Jan. 26, 1937. O. STETTLER 2,068,775

DISCHARGE TUBE

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Fig.1

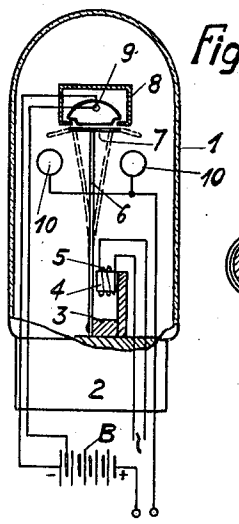


Fig.6

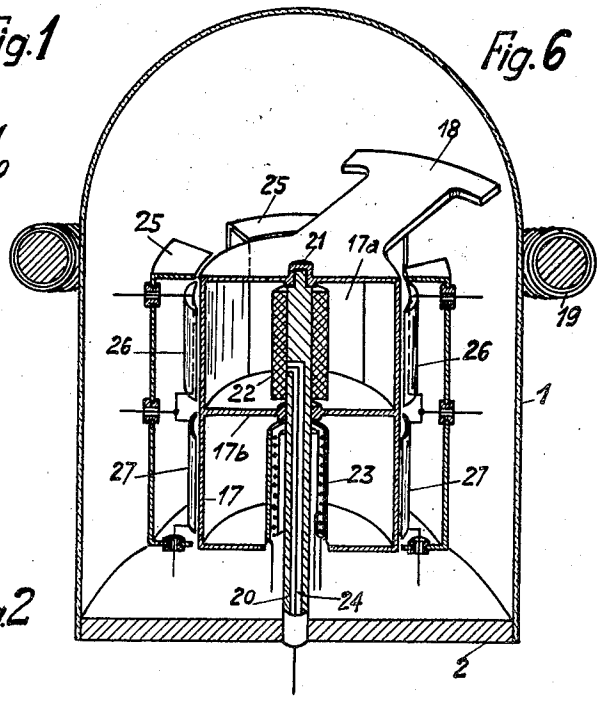


Fig.2

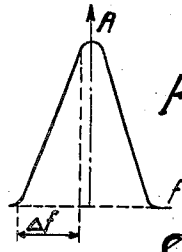
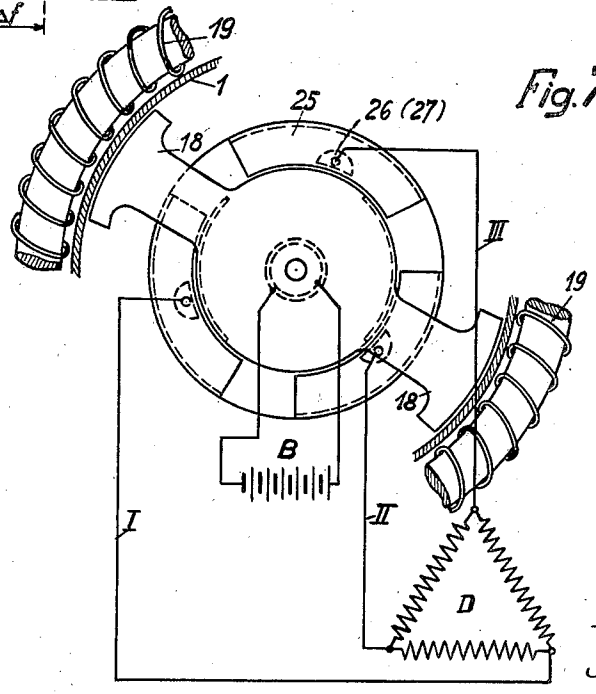


Fig.7



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Fig. 5

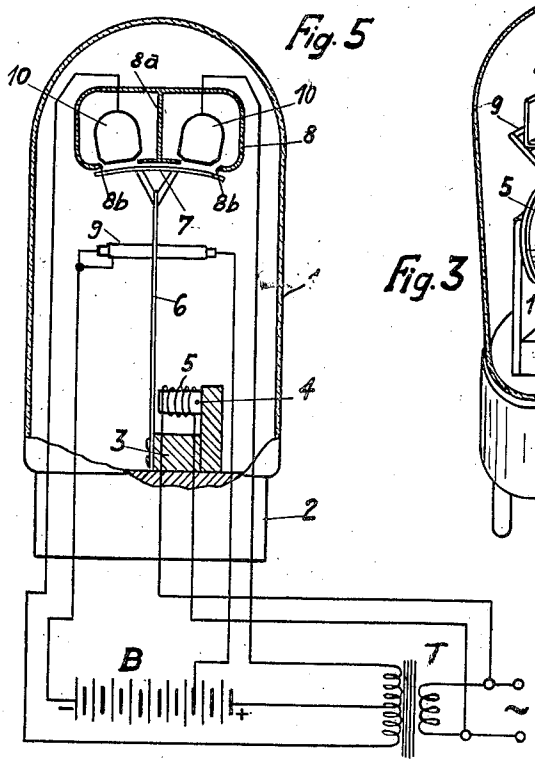


Fig. 3

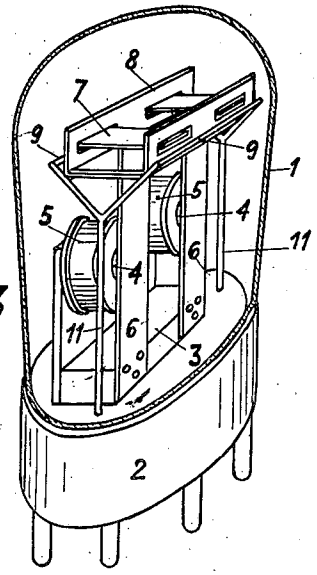
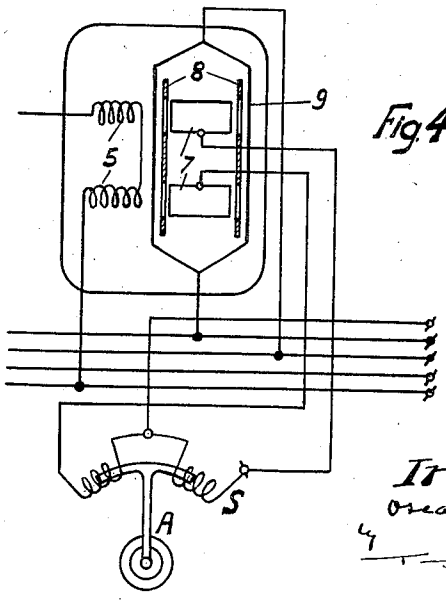


Fig. 4



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UNITED STATES PATENT OFFICE

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DISCHARGE TUBE

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11 Claims. (Cl. 250—27.5)

This invention relates to the control of the electron current in an electron tube especially for the purposes of current regulation, amplification, rectification, conversion and the like.

It has been proposed heretofore to control the electron current by regulating the cross-sectional area of the current path. Due to the peculiarities of the electron stream, however, and the fact that the stream contracts with increasing current, this manner of control is not susceptible to fine regulations. Furthermore, in a gaseous electron tube wherein the discharge current is set up mainly by vapor ions, starting and stopping the discharge ordinarily cannot be accomplished.

It is an object of the present invention to regulate the electron current in a more accurate and closer manner than has been possible heretofore by regulating, not the cross-sectional area of the electron stream, but the extent of active area of the electrodes, or at least one of them, that forms a seat for the stream. The electron current is a function of the active area and hence by varying the active area and by proper shaping of the screen or electrode area, or both, fine regulation and control in accordance with any selected plan may be accomplished. Further, by completely eliminating all active area of an electrode from the electron stream, the discharge ceases. Hence the discharge can be started and stopped at will.

A further object is in regulating the extent of effective active area of a working electrode of an electron tube by a screen which is movable across the active area, and is positioned so closely thereto that the screened area is excluded from the electron stream. For control of the electron stream it is essential that there be relative movement between the screen and electrode. It is immaterial which is the movable member although for practical purposes it is preferable that the screen be the movable member.

A further object is the provision of an electron tube having two electrodes, as two anodes, and a third electrode, as a cathode, common to the first two electrodes, with a screen so arranged as alternately to control the discharge streams between the common electrode and the two electrodes so that, for instance, the conversion of direct into alternating current can be effected.

It is a further object to mount the control screen on a vibratile support. The natural periodicity of vibration is about equal to the desired periodicity of control of the electron stream so that the screen can be vibrated electromagnetically by a small amount of alternating current energy of approximately the same periodicity, and the amplitude of vibration can be modified by small changes of periodicity of the actuating current.

As in highly evacuated tubes with a filament the magnitude of the emission, among other things, constitutes a function of the size of the active emission surface, it is possible in certain cases to arrange the movable screening member directly in front of the active cathode surface whereby there is again possible the advantage of a fine stage regulation of the discharge. Such arrangement constitutes a further object of the invention.

The movement of the member by means of which the emission is controlled may be effected by positive control, it may, for alternating current rectifying, direct current conversion into alternating current and relay purposes with relatively large time constants, be a mechanical sine shaped oscillation, while there is utilized the advantage that for the energization and maintenance of a mechanical oscillation in the natural frequency of the oscillating body, particularly when this is suitably constructed, a very small amount of energy is required. This is a further object of the invention.

For relay, alternating current rectifying or direct current converting tubes, which operate with gas discharges, the arrangement, according to the invention, enables the stationary and movable screening elements, in special cases the movable anode or cathode, to be so constructed that when the movable member is in the position of rest the anode space is so separated from the cathode space that the discharge along a path other than the usual one is obviated. This arrangement is a further object of the invention.

Examples of construction according to the subject of the invention are illustrated in the accompanying drawings, wherein:

Fig. 1 shows in diagrammatic section a first form of construction of a discharge tube as relay.

Fig. 2 shows the resonance curve of the spring thereof.

Fig. 3 shows a form of construction of a discharge tube as a double resonance relay in perspective view, and

Fig. 4 the circuit diagram thereof.

Fig. 5 shows in diagrammatic section a further form of construction of a discharge tube for the conversion of direct current into alternating current, or alternating current into direct current.

Fig. 6 shows in vertical section a form of con-

struction of a discharge tube for converting direct current into polyphase current or polyphase current into direct current, and

Fig. 7 shows a diagrammatic plan thereof.

Fig. 1 shows a discharge tube of high vacuum or with gas filling, of which the glass bulb 1 is secured in the usual manner on a base 2. On the base there is secured, inside the bulb, a magnet 3 of which the core 4 carries the winding 5. To the foot of the magnet 3 an upwardly extending spring 6 is so secured that it swings to and fro in response to variations of energization of said magnet. The spring carries at the upper end a screen plate 7 of metal or insulating material which covers a correspondingly large opening of a box-shaped screen casing 8 of metal or insulating material.

The screening and also the spring can be connected to a suitable potential through high ohmic resistances for keeping the potential constant. In the interior of the screen casing 8 is located the electrode 9 which has a surface thereof, projecting into the opening thereof. Outside the screen casing 8 there are located directly underneath, the counter electrodes 10, in this case anodes. When a potential, for example the continuous voltage of the battery B, is applied to the stationary electrodes a discharge current is produced as soon as the screen plate 7 exposes the opening of the casing 8. The active cathode surface varies according to the size of the opening thus exposed and thus also the strength of the discharge current. When the magnetic flux is varied, for example, by a variable direct current the movable screen part can be moved thereby more or less from its rest position, while the size of the active electrode surface is varied. The movement of the spring may be effected by mechanical, magnetic, electromagnetic, electrodynamic or other forces.

The advantage of this arrangement resides in the fact that by means of a very small controlling energy large energies, which traverse the discharge path, can be varied continuously and in proportion to the controlling energy. When the control electrode is so constructed that it has a low mechanical inertia, this relay may be employed, when using a gas discharge, preferably as amplifier for acoustic frequency mixtures. With such a tube it is possible with a small control energy and while using a low anode potential, to obtain a larger controlled output than with the arrangements at present known. As it is possible to suitably arrange the ratio of the discharge current, relatively to the control current, in other words to suitably shape the static and thus also the dynamic base lines, on the one hand by suitably shaping the covering openings and on the other hand by varying the rectifying force of the electrode, the distortions occurring in a preceding amplifier part or in a loud speaker can be corrected by a tube of this character.

As a continuously adjustable relay for controlling operations below the audible frequency the tube described is particularly efficient when the oscillating screen part according to Fig. 1 or a movable electrode is formed as a blade spring, while it is particularly of importance that the spring has a sharply defined natural frequency and the energy required for maintaining the oscillation is small.

When an alternating current is used as controlling current, which can be varied in the frequency range f (Fig. 2) the amplitude of the spring from zero to maximum according to the resonance curve (Fig. 2) of the spring can be obtained by the frequency variation f.

In the electrical transmission technology there frequently arises the necessity of transmitting continually varying operations by wire or by wireless and in the general art it is frequently desirable to transmit movement operations in finely adjusted form and staging by means of distant transmission. The combined problem, formed by these two problems, of electrical transmission was solved hitherto by means of more or less complicated devices which were exposed to numerous sources of error and were therefore only relatively reliable. The problem in question can be solved with advantage by the arrangement hereinafter described.

As is well known, only very small energies are required for oscillating a body which is easily capable of oscillation when the driving alternating force has a frequency in the neighbourhood of the natural frequency of the body. The transmission ratio of the relay in this arrangement is therefore particularly large.

It will be understood by the mounting of a number of springs having different natural frequencies in a tube it is possible to transmit different control operations which are continuously adjustable independently of one another. The controlling current must then be a frequency mixture which is composed of the variable alternating currents of frequency ranges of the springs which have been provided. This composite controlling frequency can best be produced on the control side by one or more tube oscillators, while for tuning there are used adjustable oscillating circuits. Each oscillating circuit must in this case include the frequency range of at least one spring.

Fig. 3 shows in perspective view a gas discharge relay wherein the size of the active anode surface is varied for regulating the strength of discharge. As in the constructional form first described all the parts including the glass bulb 1 are secured in a gastight manner on a base 2. To the base is secured a permanent magnet 3 with O-shaped magnet body, at the sides of the limbs of which are provided short cores 4 which carry two coils 5. Opposite the pole faces of these cores two blade springs 6 are secured at their lower ends for free oscillation to the magnet yoke. These two springs have different natural frequency numbers which deviate by about 10% from the average control frequency. One spring, for example, has a natural frequency of 50−5=45 cycles, the other 50+5=55 cycles. To the free ends are secured at right angles to the spring surface anodes formed as transverse plates 7, which during oscillation enter slots of metal screens 8 provided on both sides. On both sides of this screening there are provided outside thereof filaments 9 which are carried by holders 11 serving simultaneously for the supply of current. As the screening plates are also mounted on these holders there is practically no potential difference between them and the filaments. The two coil ends, the filament outgoing wires and the springs are electrically insulated from one another and are connected to the corresponding base pins and the glass bulb is filled with a gas suitable for ionization.

Fig. 4 shows diagrammatically the circuit of a tube of this character and at the same time an example of use for the production of a continuous control movement. The two anodes 7 are in this case connected to the outer ends of a two

part solenoid S of which the middle point is connected to any suitable source of current. A forked armature A, mounted on a shaft, engages with its prongs in the two solenoid coils and is rocked in one or the other of the coils according to the amplification of the current. On the armature shaft may be mounted, for example, the valve body of a controlling valve for a hydraulic or pneumatic servomotor.

The method of operation of this device is as follows: The current from an amplifier flows modulated in control frequency through the two magnet coils 5, so that the permanent magnetism is amplified or weakened in the same rhythm as the current fluctuations. If now, by means of the control member of the transmitting device, the control frequency is always approached more towards the natural frequency of one of the springs 6 this acquires gradually stronger vibrations, i. e. resonance, the more it approaches the natural frequency. The anode plate 7 of the oscillating spring passes with an always increasing amplitude on both sides through the corresponding screen slots and when a positive potential is applied to the anode 7 relatively to the filaments 9 there occurs at each passage of the plate 7 through the screen slot a powerful transmission of current between plate 7 and filament 9.

The occurring current is approximately proportional to the plate surface passing through, this in turn being proportional to the oscillation amplitude. The amplitude increases with increasing approach of the natural frequency of the control frequency towards the natural frequency of the spring. This approach is effected by suitable movements of the control member at the transmitting station from the zero position outwardly. By suitably shaping the oscillating anode plates 7 proportionality can be obtained between the angle of movement of the control member and the control movement. When the control member is moved from the zero position towards the other side the same action takes place by the other spring. This effects a control movement towards the other side.

By means of the double resonance relay it is possible to adjust control movements to the left and right through a suitable angle with great rapidity and precision. The control operation is not effected in stages, but continuously, which is essential for the precision of the control. This resonance distant control takes place with a minimum of electron tubes. It is therefore, by reason of its simplicity, also very reliable. It will be readily understood that by suitably increasing the number of springs in the relay the various controls can be actuated simultaneously.

The discharge relay for high vacuum or gas filling above described can also be used with advantage as frequency generator. Electric frequency generators, which mostly operate with back coupled electron tubes, depend upon a number of working conditions, for example on the anode potential, the grid potential, the heating potential, the guiding of the leads, on the temperature and so forth. From this it follows that the production of a constant frequency by this method is very difficult. Quartz oscillators are particularly suitable for high frequency oscillations. The frequency generator according to the arrangement above described is characterized by its great frequency constancy as mechanical oscillatory structures with prominent natural frequency are very uniform in frequency at constant temperature. The resonance curve is very steep. The steepness thereof is further increased because in the arrangement described the oscillatory structure operates in vacuum or at considerably reduced pressure. For the production of high frequency there may be used the known means of frequency multiplication. The maintenance of the oscillation may be effected by the controlled current. For the production of a number of constant frequencies a number of oscillating systems may be mounted in a tube. For the production of a variable fequency the securing point of the oscillatory structure may be varied by a suitable device.

While the discharge tube relay serves for the continuous linear or non-linear output amplification of comparatively slow control operations as also for the production of constant frequencies such a tube may also be used as an undulator of suitable currents or particularly for the conversion of continuous current into alternating current of suitable form of the current or potential wave and suitable phase number.

Fig. 5 shows the simplest form of arrangement for the conversion of continuous current into alternating current by means of a discharge tube of this character. A glass bulb 1, highly evacuated, or filled with dilute gas, which has suitable properties for the discharge operations, is secured to the base 2. A magnet system 3, which can be variously magnetized by the coil 5 fitted on the core 4, carries the blade spring 6 consisting of magnetic material. The screening casing 8 of metal or insulating material with the central portion 8*a* and the two discharge openings 8*b* contains in each of the two chambers, formed by the partition 8*a*, an anode 10 which anodes are seated directly adjacent the openings 8*b* and are connected each to a separate end of the primary winding of the associated transformer T. The middle tapping of this winding leads to the positive pole of the direct current source B. A cover plate 7, which in the rest position covers the openings 8*b*, is secured to the upper end of the blade spring 6. Outside the screening casing 8 is provided the counter electrode 9. The cathode 9 is connected to the negative pole of the direct current source B. The natural frequency of the spring is so chosen that it coincides with the alternating potential to be produced. The magnet winding 5 may be connected to the secondary winding of the transformer T. When the spring 6 is oscillated by an alternating current passing through the coil 5 the two discharge openings 8*a* and 8*b* are alternately exposed, the discharge current alternately following the path, in the manner of a simple commutator, between one of the two anodes 10 and the cathode 9. By suitably shaping the discharge openings the curve of the alternating current may be given any suitable shape. By the use of an indirectly heated cathode, as shown the whole of the direct current potential may be utilized for heating.

By means of a direct current winding, which is superposed on the winding 5, not necessarily illustrated, the spring initially may be rocked by the switching-in current impulse. The natural frequency of the spring thus determines the frequency of the alternating current produced. When the tube is adapted for the additional feeding on alternating current mains already under voltage the control of the spring must be

effected positively from the mains which can be effected in a simple manner.

An alternating current rectifier of the construction described may also be used in a suitable manner as continuous current converter preferably for high voltages, as by the mechanical closing of the discharge path the danger of a back fire can be obviated to a far-reaching extent.

Instead of a control element with a reciprocating oscillatory movement, such as spring 6, there may also be used a control member with a rotary movement. The rotary movement thereof may be produced by means of a magnetic rotary field of which the energizing winding is located outside the bulb of the discharge tube. By means of a rotary system of this character transforming undulations of different types can be obtained.

In Figs. 6 and 7 is shown such an arrangement with the use of double commutation for converting direct current into alternating current or polyphase current into direct current. On a base 2 there is again fitted a glass bulb 1. As a movable part of the screening there serves a rotary hollow cylinder or rotor 17. When the rotary movement has a speed of 3000 revolutions per minute (for producing 50 cycles) there is provided in each upper part of the rotor 17 a slot 17*a* of 90° peripheral length or width and both slots are arranged diametrically opposite one another so that in the drawing only the upper one is visible. At the upper and lower ends the hollow cylinder 17 is closed. At the upper end of the rotor is a two pole armature 18 of magnetic steel which is rotated by a rotary field, produced by a winding 19 (for polyphase current or single phase alternating current) surrounding the bulb on the outside. To the base 2 is secured centrally a shaft 20 on which the rotor rests by an upper pivot bearing and is guided by a bore in a central partition 17*b*. In the upper rotor chamber an anode 22 of graphite is arranged on the shaft 20. In the lower rotor chamber is fitted an indirectly heated cathode 23. The current lead 24 of the central electrode 22 passes through a longitudinal bore of the shaft 20 to the anode. The rotor 17 is surrounded by a stationary part or stator, which is formed by three uniformly spaced casing sectors 25 provided on the periphery. Each of these casing sectors receives in its upper part an indirectly heated cathode 26 and in its lower part an anode 27 which closes the said opening of the sector. The cathode and anode of each casing sector are connected together conductively and their leads are passed with insulation through the wall of the casing sector. To each anode-cathode pair is connected a three phase current lead I, II, III as shown in Fig. 7. The positive pole of the battery B is connected to the central anode 22 and the negative pole of the former to the central cathode 23. In this arrangement a three phase current of the usual type is produced in the three phase system D by three single phase currents relatively displaced by 120°. The sine shape of the alternating current produced may in this case also be produced by suitable construction of the lateral limiting edge of the rotor slots.

When additionally feeding three phase mains already under voltage with such a discharge device the rotary field for the rotor drive is preferably produced by the current taken from the three phase mains and an entire phase uniformity can be obtained in this case by the rotary arrangement of the rotary field winding and its adjustment. When feeding three phase mains not otherwise excited at a governed frequency the frequency constancy can be obtained by obtaining the rotary field, for example by means of a discharge device with a pendulum control of the type of the discharge tubes hereinbefore described of which the magnet is provided with a main and a phase displaced auxiliary winding.

Devices for converting direct current into alternating and three phase current by this arrangement are characterized by their great simplicity and security in operation, do not suffer from spark formation, oxidation or burning of the active parts, have no dimensions and a low weight and require no attention. It is also possible to suitably influence the shape of curve of the alternating current produced. Such converters and relay discharge tubes can also be produced in small units with economical methods of operation.

In the examples described with movable electrode the anode is arranged to oscillate, the cathode could also be arranged to oscillate equally well.

I claim:

1. A discharge tube comprising an anode and a cathode between which a discharge is adapted to take place, and movable means mounted closely adjacent one of said electrodes for varying the effective discharge surface area of the adjacent electrode from which the discharge takes place.

2. A discharge tube comprising an anode and cathode, a movable anode screening member located between said anode and cathode and closely adjacent to the active face of said anode to exclude the adjacent part thereof from the discharge, a movable support on which said member is mounted, and means for actuating said support whereby said screening member is moved relatively to said anode and cathode to vary the effective area of said anode.

3. A discharge tube comprising a base, a glass bulb on said base, an electromagnet mounted on said base inside said bulb, a housing in said bulb, said housing having an aperture therein, a cathode located in said housing adjacent said aperture, a pair of anodes in said bulb, a resilient support mounted in said base on said bulb, and a screen member carried by said support and extending between said cathode and said anodes.

4. A discharge tube comprising an anode and cathode, a movable screening member located between said anode and cathode and closely adjacent one of them to exclude the adjacent part of the electrode from the discharge between said anode and cathode, a resilient support on which said member is mounted, electromagnetic means for actuating said resilient support whereby said member is moved relatively to said anode and cathode to vary the extent of screened electrode surface, said movable member being adapted to be oscillated by energizing the electromagnetic means by the alternating current that is independent of the anode-cathode current, the average strength of the discharge being a function of the amplitude of oscillation of the movable member, while the magnitude of the amplitude of oscillation is a function of the output of the controlling alternating current of constant frequency.

5. A discharge tube comprising a base, a glass bulb on said base, and electromagnet mounted on said base inside said bulb, a housing in said bulb, said housing having an aperture therein,

a cathode located in said housing adjacent said aperture, a pair of anodes in said bulb, a resilient support mounted in said bulb, and a discharge-controlling screening member carried by said support between said cathode and said anodes and movable alternately to control the separate discharge paths between said anodes and said cathodes.

6. A discharge tube comprising a base, a glass bulb on said base, an electromagnet mounted on said base inside said bulb, a housing in said bulb, said housing having an aperture therein, a cathode located in said housing adjacent said aperture, a pair of anodes in said bulb, a resilient support mounted in said base in said bulb, and a screening member carried by said support and adapted to extend between said cathode and said anodes, and means for vibrating said support to move said screening member into controlling position between said cathode and alternately between said anodes.

7. A discharge tube comprising a base, an evacuated bulb on said base, a permanent magnet with U-shaped body on said base, short cores on the limbs of said magnet, coils on said cores, blade springs confronting said cores and attracted thereby, said blade springs having different natural frequencies of oscillation, anodes in the form of plates secured to the free ends of said springs, screens having slots therein mounted in said bulb, said anodes being movable through said slots, holders on said base, and filaments supported by said holders, said holders also supporting said screens which are located between the filaments and the anodes.

8. An electron tube having a pair of cooperating electrodes between which an electron current may pass, means for varying the active area of one of said electrodes including a control screen closely adjacent said one electrode to exclude the adjacent screened surface thereof from the discharge between said electrodes, and means for effecting relative movement between said one electrode and screen for varying the extent of screened electrode surface.

9. An electron tube having a pair of cooperating electrodes between which an electron current may pass, means for varying the electron current comprising a housing surrounding one of said electrodes having an opening occupied by an active face of said one electrode, and a screen member movable across said opening and also across and closely adjacent to the active face of said one electrode to isolate the screened part of the active face thereof from the current path between said electrodes.

10. An electron tube having a cathode and a pair of anodes, and movable screening means closely adjacent the active areas of said anodes to exclude the adjacent screened areas from the discharge path between said anode and cathode and movable relatively thereto for alternately varying the effective areas of said anodes.

11. A discharge tube comprising a cathode and anode, a movable screening member located between said cathode and said anode and closely adjacent one of them to isolate the adjacent area thereof from the discharge path, and means for relatively moving said member and screened electrode to vary the effective surface area of the electrode that is exposed to the discharge betwen said cathode and anode.

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