Aug. 20, 1935. P. F. SCOFIELD 2,011,951

ELECTRICALLY DRIVEN VIBRATOR

Original Filed Feb. 1, 1932

Fig. 1.

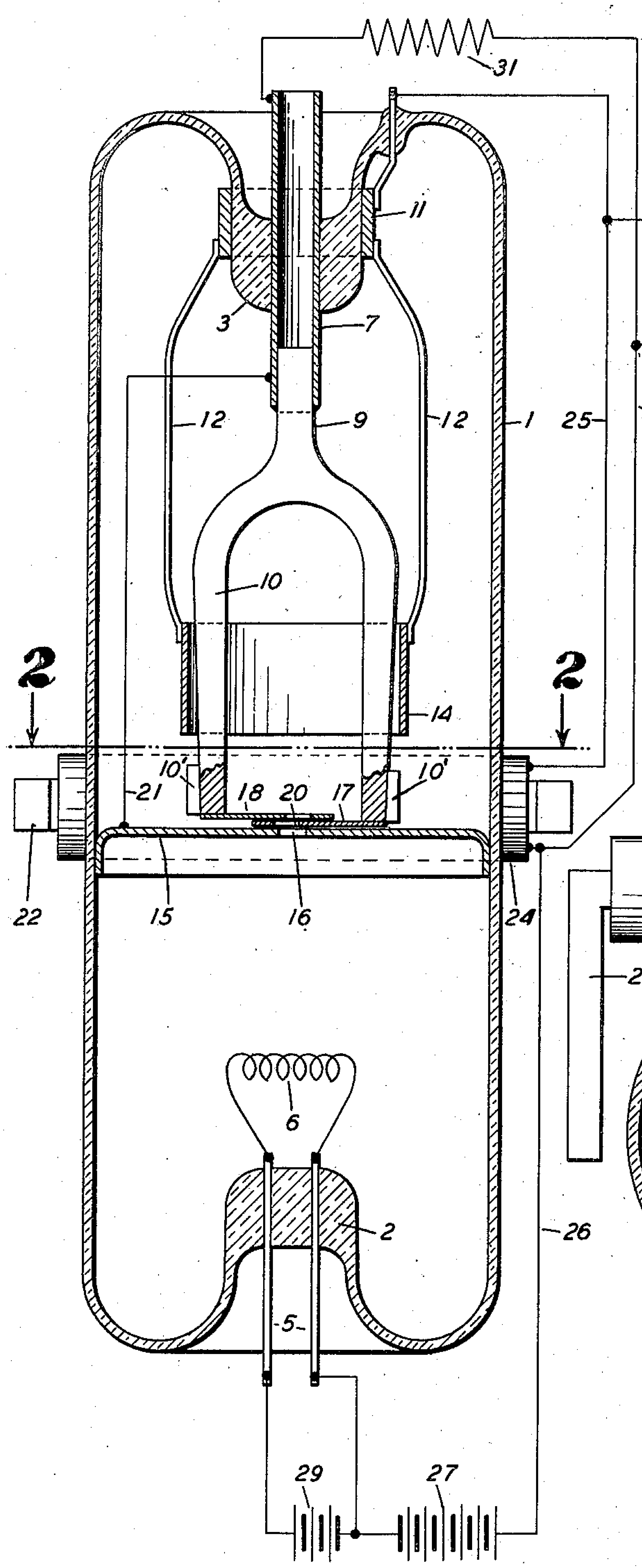


Fig. 3.

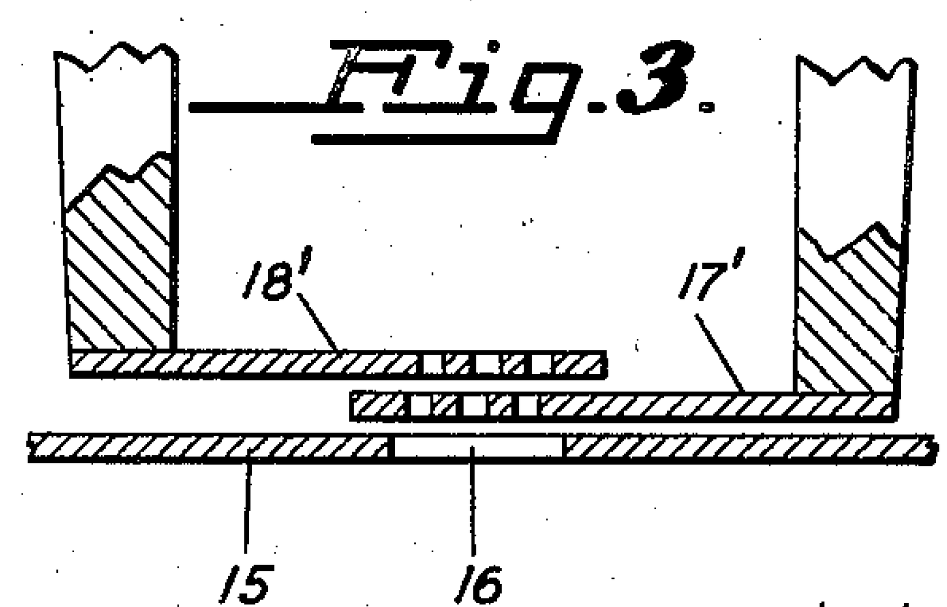
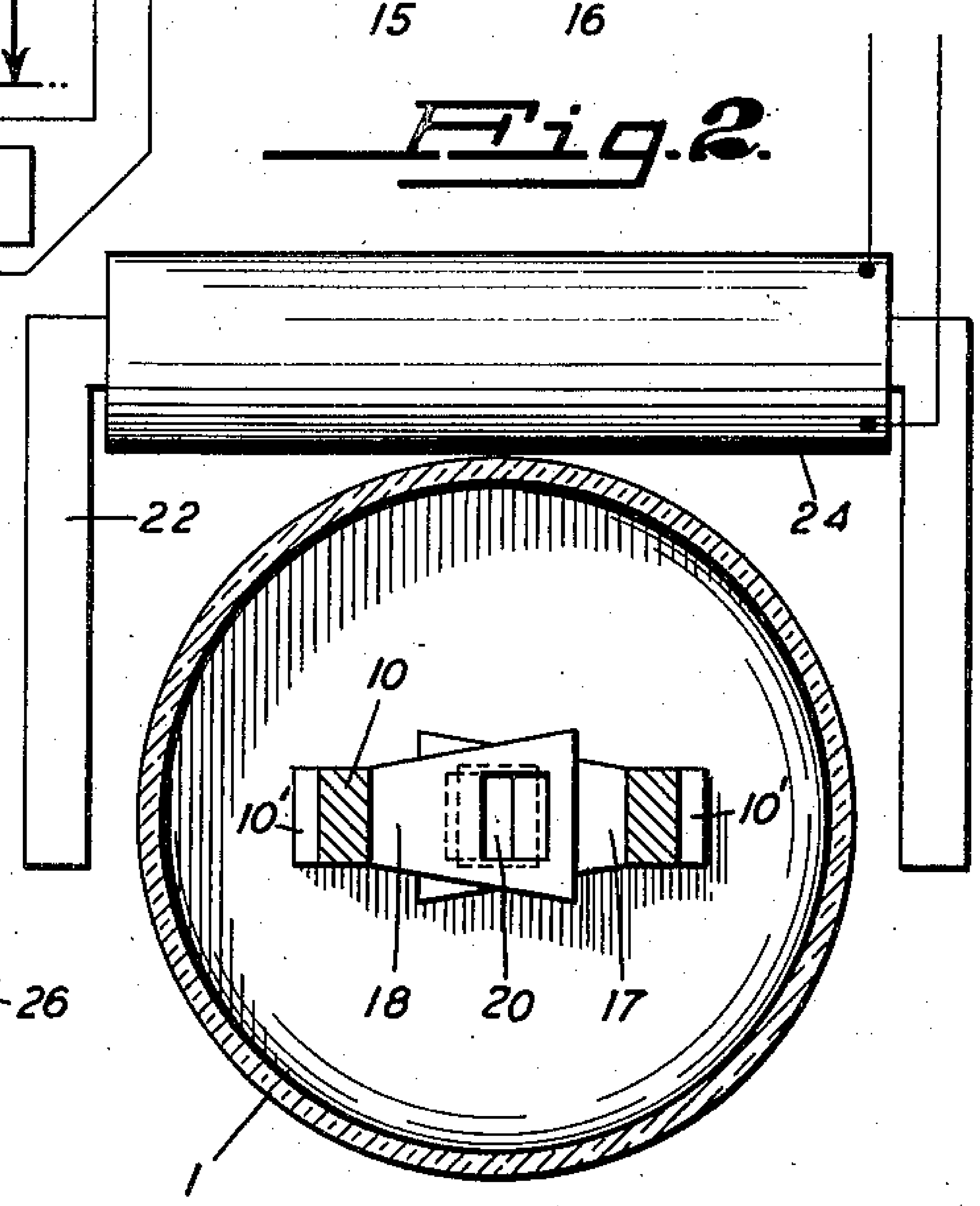


Fig. 2.



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ELECTRICALLY DRIVEN VIBRATOR

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Original application February 1, 1932, Serial No. 590,099. Divided and this application January 28, 1933, Serial No. 654,083

6 Claims. (Cl. 250—27.5)

This invention relates to electrically driven vibrators for generating electrical current of fixed standard frequency, particularly to electrically driven tuning forks, and is a division of my copending application, Serial No. 590,099, filed February 1, 1932, relating to matter disclosed but not claimed in the aforesaid application.

Electrically driven forks have been common laboratory equipment for many years. Their limitations have been either that the power output obtainable therefrom was extremely small, or else that the current controlling device operated by the fork has introduced factors tending to damp the fork's motion and hence to vitiate its reliability as a frequency standard.

The primary purpose of my invention is to avoid the former limitations of electrically driven vibrators of this character.

With this in view, among the objects of my invention are: To provide an electrically driven tuning fork wherein the current controlling elements actuated by the fork exercise no damping effect upon the fork's vibration; to provide an electrically driven fork in which even the damping due to the radiation of sound is minimized; to provide an electrically driven vibrator which is capable of delivering relatively large power output; and to provide a vibrator of the type mentioned wherein the amount of power withdrawn from the circuit is substantially without effect upon the frequency or amplitude of vibration.

Other objects of my invention will be apparent or will be specifically pointed out in the description forming a part of this specification, but I do not limit myself to the embodiment of my invention herein described, as various forms may be adopted within the scope of the claims.

Referring to the drawing:

Figure 1 is a longitudinal section, partly schematic, of an electrically driving tuning fork embodying my invention, together with a circuit diagram of the connections employed in operating the fork.

Figure 2 is a transverse section of the fork illustrated in Figure 1, the plane of projection being indicated by the line 2—2 of the first figure.

Figure 3 is a fragmentary diagram showing a modified form of shutter which may be substituted for that illustrated in the first two figures.

Broadly considered, my invention comprises an evacuated vessel which preferably contains a small amount of ionizable vapor, such as mercury vapor. Within this vessel are sealed a cathode, preferably of the thermionic type, and an anode. A vibratory member, preferably a tuning fork, because of its convenience and frequency stability, is mounted within the tube, and upon this member is mounted a shutter or shutters positioned to interrupt the path between the cathode and the anode at one phase of the vibration. Preferably a shield or screen is provided between the cathode and anode which is maintained at a potential intermediate the potential of the two electrodes. This screen is provided with an orifice which is occulted by the shutters to interrupt the discharge between the cathode and the anode, the shutters being preferably directly connected to the shield so as to operate at the same electrical potential. Means, actuated by the current to the anode, are provided for deflecting the vibratory member so as to interrupt the current. Hence, when the device starts to operate, current flows to the anode, the deflecting means is excited, which interrupts or greatly reduces the anode current, thereby allowing the vibratory member to resume its original position and again permit the anode current to flow. This cycle being repeated, the vibratory member quickly builds up to full amplitude, so that the orifice is alternately fully opened and fully closed.

As is well known, when a thermionic cathode is operated in an ionizable vapor, such as mercury vapor, a large amount of ionization occurs and relatively heavy currents flow with very small potential drop. Since the shield and the shutters are both operated at a positive potential to the cathode, a glow discharge is constantly maintained to these parts and an abundance of ions is always available to carry current to the anode. There is, however, little or no conduction to the anode when the orifice is occulted. When the shutters are open, an immediate heavy current flow takes place to the anode, and currents of several amperes may easily be withdrawn from the device. The amount of current flowing, however, has no effect on the loading of the vibratory member, which therefore does not tend to change its frequency with the load drawn. This makes it possible to derive many watts of oscillatory power from the fork without destroying its accuracy, whereas previous methods of drive have been limited to outputs of a fractional watt where accuracy need be maintained.

A preferred form of my invention comprises a tubular evacuated envelope 1 having stems 2 and 3 sealed into opposite ends thereof. Through the stem 2 are sealed leads 5 which carry an electron-emitting filament 6. The stem 3, at the opposite end of the tube, has sealed through it a tubular lead 7, into the end of which is welded the stem 9 of a tuning fork 10. It is to be understood that any form of vibrating reed may be substituted for the tuning fork, the latter being preferred merely because long standardization and experiment have shown that this form of vibratory element may be made to maintain a desired frequency of vibration with great accuracy. To further this, I prefer to construct a fork of the alloy known as "elinvar", which is characterized by a temperature coefficient of elasticity which is substantially nil. In this event soft iron armatures 10' may be secured to the tines of the fork to increase its magnetic response.

A clamp 11 surrounds the stem 3, and has welded or otherwise secured to it supports 12, to which is mounted an annular anode 14, which in the present instance encircles the tines of the fork. The position of the anode within the tube may be varied widely without affecting the operation of the apparatus, the form shown being merely one which has proved convenient in practice.

Extending across the tube between the cathode and anode is a shield or diaphragm 15, which separates the tube into two compartments joined only by an orifice 16 through the center of the shield. Closely adjacent to the orifice are a pair of shutters 17, 18, one of these shutters being secured to each of the tines of the fork. These shutters may be blades which simply overlap when the fork tines approach each other most closely in their vibratory cycle, but I prefer to make these blades somewhat larger, and pierced with holes 20. The holes are so alined that when the fork is at rest and unstressed the orifice 16 is half covered, while when the tines of the fork are most widely spread, the orifice is fully occulted. Thus when the fork is in full vibration the orifice will be alternately fully opened and fully closed, the closure occurring at only one phase of the vibratory cycle.

An electrical connection 21 joins the shield and the fork, so that shield, fork, and shutters are maintained at the same electrical potential.

Embracing the tube in line with the tines of the fork is a magnetic yoke 22 which is excited by a winding 24. The anode 14 is connected to this winding by a lead 25, the other end of the winding connecting through another lead 26 to the positive terminal of a direct current supply 27, which may be a battery as shown, or a D. C. generator. A battery 29 or other source is also provided to excite the filament 6.

A lead 30 connects from the positive terminal of the battery, through a resistor 31, to the fork and shield. Power may be withdrawn from the circuit through a transformer 32 whose primary is connected in parallel with the winding of the magnetic yoke.

In operation, the filament 6 serves as a source of electrons which, attracted to the shield 15, by potential derived from the battery 27, ionizes the vapor within the tube and maintains a glow discharge between filament and shield. Owing to the presence of the resistor 31, this discharge is stabilized and is strictly limited, merely serving as a constant source of ions which is ready instantly to initiate the main discharge to the anode.

The anode, whose potential is not limited by the voltage drop through the resistor 31, draws a much heavier current through the partly opened orifice 16. A portion of this current flows through the winding 24, exciting the magnetic yoke and drawing the tines of the fork apart to tend to close the gap. This decreases the current to the anode, allows the tines of the fork to spring together again, thus opening the orifice once more and allowing the cycle to repeat. Within a very few cycles the oscillation of the fork will build up to full amplitude, after which table conditions are maintained, the anode flow being cut off entirely and building up again to a maximum once during each cycle of vibration of the fork.

When the orifice is closed or occulted by the shutters, the discharge from the filament and the ionized space surrounding it, flows through the orifice 16 and is completely stopped by the shutters. There being no source of electrons on the anode side of the shield to initiate ionization, there is no secondary discharge between the shield and the anode.

The winding 24 of the driving magnet is preferably made of relatively high impedance, and the load is withdrawn from the transformer whose primary is connected in shunt therewith. It is, of course, possible to operate the magnet in series with the output circuit, or even to utilize the magnetic yoke as the core of the output transformer, these being well known expedients and the circuit shown being merely one form which is preferred owing to its efficiency and its flexibility with respect to the load which may be withdrawn from the circuit.

It will be seen that the current flow through the orifice has no loading effect upon the fork, and therefore has no tendency to change its frequency of operation.

Suitable temperature controlling means, well known in the art, may be utilized to maintain the walls of the envelope at a constant temperature. This temperature will regulate the vapor pressure within the tube, and hence, indirectly, the temperature of the fork. By constructing the fork or other vibrating element of elinvar, such small changes in temperature as do occur may be made substantially without effect upon the frequency of operation of the device, which is hence well adapted to serve as a frequency standard which is capable of supplying relatively large amounts of power, several hundred watts being well within the capabilities of a device of this character.

The apparatus may be modified by constructing the shutters as shown in Figure 3, in which each of the blades 17', 18' is pierced by a plurality of narrow orifices, instead of the single wide orifice shown in Figure 2. This structure is particularly adaptable where it is desired to have the fork vibrate to a small amplitude in order to obtain extreme accuracy in frequency control. It is to be noted that these plural apertures are also constructed to open and close but once in each cycle of operation of the fork, if the latter device is to be self-driven. If more than a single opening and closure takes place per cycle, the device becomes a frequency multiplier, and cannot, in general, be self-excited.

It will be noted that the shutters are freely movable and do not touch, so that no damping is applied by friction of the blades one on another, or on the shield. I have found that the shutters may be separated by not more than the mean free path of the ionized vapor and still control the beam without leakage. As no extraneous harmonics are introduced by frictional damping, the wave form is exceptionally pure.

I claim:

1. A vacuum tube comprising an envelope, a cathode and an anode within said envelope, a shield between said cathode and anode having an orifice therein, and a tuned undamped shutter mounted to occult said orifice to interrupt space current therethrough, said shutter and said shield being electrically connected within the tube.

2. A tube comprising an envelope containing an ionizable vapor, a thermionic cathode within said envelope, an anode within the envelope, a shield in said envelope between said cathode and anode and having an orifice therein, and a tuned freely movable shutter mounted to occult said orifice and electrically connected to said shield whereby ionic current between said cathode and anode may be interrupted.

3. A tube comprising an envelope containing an ionizable vapor, a thermionic cathode within said envelope, an anode within the envelope, a shield in said envelope between said cathode and anode and having an orifice therein, a vibratory member mounted within said tube, and a freely movable shutter mounted on said member and positioned adjacent said orifice to periodically occult said orifice upon vibration of said member, said shutter being separated from said shield by less than the mean free path of said vapor.

4. A tube comprising an envelope containing an ionizable vapor, a thermionic cathode within said envelope, an anode within the envelope, a shield in said envelope between said cathode and anode and having an orifice therein, a tuning fork mounted within said envelope, and a freely movable shutter fixed to the tines of said fork and positioned adjacent said orifice to occult said orifice periodically upon vibration of said fork.

5. A tube comprising an envelope containing an ionizable vapor, a thermionic cathode within said envelope, an anode within the envelope, a shield in said envelope between said cathode and anode and having an orifice therein, a tuning fork mounted within said envelope, and a freely movable shutter fixed to each of the tines of said fork and positioned adjacent said orifice to occult said orifice periodically upon vibration of said fork, said shutters being overlapped and separated from each other by less than the mean free path of the ionized vapor.

6. A vacuum tube comprising an evacuated envelope, a cathode, an anode and a tuning fork within said envelope, and an undamped shutter mounted on a tine of said tuning fork, said shutter being interposed in the path between said cathode and anode to interrupt space current therebetween.

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