 and 24, a resonant circuit 25 consisting of an inductance and a condenser is also connected to said plates 19 and 20 acting as a tank circuit for frequency multiplication. The two plate electrodes 19 and 20 are also connected through the resistors 26 and 27 to the resistance 1A which is connected in parallel to the electric source of current 1 thus permitting any potential desired to be applied to these plate electrodes, any static charges are also permitted to flow off through this means; if desired these resistors may be omitted.

A source 1 of electric current of any suitable potential, either direct current or alternating current is connected across the tube 16 to the two electrodes 17 in order to energize the discharge device. The tube 16 may also be highly evacuated and be operated as a device being dependent on the pure electron emission from the thermionic electrodes 17 instead of a gaseous discharge as above mentioned in connection with a gasfilled tube or bulb.

In operation of the device, a suitable current, either direct or alternating current from the source 1, will flow through one part of the resistance 1A acting as a stabilizing means and through the tube 16, by means of the electrodes 17 emitting electrons and the ionized gas, through the perforations 21-22 of the condenser electrodes 19 and 20 thus establishing a closed circuit. Since the two plates 19-20 acquire at the same time opposite charges, a plasma film of ionized gas forms in and around the perforations and increasing in size until the current is interrupted. At this time the two plates 19 and 20 act as a condenser, no discharge taking place between them due to their close spacing, which is less than the mean free path of the gas molecules at the gas pressure prevailing in the tube, and become charged therefore.

These charges will flow off through the resistors 26 and 27 and permit the ionized discharge to pass again through the perforations and also close the current circuit through the tube. These current interruptions take place, according to the diameter of the perforations, gas pressure, capacity value of the condenser-plates 19-20, very rapidly and may cover a range from several hundred per second up to several million per second and more. The voltage fluctuations between the plates 19 and 20 and acting as interrupter and condenser simultaneously are transferred to the tank circuit 25 and the antenna dipoles 23 and 24. If therefore the L-C values of the tank circuit 25 are small, the resonant frequency produced in the circuit may be of increased frequency compared against the interrupter frequency. Frequency multiplication to the extent that the dipoles 23 and 24 will radiate high frequency fields of the order corresponding to wavelengths of several centimeters and of large power is obtained.

As previously mentioned the operation of the

device is not limited to gaseous discharges, but is also operative if a high vacuum exists within the tube 16. In this case pure electron emission from the thermionic electrodes produces electron streams or beams between the two heated electrodes 17 which will flow through the perforations of the plates 19 and 20 and cause due to potentials present on the plates 19 and 20, these electron beams and streams to break and close, thus causing interruptions in the current flowing through the tube. These current interruptions accordingly excite and energize the tank resonant circuit 25 by impulse excitation at its own natural frequency and produce in a connected antenna system high frequency radiations.

In Fig. 4 is illustrated an electric lamp or discharge device to be used for illuminating purposes embodying means so as to produce current interruptions or high frequency oscillations within said lamp for the purpose to increase the luminous efficiency of said lamp. A tubular bulb or tube 28 contains at the opposite ends of the tube two electrodes 29 similar to the ones shown in Fig. 1. Said filamentary electrodes are preferably made of highly refractory metals, such as tungsten for example and are also preferably coated with oxides of the alkali metals or rare earth metals, as for example barium-strontium-calcium oxides or oxides of thorium-zirconium etc. Carbides of metals, such as tantalum, rhenium, zirconium or of other metals may also be used or mixtures of oxides with carbides may be used. If very concentrated filamentary electrodes are desired, said filament may be of the coiled coil type. The use of above mentioned oxides assures high electron emission from said heated electrodes. The tube 28 is provided with a coating 28A of a compound which exhibits the characteristic of becoming fluorescent or phosphorescent under the influence of shortwave radiant energy, thereby converting the shortwave ultraviolet radiation into longer wave visible light radiation and thus producing an illuminating light source of high efficiency. Compounds which exhibit the characteristic of becoming fluorescent under ultraviolet light excitation are, for example, calcium tungstate, zincsilicate, magnesium tungstate etc. The fluorescent coating 28A as indicated by the dotted line in Fig. 4 is preferably on the inside of the tube. A globule of mercury 35 or mercury alloy or any other suitable metal vapor at the operating temperature of the lamp is also provided for.

A gaseous atmosphere of a suitable pressure using monatomic gases such as argon, neon etc. is provided within the tube, although in certain instances no gaseous atmosphere is required, since the filamentary electrodes provide enough heat radiation to vaporize the mercury globule 35 and provide enough metallic vapor for the operation of the tube, thereby providing the necessary source of ultraviolet radiation to excite the fluorescent coating material 28A by means of the ionized mercury vapor.

Interposed between the electron emitting electrodes which may be of any well known design, are the two condenser plate electrodes 34 and 33 having one or more perforations near the centre of said plates, which fit closely to the tube walls to reduce a current leakage around them. Connected to the two plates 34 and 33 is a resonant circuit 32 comprising an inductance and condenser and acting as a tank circuit for frequency multiplication.

In operation of the tube, the source of electric

current 30 of suitable potential through the stabilizing choke coil 31 produces a glow or arc discharge between the filamentary electrodes 29 which ionizes the gaseous atmosphere and the mercury vapor between them, producing ultraviolet radiations to excite the fluorescent material 28A. The electronic gaseous discharge is interrupted by means of the perforated plates 33 and 34 at a great rate, thus producing oscillations of increased frequency in the resonant circuit 32 as similarly as disclosed in the operation of the device shown in Figs. 3 or 1. The frequency of interruptions may vary from several hundred cycles per sec. up to hundred-thousand cycles per second or more, thus causing an increase in the luminous efficiency of the illuminating tube or lamp as compared against operation of the tube at the conventional 60 cycles per second alternating current. A 40 watt fluorescent tube operated at about 500 cycles per second gives about a gain of 20% in luminous efficiency (lumens per watt) against 50 to 60 cycles per second operation, with a corresponding increase in luminous efficiency at higher frequencies. The switch 36 is used for starting the tube and permits heating the electrodes up to electron emission temperature before the discharge starts, thus increasing the life of the electrodes. The condenser 37 in parallel to the switch reduces arcing and acts also to a certain degree as a by-pass condenser for the high frequency currents, being in shunt circuit to the tube.

Although the preferred location of the two plate electrodes 33—34 is about halfway between the two end electrodes 29, any other locations may be chosen by moving said plate electrodes to either end of the tube to any desired location. The plate electrodes 33 and 34 may be made of any suitable refractory material, preferably metals of high melting point and of low vapor-pressure, such as tungsten, tantalum, molybdenum etc.

Fig. 5 illustrates a modified structure of an electronic discharge device for illuminating purposes of the fluorescent tube type employing means to act as a light source and high frequency current oscillator simultaneously for the purpose to increase the luminous efficiency of the lamp. A tube 41 of a suitable length and diameter, for example having a diameter of about 2 inches and a length of about 48 inches contains at the opposite ends of the tube two electrodes 39 similar to the ones disclosed in Fig. 4 or any other type of electrodes well known in the art of high vacuum or electronic discharge devices. The tube 41 is also provided with a coating 40 of a fluorescent compound similar to the ones previously mentioned and indicated by a dotted line 40. A globule of mercury 48 is also provided for within the bulb. The fluorescent coating 40 may be either on the outside or on the inside of the tube, preferably on the inside.

A suitable gaseous atmosphere of a suitable pressure is also provided for within the tube. Interposed between the electron emitting electrodes are two metalplates 42 and 43 having between them a mica plate or a quartz plate 45. The two metalplates 42 and 43 having between them, as mentioned before, a mica or quartz plate represent therefore a condenser of a certain capacity and are of such shape and size so as to fit closely to the tube walls of the tube 41, thereby preventing any discharge to leak by and dividing the tube into two separate chambers.

A tank or resonant circuit 47 comprising an

inductance and a condenser are connected to the two condenserplate electrodes 42 and 43. The inductance of the resonant circuit 47 is preferably coupled to the inductance 46, which in series with the condenser 44, represents a shunt resonant circuit across the tube electrodes 39. A switch 45 is connected in parallel to the condenser 44 for the purpose of preheating the electrodes 39 to a temperature sufficient to produce electron emission before the gaseous discharge takes place; and as soon as the gaseous atmosphere is ionized and started the discharge, the switch is opened leaving it to the discharge to keep the electrodes 39 at a electron-emitting temperature. A source 38 of electric current either direct current or alternating current of a suitable potential is connected across the tube electrodes 39. Very little ballasting is required, such as resistors or choke coils in the supply line of the electric current, since the two plates 42 and 43 act as a condenser, which in connection with the resonant circuit 47 represents a positive resistance to counteract the negative resistance of the gaseous electronic discharge, which has a falling volt-ampere characteristic.

In operation of the tube or device, being energized from the electric source 35, a discharge takes place from one of the electrodes 39 through the ionized gas and/or metal vapor to the plate electrode 42, through the resonant circuit 47 to the plate electrode 43 into the ionized gas to the electrode 39 at the other end of the tube. The two condenser-plate-electrodes 42—43 become alternately charged to opposite potentials and discharged if the energizing current has a certain frequency, causing the resonant-circuit 47 to oscillate at its own natural frequency which is of a higher value, than the supply frequency.

The current changes in the circuit 47 are transferred by induction by means of the coil 46 to the shunt circuit 46 and 44 and are re-introduced again into the electronic discharge tube until steady operating conditions have been reached, very large voltage and current amplitudes may be obtained by means of this feed back circuit, favorable to excitation and ionization of the gaseous and vapor atmosphere for light production.

By using between the metal plates 42 and 43 a quartz-crystal-plate 45 of a suitable thickness, the frequency produced within the tube is controlled and generated by the properties of the quartz-crystal.

Radio frequencies are obtainable in the resonant circuit 47 and transferred into the gaseous discharge path of the tube by this method. In some instances the resonant circuit 47 may be completely omitted leaving only the plate electrodes 42 and 43 within the tube, representing a condenser of a suitable capacitive reactance to permit current flow at high frequencies, since a capacitive reactance of a condenser has a positive value, no external ballasting of the tube is required.

An oxide or azide coating of electron emitting properties may be provided for on the condenser-plate-electrodes 42 and 43 in order to lower the electrode voltage drop of the two plates acting as electrodes.

Fig. 5A illustrates in an enlarged view a structure of the condenser plate electrodes 42 and 43 having special means attached thereto in order to reduce the electrode voltage drop. The two metalplates 42 and 43 being spaced and having interposed between them a sheet of mica or a

quartz-crystal-plate 45 have attached to each plate an electrode member 42B and 43B of any suitable shape. These two electrode members may also be provided for with an oxide coating of high electron emission properties and in operation of the tube the discharge will maintain these two electrodes 42B and 43B at a temperature sufficient to produce electron emission, in the preferred type they consist of two small tungsten coils of a suitable coil diameter and pitch using a wire size small enough to heat up under the influence of the discharge.

The two metal plates 42 and 43 may also have an electron emitting coating 42A and 43A as previously stated, as for example, a barium azide coating and if desired the two coil electrode members 42B and 43B may be omitted in this case. The resonant circuit consists of an inductance 47 and a condenser 47A and is connected to the metal plate electrodes either as a parallel resonant or a series resonant circuit. For direct current operation of the tube a parallel circuit as shown in Fig. 5 is preferred in order to enable the direct current to flow through the inductance 47 and keep the discharge going. For alternating current operation the capacitive reactance of the condenser 47A is low enough to keep the discharge going in connection with the inductive reactance of the coil 47 in case of a series circuit connection.

An electronic discharge device of the fluorescent type used for illuminating purposes and acting as an electric current interrupter of a high-frequency simultaneously to raise the luminous efficiency, is shown in Fig. 6. The tube 50 is provided with a fluorescent coating 49 and a suitable gaseous atmosphere of proper pressure and has two electrodes 51 at the opposite ends of the tube. A globule 52 of mercury is also contained within the tube. Interposed between the two electrodes 51 is a plate or diaphragm 53 having a small perforation 54 in the centre of the plate. Said plate may be made of any suitable material, such as mica, porcelain, carbon, metal, etc., preferably a metal plate of a highly refractory nature is desired. A source 57 of electric current of a suitable potential is connected through the wires 57A and 57B over a small inductance 55 to the two electrodes 51, across the tube. A condenser 56 in connection with the inductance 55 acts as a shunt resonant circuit across the tube 50. In operation of the tube, being energized either from D. C. or A. C. current of proper voltage, a discharge is produced between the two electrodes 51, which pass through the small perforation 54. The shape of the plate is such so as to fit closely to the tube walls.

An ionized plasma or gas film forms in the perforation 54 due to charges acquired by the plate 53 and causes the diameter or the thickness of the plasma to increase or decrease and close and open the perforation for the electric discharge current flowing through, thus causing electric current interruptions at a very high rate.

The resonant circuit consisting of condenser 56 and inductance 55 will also be utilized for the production of oscillations by being connected in shunt circuit to the tube 50, acting as a tank circuit.

However it is understood that for the production of the interruptions this resonant circuit is not necessary, that is to say only a very small inductance 55 is required while the condenser 56 may be omitted or vice versa. Since the perforation 54 is small it has sufficient resistance

to act as a stabilizing means for the electric discharge and will permit the rise of the current flow only to a certain value, when it starts to break the current, consequently a very small inductance is required having an inductance value insufficient to stabilize the discharge if the diaphragm 53 were omitted.

Fig. 10 shows in a diagram the current flowing through the tube 50, having perforated diaphragm 53, plotted as a function of the time. The dotted line shows the exponential current rise and the final value the current would have due to the inductive time constant of the circuit, ionization time of the gas-vapor atmosphere etc.; however due to the perforated diaphragm the current is limited to a certain value and is interrupted periodically, producing current pulses as shown in the graph or diagram thus preventing excessive current-values to flow through the tube. The time constant of the circuit, the ionization and de-ionization time, gas pressure, size of the perforation and the thickness of the diaphragm 53 are factors determining the interrupter frequency of the current flowing through the tube.

The lamp structure shown in Fig. 7 consists of a bulb 58 having light transmitting properties adapted to be provided with a screw base or its equivalent, so that it may be used in an ordinary lamp socket having the usual line voltage of about 120 volts. The inside wall of this bulb, preferably being an oversized bulb to obtain a large surface area for the fluorescent or phosphorescent coating material 59 is coated with the usual fluorescent compounds as previously disclosed, suitably selected to produce different colors or a white light approximating daylight. Although the actual wattage in the lamp consumed may be such that a smaller bulb would give sufficient wattage dissipation per square inch of bulb area, an oversized bulb is preferred to give increased coating surface area for the fluorescent or phosphorescent material and to keep the fluorescent coating sufficiently cool which is necessary for efficient light radiation and conversion from the ultraviolet into the visible light. The bulb 58 contains a gaseous atmosphere of gases as previously mentioned at a suitable pressure and a globule of mercury 68 or an alloy of mercury. Supported in the press 64, of a stem, by lead-in wires 69 and 70 are a pair of electron emitting electrodes of any well known type, preferably a pair of oxide coated electrodes 63 and 64 consisting of coils of wire such as tungsten, having a fine wire coiling on the tungsten wire core and an oxide coating thereon. The two electrodes 63 and 64 are connected to a source 67 of electric current of a suitable potential through the lead wires 69 and 70. Interposed between the suitably spaced electrodes 63 and 64 are two metal plates 61 and 62 which are slightly separated by a sheet 60 of mica or a quartz plate acting as a dielectric for the two plates acting as a condenser. The two plates and the mica sheet are supported by the support wires 71 and 72 in the press of the stem. Connected to the two metal plates 61 and 62 by the two lead wires 71 and 72, is a resonant circuit consisting of an inductance 66 and a condenser 65 acting as a tank circuit for the production of high frequency oscillations and frequency multiplication. In certain instances this tank circuit may be omitted and the condenser plates 61 and 62 have sufficient capacity to act as a ballasting device and as a condenser, becoming

charged and discharged at a great rate, produce current interruptions of the electronic discharge and thus increase the luminous efficiency of the lamp. If the dielectric used for the condenser plates 61 and 62 is a quartz plate or crystal of suitable dimensions, use is made of the piezo-electric properties of such crystals causing said quartz plate to oscillate at its own natural frequency, producing oscillations of very constant frequency.

The modified structure of Fig. 5A may be used in the lamp of Fig. 7 in place of the plate-electrodes 61 and 62 shown, if desired. In operation of the lamp the source 67 of electric current produces an ionization of the gaseous atmosphere and mercury vapor surrounding the electrodes 63-64 and the plate electrodes 61-62, causing a glow and/or arc discharge, said luminous glow producing ultraviolet radiation and excitation of the fluorescent coating compound. The condenser plate electrodes 61 and 62 being interposed into the discharge path of the two electrodes 63 and 64, resist the ion and electron flow between these electrodes and act as a stabilizer, thus permitting the use of this lamp to be operated without any further external ballasting device. The resonant circuit comprising the inductance 66 and condenser 65 connected to the plate-electrodes will be energized by the discharge and cause the current flowing through the tube to vary alternately at a regular rate. If the area of the two plate electrodes 61-62 is relatively large compared against the area of the two electrodes 63 and 64, point to plate rectification will take place and the rectified current pulses will cause by impulse excitation oscillations being produced in the resonant circuit of a higher frequency than the supplied frequency of the electric current source. If the frequency in the resonant circuit is sufficiently high, very high resonant voltages will be produced in this circuit across the condenser plate electrodes 61 and 62, forcing these plates to act as a small condenser-antenna, radiating high frequency fields which due to the high conductivity of the surrounding gaseous atmosphere is absorbed and converted into luminous radiation of the gaseous-metal vapor medium, which extends in the form of a luminous glow all over the bulb. Rectification between the electrodes is of course also obtained if the electrodes 63 and 64 are of the heated electron emitting type and the plate electrodes 61-62 of the cold electrode type, instead in the case of point to plate rectification in which case all electrodes may be cold electrodes.

Fullwave rectification of the supplied alternating current is obtained in the lamp shown in Fig. 7 and utilized for the purpose of frequency multiplication as previously disclosed.

The inductance 66 will permit for direct current operation current flow through the lamp and cause operating conditions as previously disclosed. As soon as the D. C. voltage is applied to the electrodes 63 and 64 the condenser plates 61-62 and the condenser 65 will become charged and cause the voltage across these plates to increase to twice the value of the supplied line voltage. Ionization takes place in the gaseous medium around these condenser plates and causes discharging and de-energizing of the condensers with consequent current pulsations and interruptions of a given frequency, determined by the time constants of the circuit.

It is also sufficient to state here that the dimensions of the two plate electrodes 61 and 62

should be such that a discharge either in the form of a glow or arc cannot take place directly between the two electrodes 63 and 64, while otherwise a glow discharge between the two charged condenser plates 61 and 62 through the outside surfaces facing the electrodes 63-64 (no discharge being possible between the inside of the plates due to the mica sheet) should be permitted in order to discharge or de-energize the circuit consisting of the condenser plates 61-62, condenser 65 and inductance 66.

The proper spacing of the electrodes 63-64 from the plates 61-62 and a suitable gas pressure within the bulb will permit such operating conditions.

Referring now to Fig. 8 a modified structure of the lamp disclosed in Fig. 7 is shown. A bulb 71 of glass or other material having light transmitting properties and a gaseous atmosphere of a suitable pressure is provided for. A quantity of mercury 74 or alloy is also contained within the bulb 71. The bulb 71 is covered either on the outside or inside with a fluorescent material having a certain coating density of fluorescent material per unit surface area of the bulb, the material being any one of the large group of compounds known to become fluorescent or phosphorescent under the influence of a electronic discharge or a ultraviolet radiation. A tubular stem 73 supports by means of lead-wires the electrodes 75 and 76, which may be of any well known type, cold electrodes, hot cathodes, direct and indirect heater type or of the type previously disclosed. The two electrodes 75 and 76 are connected through the lead wires 75A and 76A to an electric source of current 79 of a suitable potential. Interposed between the two electrodes is a cylindrical cup-shaped member 77 which has a perforation 78 of a suitable size facing the two electrodes. Said member 77 may be provided for on the inside and outside with a barium oxide or azide compound in order to produce a negative glow discharge for starting of the lamp. The cup-shaped control member 77 is supported by a tight-fitting glass or isolantite insulating sleeve 73A attached to the stem 73, thus shielding the electrode 76 completely from the rest of the bulb space, except through the perforation 78. The member 77 is connected through a lead-wire and a condenser 80 to one side of the electric source 79 at a point 81.

In operation of the lamp the electric source of current 79 will produce between the two electrodes 75 and 76, which are suitably spaced, an electronic, glow or arc discharge causing through a plasma film or ionic sheath surrounding the perforation 78 a periodic constriction and expansion of the electronic discharge, thus causing current pulsations or interruptions of a high-frequency or rate. As previously stated the gaseous atmosphere may be omitted in certain instances and the mercury vapor present in the bulb may provide the current conducting and ionizing medium to produce ultraviolet radiation for the excitation of the fluorescent or phosphorescent material.

The cup-shaped control member 77 has a relatively large surface area against either of the two electrodes 75 and 76 and produces rectification of the electric current, in case of A. C. current, between the electrode 76 and the member 77 in the form of a glow discharge, thus charging the condenser 80 with pulsating direct current and discharging through the gaseous atmosphere by means of the metal member 77 to either of the

electrodes 75 or 76 at a great rate set by the time-constant of the condenser 80 and the resistance of the discharge path through the gas-vapor atmosphere. The control member 77 therefore receives periodic potential pulses, thus causing the plasma film or ionic sheet, surrounding the aperture 78, to vary in size and thus cause modulation, pulsations or interruptions in the main discharge taking place between the electrodes 75 and 76 accordingly, as previously disclosed. The condenser 80 may in certain instances be omitted and the member 77 be left open or neutral without any wire connections to any of the electrodes or to the circuit. Sufficient charges acquired by the member 77 will produce a varying plasma film around and in the perforation 78 to produce current interruptions of a high-frequency as disclosed in Fig. 6.

Since both electrodes 75 and 76 are of the hot cathode electron emitting type they will act as anodes and cathodes alternately on A. C. current and permit rectification of the A. C. current relative to member 77 for charging the condenser 80, which discharges consequently through the tube. As previously mentioned, the proper spacing between the electrodes, the proper size of the perforation 78 in the member 77, a suitable gas or vapor pressure, the capacity of the condenser 80 are the factors determining the generated frequency. The electric source 79 may be either direct-current or alternating current of a suitable potential. The frequency generated within the lamp may vary from a few hundred cycles per second up to several hundred thousand per second or more.

Fig. 8A discloses a modified structure to be used in a fluorescent lamp device as shown in Fig. 14. All parts of the electrodes and the circuit are shown for the purposes of simplicity without the bulb and are identified by the same numbers used in Fig. 14.

The electrode 76 in order to facilitate easy starting of the lamp on low voltage circuits consists of a tungsten wire coil being connected through the lead-wires 76A and 76B over a switch 82 and a small ballasting device 83 to a electric source 79 of a suitable potential.

If the switch 82 is closed an electric current flows through the electrode coil 76 heating it to a temperature sufficient to produce electron emission and ionization of the gas-vapor atmosphere within the bulb and as soon as this point has been reached the switch may be opened causing the electric source 79 to maintain a discharge between the electrodes 75 and 76. A rectification action takes place between the electrode 75 and the cup shaped electrode member 77 thus charging the condenser 80 with a direct current potential. The periodic interruption of the current flowing through the lamp is accomplished by the use of the condenser 80 and resistor 83 combination in the circuit containing the member 77, having one or more perforations 78. The condenser 80 acquires a charge from the electric current source 79 through the resistance 83 as previously mentioned. Initially the voltage across the condenser is zero, but as time goes on, the voltage across the condenser increases until at the end of $R \times C$ microseconds, it has a value of about 63 per cent of the full line voltage value. The charged condenser alternately discharges through the lamp, recharges from the line voltage, recharges into the lamp and so on at a great rate per second thus causing a periodic in-

terruption of the current flowing between the main electrodes 75 and 76 at the same rate.

Fig. 9 illustrates an electronic discharge tube used as a illuminating lamp of the fluorescent tube type embodying means to produce current interruptions or high frequency oscillations within said tube for the purpose to increase the luminous efficiency. A tube 84 of light transmitting material is provided with a gaseous atmosphere of a suitable pressure and contains a globule 86 of mercury. A coating 85 of fluorescent or phosphorescent material either on the inside or outside of the tube or embedded in the glass or other light transmitting material of the tube 84 is also provided for. Two electron emitting electrodes of the type previously described are at the opposite ends of the tube as indicated by the numbers 86A and 86B. One of the electrodes 86A is connected through an inductance 93 to one side of the electric source of current 91 while the other electrode 86B is connected through a resistance 95 to the other side of the electric current source 91 of a suitable potential. A resistance 92 is connected across the current source 91. A switch 97, having a condenser 96 across it, is also provided for preheating the electrodes for starting purposes. A cup shaped control member 88 having one or more perforations 87 acting as a control electrode member is placed near or around the electron emitting electrode 86A and is connected by a wire and a variable contact member to the resistance 92. Using the condenser 94 and resistance 95 combination in connection with the perforated control-member 88, periodic interruptions of the electric current flowing through the gas and/or vaporfilled tube is accomplished. When the voltage of the source 91 is connected to the tube by means of a switch, the electric source being assumed in this particular case to be direct current, the condenser 94 charges from the source 91 through the resistance 95.

Initially the voltage across the condenser is zero, but as time goes on the voltage across the condenser increases until after the time-interval of R times C microseconds, a value of 63% of the full line voltage is reached (R =resistance, C =capacity). This increasing condenser voltage is impressed across the inductance and the cathode-anode circuit of the tube, which is prohibited from passing current by the direct bias voltage impressed to the control member 88 of the tube. This bias voltage, obtained by the resistor 92 across the direct current line 91 and acting as a potentiometer or voltage divider has such a value that it allows conduction through the tube when the condenser voltage has increased to a value less than the supply line voltage 91. The tube conducts at this moment and the condenser 94 starts to discharge sending a pulse of current through the inductance 93 and the tube 84. Because the resistance of the inductance and the tube is less than the charging resistor 95, the condenser loses its charge through the tube much faster than it gains from the source 91 and consequently the voltage across the condenser decreases more or less rapidly to a value sufficiently low to stop the discharge in the tube. It is necessary however to have the tube continue to be conducting at this time or the condenser would start recharging from the source 91 immediately again and the tube would be conducting again before deionization had occurred or before the control member 88 had regained control.

The inductance 93 maintains the discharge for a brief time after the voltage value of extinction is reached. As soon as the discharge finally stops, the condenser requires time for recharging to the conduction or ignition point, thus obtaining enough time for deionization. Therefore the tube is non-conducting until the condenser has been charged to a value which is below the line voltage at which the control member permits normal conduction to start.

The condenser therefore charges from the source 91 and discharges through the tube, recharges from the source again and redischarges through the tube at a great rate per second.

Instead of employing a control member 88 enclosing the electrode 86A completely as shown in the upper half of the Fig. 9, a perforated flat disc diaphragm or control member 89 as shown in the lower half of the Fig. 9 may be used to produce current interruptions in the tube. The broken lines in the middle of the tube indicate a composite drawing illustrating another way and means of producing interruptions. In this particular case a perforated disc or plate acting as a control member is placed relatively close to one of the electrodes 86A and 86B or each of the electrodes may have a perforated plate placed ahead of them. No connections to any part of the circuit are required and the actions taking place are similar to the ones disclosed in Fig. 6. By placing the perforated plate control-members 89 having one or more perforations 90 close to the electrodes 86A and 86B, these plate members will also act as shields and prevent depositing of evaporated and sputtered electrode material on the fluorescent coating material 85 in the positive column part of the tube 84 while all the sputtered electrode material will be held back behind the plate members in the space surrounding the electrodes. Better lumen maintenance is thus maintained throughout the life of the tube, besides the fact that the plate members act as means to produce current interruptions or high frequency oscillations simultaneously for the purpose to increase the luminous efficiency. The gaseous atmosphere may also be omitted if desired and the mercury vapor alone within the tube is sufficient to carry the current, a condition of this type is very favorable for the operation of the tube as a current interrupter in connection with one or more perforated plate members within the tube.

It is of course also understood that the term "high frequency" used throughout the specifications in describing the various circuits covers the range from about 100 cycles per second or more up to ultra high frequencies, since considerable increases in luminous efficiency for fluorescent tubes and lamps are obtained at a frequency of several hundred cycles per second already.

It will be apparent to those skilled in the art that the features of this invention may be embodied in other physical structures without departure therefrom. I do not, therefore, desire to be strictly limited to this disclosure, which is provided for the purpose of illustrating and describing the invention, but rather to the scope of the claims granted.

What I claim is:

1. A high frequency oscillator comprising an electronic discharge device and a resonant circuit, said electronic discharge device consisting of a tube having thermionic electrodes spaced opposite each other and having interposed between said thermionic electrodes spaced metal

plates acting as a condenser and electrodes for the electronic discharge at the same time, an inductance connected to said condenser electrodes thereby constituting a resonant circuit, a source of electric current energizing said electronic device and charging and discharging said condenser electrodes by means of the electronic discharge from said thermionic electrodes and causing said condenser electrodes and said resonant circuit, to produce high frequency oscillations in said circuit.

2. In an oscillator, a bulb containing a gaseous atmosphere, thermionic electrodes for passing a discharge through said gas, a plurality of closely spaced metal plate members interposed between said thermionic electrodes acting as condenser and electrodes simultaneously, said condenser plates having small perforations, a source of electric current causing an electronic discharge between said thermionic electrodes, said perforated condenser plates periodically interrupting the electronic discharge flowing through said perforations of the condenser plates, thus causing said condenser plates to charge and discharge through a resonant circuit connected to said condenser plates, thereby producing high frequency oscillations.

3. A light radiating electronic discharge oscillator, comprising a light transmitting gas-filled tube, luminescent material associated with said tube, thermionic electrodes spaced opposite within said tube, closely spaced perforated metal plates interposed between said electrodes acting as condenser electrodes, a source of electric current causing an electronic discharge between said thermionic electrodes, said perforated condenser electrodes periodically interrupting the electronic discharge, thus causing said condenser electrodes to charge and discharge through the tube by means of a resonant circuit connected to said condenser plate electrodes, thus energizing and ionizing the gas and the luminescent material with high frequency currents thereby causing said tube to radiate light of increased luminous efficiency.

4. A light radiating electronic discharge oscillator, comprising a light transmitting gas-filled tube, a coating of luminescent material attached to said tube, spaced thermionic electrodes within said tube, spaced metal plates interposed between said electrodes, a resonant circuit connected to said metal plates, a source of electric current energizing said tube and charging and discharging said metal plates by means of the electronic discharge from said thermionic electrodes, thereby converting the current flowing through said tube into high frequency currents and causing the gaseous atmosphere and the luminescent coating to radiate light of increased efficiency.

5. A light radiating electronic discharge oscillator, comprising a light transmitting gas-vapor filled tube, a coating of fluorescent material associated with said tube, spaced thermionic electrodes within said tube, a perforated plate member interposed between said thermionic electrodes, a source of electric current producing an electronic discharge between said electrodes, said perforated plate member periodically interrupting the discharge current at a high-frequency thereby energizing the gas-vapor atmosphere and the fluorescent material with high-frequency currents and thus causing light radiations of increased efficiency from said electronic discharge oscillator tube.

6. A light radiating electronic discharge lamp

oscillator device, comprising a gas-filled bulb, a metallic vapor also within said bulb, a fluorescent material associated with said bulb, spaced thermionic electrodes within said bulb, a perforated member interposed between said electrodes, a source of electric current producing an electronic discharge between said electrodes, said perforated member being connected to a point of suitable potential of the electric circuit, a condenser connected across said electrodes, said perforated member and condenser causing the electronic discharge to be converted into high frequency current pulsations thereby producing light radiations of increased luminous efficiency from said lamp oscillator device.

7. A light radiating lamp oscillator, comprising a gas-vapor filled tube, a fluorescent material associated with said tube, spaced electrodes for passing a discharge through said atmosphere within said tube, a perforated electrode interposed between said electrodes, a resonant circuit comprising a condenser and an inductance connected to said perforated electrode and said other electrodes, a source of electric current energising said tube, said perforated electrode producing high frequency pulses or current interruptions within said tube and its associated resonant circuit, thereby producing a high frequency pulse radiation of increased luminous efficiency from said lamp oscillator.

8. A radiating electronic oscillator comprising

a gas-vapor filled tube, spaced electrodes within said tube, perforated members interposed between said electrodes, a resonant circuit comprising a condenser and an inductance connected to said members, a source of electric current producing an electronic discharge between said spaced electrodes, said perforated members and resonant circuit causing the electronic discharge to be converted into high frequency current pulsations of large current and voltage amplitudes having a very short time duration, thus causing said oscillator to produce very intense electromagnetic radiation pulses of increased efficiency.

9. A light radiating electronic discharge lamp oscillator, comprising a gas-vapor filled tube, spaced electrodes for passing a discharge through said gas-vapor atmosphere, a perforated member interposed between said electrodes a resonant circuit comprising a condenser and an inductance connected across said electrodes, a source of electric current energising said tube, said perforated member producing periodic current interruptions or pulses of high voltage and large current amplitudes and of a very short time duration at a high rate of repetition, thereby producing high frequency oscillations and/or pulsations within said tube and its associated resonant circuit, thus causing said lamp oscillator to produce intense electromagnetic radiations of increased efficiency.

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