June 22, 1937. W. DÄLLENBACH 2,084,725

GAS-FILLED DISCHARGE TUBE

Filed Jan. 6, 1933

Fig. 2

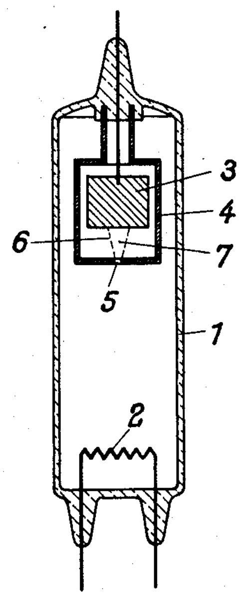


Fig. 3

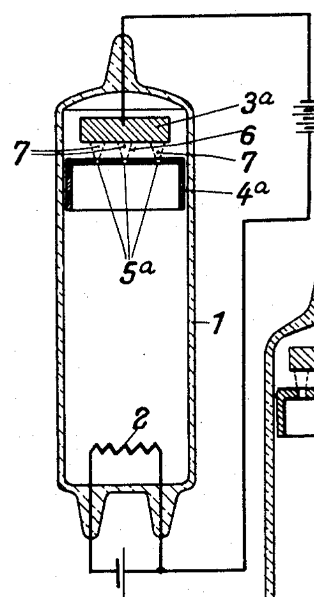


Fig. 4.

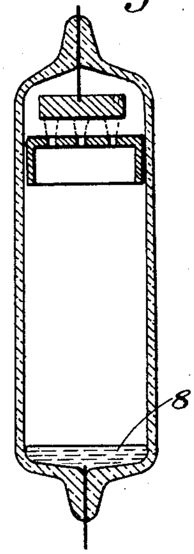
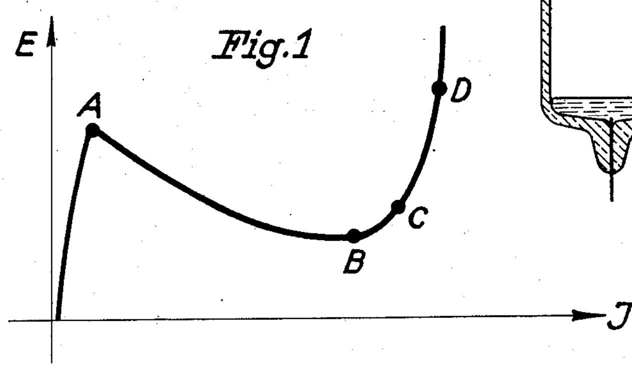


Fig. 1



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GAS-FILLED DISCHARGE TUBE

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9 Claims. (Cl. 250—36)

It is known that discharge-tubes if filled with rarefied gases show with an increase of the current intensity a decrease of the drop of potential across the tube and again an increase in the case of very high current intensities.

It is clear that such an increase is desirable also in the case of small current intensities and according to the present invention it has been established that such an increase also in the case of small current intensities can be obtained by putting the anode in a chamber which is communicating with the rest of the interior of the discharge-tube by means of an aperture. The smaller the voltage of the chamber surrounding the anode and the narrower the communicating opening between the chamber and the rest of the interior of the tube is chosen, the steeper the rise of the characteristic of the current voltage above a certain current load and the smaller the current intensity from which the characteristic is rising again.

The rise of the drop of potential in the case of higher current intensities is thought to be caused by an impoverishment of ions in the surroundings of the anode. During the passage of the current the electrons emitted at the cathode are travelling to the anode, the positive ions in the opposite direction from the anode to the cathode. As generally a subsequent production of positive ions from the surface of the anode does not take place it follows that in the case of high current intensities the density of the positive ions in the surroundings of the anode is not sufficient to compensate the electron space charge. In the surroundings of the anode therefore a negative space charge arises which is the reason for the increase of the characteristic of the current voltage.

Experiments have shown that in the rising part of the current voltage characteristic of the tube high frequency oscillations can occur which are the more intensive in the zone of the rising characteristic adjacent to the minimum, the higher the current intensity and thereby also the drop of potential is chosen.

Fig. 1 is a diagrammatic view showing the current potential characteristic of the tubes.

Fig. 2 is a vertical cross section of the tube according to the present invention.

Fig. 3 is a similar view showing a modification of the invention employing a plurality of openings.

Fig. 4 is a vertical cross section of another modification of the invention employing a mercury cathode.

The relations referred to above are shown in Fig. 1. J means the current intensity across the tube, E the drop of potential between anode and cathode. From A near the no-load voltage the drop of potential at first decreases to a minimum at B and increases from this point. At C oscillations arise the intensity of which increases in the direction to D.

The object of the present invention therefore is to show a discharge-tube with rarefied gas- or vapour-content for producing, amplifying or receiving high frequency oscillations in which the path of the discharge between anode and cathode is interrupted by a wall having an opening therein restricting the cross-section of the discharge, the wall cutting off a space adjacent to the active surface of the anode from the rest of the interior of the tube, the tube being worked by current intensities which show in the space adjacent to the active surface of the anode an increasing drop of potential with increasing current intensity.

Fig. 2 shows a form of embodiment of the invention. 1 is the glass-wall of the vacuum discharge-tube, 2 the incandescent filament, 3 the anode, 4 a case or wall of a conducting, solid metal, preferably of copper which surrounds the anode from all sides and being isolated in a suitable way from the anode. The walls of this case are placed very close to the anode because according to the invention it is necessary to obtain an impoverishment of ions inside this special space and this impoverishment is the more intensive the smaller this space is chosen; on the other hand, the smaller the space, the hotter it becomes. It has been found that a distance of about 1½ mm. from the anode is suitable. In the wall of the case opposite to the cathode an opening 5 is provided as an aperture of any suitable shape preferably being circular-shaped and having a diameter of 0,5–10 mm. preferably 3 mm. in such a way that the surface of the cross-section of the aperture is about 0,2–80 mm.^{2}, preferably 7 mm.^{2} As can be understood from the method of operation of the device, the diameter of the aperture is selected to be of the order of the mean free path lengths of the electrons in the gas filled tube. 6 is the part of the space adjacent to the active surface at the anode which space is separated from the interior of the tube by means of the device provided with the aperture. This separation must be only of such an efficiency that any other path for the discharge between anode and cathode needs a higher drop of potential compared with the discharge-path crossing the aperture; it then results that another path is not used. This can be obtained in a way known per se: by putting narrow and sufficiently long, gap-shaped spaces between the anode **3** and the metal case **4**.

As the tube according to the invention is working on the rising branch of the characteristic it is possible to put a plurality of apertures or the like in front of the anode in such a way that at the same anode several paralleled discharges simultaneously exist.

This construction is represented in Fig. 3. Instead of an aperture **5** three apertures **5***a* are shown which because of the positive characteristics are able to carry simultaneously parallel to each other a current. The term "positive characteristic" is used to signify the increase of the potential with the current as shown by the line B, C, D of the curve in Fig. 1. The metal case **4** of Fig. 2 is replaced in Fig. 3 by a screen **4***a* with apertures **5***a*, the screen being either tightly molten with the glass-wall of the tube or, as shown in the figure, fitting to the wall by a narrow gap.

The vacuum discharge-tube may be filled by the following gases or vapours: a monatomic gas, a metal vapour, especially mercury vapour or a mixture of different monatomic gases and metal vapours. Especially mercury-vapour is advantageously used.

In order to obtain a working of the apertured wall according to the present invention it is necessary as already mentioned above to provide a distance of the aperture from the active surface of the anode which is not too long. The emission of electrons travelling from the aperture to the active surface of the anode must result in the space lying between the anode and the aperture in relatively few ionizing collisions with the gas- or vapour-content. It is especially advantageous that the electron emission from the aperture to the active surface of the anode amounts only to several mean free electron path-lengths in the rarefied gas- or vapour-content. The emission travelling from the aperture to the active surface of the anode is indicated by **7** in Figs. 2 and 3.

The production of oscillations according to the invention is explained as follows. As known, in a gas discharge tube with arc discharge the current increases very rapidly after igniting the tube, corresponding to the increase in the number of ions and electrons formed by impact ionization. During the discharge, electrons pass to the anode while the positive ions formed pass to the cathode.

The ionization and migration of the charge vehicles amount to a multiple of the values in the remainder of the discharge chamber. This concentration takes place at the wall by reason of the high current density formed by the constriction of the discharge path. Accordingly, with the increasing current, a progressively greater part of the available voltage is consumed at the wall. The gas volume immediately adjacent the wall can thereby be so powerfully ionized and the charge vehicle formed by impact from the neutral gas molecules can as a result of stronger fields be carried off so rapidly as to produce a paucity of gas molecules and charge vehicles which are primarily ions. This is at once clear when it is considered that the diffusion rate or speed of the neutral gas molecules newly arrived from the portions of the tube remote from the aperture amounts to a small fraction (10^{-1}–10^{-2}) of the speed of the ions in the field.

With lesser current intensities the negative space charges in front of the wall are compensated for by the positive ions produced and the discharge current can thus pass unhindered. But with the increase of current intensity a condition is approached in which all gas particles are ionized and no longer suffice to compensate for the negative space charge in front of the wall. This results in increase of the potential drop. The negative space charges in front of the wall increase more and more, so that finally the current flow is throttled or choked. One explanation may be that a high vacuum bubble has formed at the wall and as a result the current drops to the value which corresponds to the absolute electron flow in the geometric dimensions of the vacuum and the total potential available.

In proportion as the degasified space is again filled by new neutral gas or vapor molecules the potential necessary for re-instating the discharge drops until finally ionization and current passage can again begin. The discharge then takes place again. At first the positive ions suffice again to compensate for the discharge in front of the wall. With increasing current intensity the condition again arises where the number of positive ions no longer suffices to compensate for the space charge, and therewith throttling of the current. The cycle is continually repeated, with frequencies which, according to the size of the aperture, correspond to the gas pressure and the magnitude of the drive current intensity with a wave length, for example, of 1000–3000 m.

The anode potential naturally rises and falls with the positive increase and disappearance of the space charges in front of the anode. The potential at the tube is thus combined of a direct potential and a high frequency alternating potential component.

It is thus seen that the high frequency oscillations always take place when the discharge tube operates characteristically in the positive ascending part, and this without the presence of an oscillatory circuit consisting of a self-induction and capacity or a tilting switch connection. It may be advantageous per se to couple an oscillatory circuit to the tube serving as an oscillation generator, but in contrast to known connections of this type, it does not serve to produce and maintain the oscillations, but merely to facilitate the transmission of the oscillations to the consumer, or to complete, for example, the coupling and adjustment at a sending aerial.

The cathode of the vacuum discharge-tube may be either a mercury-cathode or an incandescent filament of any construction.

In the specification and claims the term "order of the mean free path lengths" means any distance that, in the operation of the gas tube, has the same operative effect as the mean free path itself. That is to say, the relation of the diameter of the aperture to the mean free path length must be such as will produce the vacuum bubble referred to above.

Due to the restriction of the discharge by the aperture or the like it is possible that at higher loads a considerable formation of heat results at the aperture. It is therefore advisable and of further advantage to form the wall having the aperture of a high melting material especially of a high melting metal. Finally it has been established that in the most cases it is very advantageous to couple high frequency oscillatory circuits without regard to the fact whether the tube is used for producing, amplifying or receiving high frequency oscillations. This coupling may be carried out either by means of a field or by galvanic coupling. One or more electrodes inside the tube are used for the coupling. Apart from the anode or the cathode it is also possible to use the aperture for such a coupling; especially the anode is used for this coupling. The high frequency oscillations may be produced by a separate high frequency producer known per se, e. g. by a tube.

The new tube is especially suitable for the production of very short electric waves such as ultra-high frequency waves.

Figure 4 shows the same constructional form as Fig. 3 except that a mercury cathode 8 is provided instead of an incandescent cathode.

I claim:

1. An electric discharge tube for the production of high frequency oscillations comprising a closed vessel, an anode, a cathode adapted to be maintained in incandescent state, an ionizable medium of sufficient pressure to maintain an arc discharge between said electrodes when potentials are applied to the latter, a separating wall between said electrodes, said wall having an opening therein the diameter of which is of the order of the magnitude of the mean free path length of the electrons, whereby the discharge path is constricted at said opening to a fraction of the remainder of the discharge path, and the prevailing current density of said discharge adjacent said opening causes a paucity of ions whereby the potential drop in the vessel increases with increase of current.

2. An electric discharge tube for the production of high frequency oscillations comprising a closed vessel, an anode, a cathode and an ionizable medium of sufficient pressure as to be adapted to maintain an arc discharge between said electrodes when potentials are applied to the latter, a separating wall between said electrodes, said wall having an opening therein which is in cross section a fraction of the cross section of the remainder of the discharge space and being spaced away from said anode a distance in the order of the mean free path lengths of the electrons, whereby the discharge path is constricted at said opening to a fraction of the remainder of the discharge path and the prevailing current density of said discharge adjacent said opening causes a periodic paucity of ions whereby the potential drop in the vessel increases with increase of current.

3. An electric discharge tube for the production of high frequency oscillations comprising a closed vessel, an anode, a cathode, an ionizable medium of sufficient pressure as to be adapted to maintain an arc discharge between said electrodes when potentials are applied to the latter, a separating wall between said electrodes, said wall having a plurality of openings therein, each opening having a diameter which is of the order of the magnitude of the mean free path length of the electrons, whereby the discharge path is constricted at said openings to a fraction of the remainder of the discharge path and the prevailing current density of said discharge adjacent said openings causes a periodic paucity of ions whereby the potential drop in the vessel increases with increase of current.

4. An electric discharge tube for the production of high frequency oscillations comprising a closed vessel, an anode, a mercury cathode and an ionizable medium of sufficient pressure as to be adapted to maintain an arc discharge between said electrodes when potentials are applied to the latter, a separating wall between said electrodes, said wall having an opening therein the diameter of which is of the order of the magnitude of the mean free path length of the electrons whereby the discharge path is constricted at said opening to a fraction of the remainder of the discharge path and the prevailing current density of said discharge adjacent said opening causes a periodic paucity of ions whereby the potential drop in the vessel increases with increase of current.

5. An electric discharge tube for the production of high frequency oscillations comprising a closed vessel, an anode, a cathode, adapted to be maintained in incandescent state, a rare gas filling of sufficient pressure as to be adapted to maintain an arc discharge between said electrodes when the potentials are applied to the latter, a separating wall between said electrodes, said wall having an opening therein the diameter of which is of the order of the magnitude of the mean free path length of the electrons whereby the discharge path is constricted at said opening to a fraction of the remainder of the discharge path and the prevailing current density of said discharge adjacent said opening causes a periodic paucity of ions whereby the potential drop in the vessel increases with increase of current.

6. An electric discharge tube for the production of high frequency oscillations comprising a closed vessel, an anode, a cathode adapted to be maintained in incandescent state, an ionizable medium of sufficient pressure as to be adapted to maintain an arc discharge between said electrodes when potentials are applied to the latter, a housing electrically encompassing said anode, said housing having an opening in the side toward the cathode, said opening having a diameter which is of the order of the magnitude of the mean free path length of the electrons whereby the discharge path is constricted at said opening to a fraction of the remainder of the discharge path and the prevailing current density of said discharge adjacent said opening causes a periodic paucity of ions whereby the potential drop in the vessel increases with increase of current.

7. An electric discharge tube for the production of high frequency oscillations comprising a closed vessel, an anode, a mercury cathode and an ionizable medium of sufficient pressure as to be adapted to maintain an arc discharge between said electrodes when potentials are applied to the latter, a separating wall between said electrodes, said wall having a plurality of openings therein, each opening having a diameter which is of the order of the magnitude of the mean free path length of the electrons whereby the discharge path is constricted at said openings to a fraction of the remainder of the discharge path and the prevailing current density of said discharge adjacent said openings causes a periodic paucity of ions whereby the potential drop of the vessel increases with increase of current.

8. An electric discharge tube for the production of high frequency oscillations comprising a closed vessel, an anode, a cathode adapted to be maintained in incandescent state, an ionizable medium of sufficient pressure to maintain an arc discharge between said electrodes when potentials are applied to the latter, a separating wall between said electrodes, said wall hav-

ing an opening therein the diameter of which is of the order of the magnitude of the mean free path length of the electrons, whereby the discharge path is constricted at said opening to a fraction of the remainder of the discharge path, and the prevailing current density of said discharge adjacent said opening causes a periodic paucity of ions whereby the potential drop in the vessel increases with increase of current, and whereby an oscillatory circuit may be coupled with said tube for utilization of oscillations produced within said vessel.

9. An electric discharge tube for the production of high frequency oscillations comprising a closed vessel, an anode, a cathode, an ionizable medium of sufficient pressure as to be adapted to maintain an arc discharge between said electrodes when potentials are applied to the latter, a separating wall between said electrodes, said wall having a plurality of openings therein, each opening having a diameter which is of the order of the magnitude of the mean free path length of the electrons, whereby the discharge path is constricted at said openings to a fraction of the remainder of the discharge path and the prevailing current density of said discharge adjacent said openings causes a periodic paucity of ions whereby the potential drop in the vessel increases with increase of current, and whereby an oscillatory circuit may be coupled with said tube for utilization of oscillations produced within said vessel.

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