June 4, 1929. C. T. ALLCUTT 1,716,161

VARIABLE CAPACITY ELEMENT

Filed Sept. 1, 1921

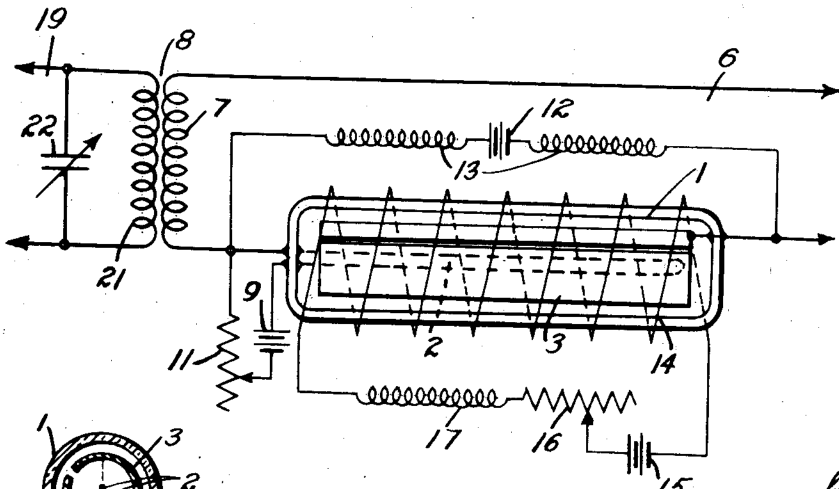

Fig. 1.

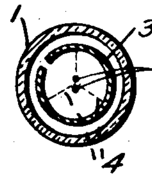

Fig. 4.

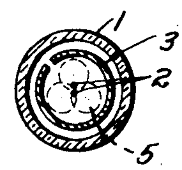

Fig. 5.

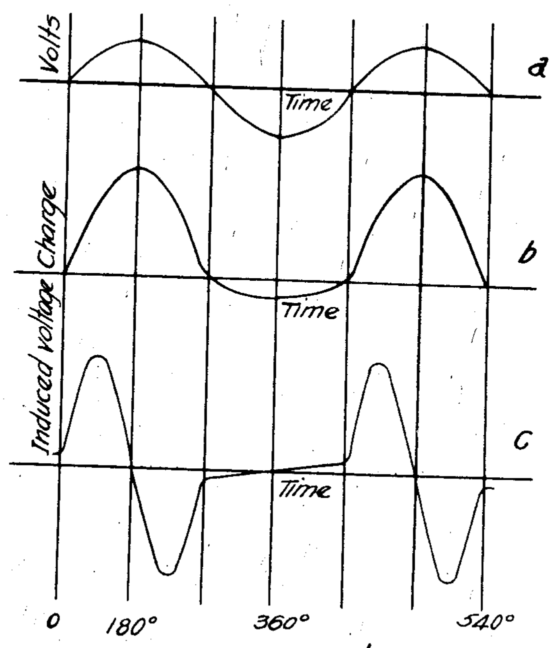

Fig. 3.

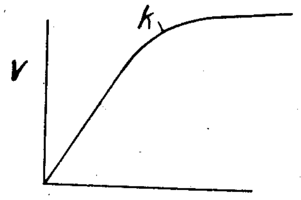

Fig. 2.

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Patented June 4, 1929. 1,716,161

UNITED STATES PATENT OFFICE.

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VARIABLE-CAPACITY ELEMENT.

Application filed September 1, 1921. Serial No. 497,553.

My invention relates to electric devices and more especially to variable-capacity electric devices.

One of the objects of my invention is to provide an electrical device, the capacity of which is a function of the voltage impressed thereon.

Another object of my invention is to provide a circuit arrangement, whereby my device may be employed as a frequency multiplier.

As is well known, the capacity of condensers, as heretofore employed, is fixed in the construction of the condenser. That is to say, the capacity of the condenser is independent of the voltage impressed across its terminals. It may readily be seen, however, that, by employing a condenser wherein the capacity is a function of the voltage, greater flexibility may be attained in certain types of static net-works.

According to my invention, I provide a capacitive reactance device in which the capacity is a function of the voltage impressed thereon and which may be applied in applications similar to inductive reactance devices utilizing the magnetic-saturation properties of iron cores.

The variable-capacity element embodying my invention comprises an evacuated electric device having a central cathode and a coaxially mounted anode contained therein. In addition, means are provided for producing a substantially constant magnetic field transverse to the electron path between the anode and the cathode, all as will be explained more fully hereinafter. This magnetic field causes the moving electrons to travel in a curved path. The field must be made of sufficient strength to cause the electrons to curve so much that they will return to the cathode or to the neighborhood of the cathode without having reached the anode.

As the electrons travel in their curved paths they approach and then recede from the anode without actually reaching it. They thus constitute a space charge. This charge is located within the surface that constitutes the geometrical envelope of the several curved paths. The whole space within this surface may be regarded as the cathode since it is the seat of the charge. The effect, therefore, of the presence of the traveling electrons which do not reach the anode is equivalent to an increase in the size of the cathode. This effect may be regarded as a change in the effective diameter of the cathode. Because of the presence of a considerable number of traveling electrons in the space between the filament and the said geometrical envelope, it may be regarded as a conductive space, while the space between this geometrical envelope and the anode, being free or almost free from electrons, is not conductive.

The space charge, acting as an equivalent to an increase in the diameter of the cathode, is similar to a reduction of the distance separating the two electrodes. In any condenser the distance between the electrodes is one of the factors determining the capacity. The capacity increases as this distance diminishes.

These and other objects of my invention, as well as details of construction, whereby my invention may be practiced, will appear more fully in the following description, when read in connection with the accompanying drawing, wherein:

Fig. 1 is a diagrammatic view of circuits and apparatus embodying my invention, as applied, particularly, to a frequency-doubler system.

Fig. 2 is a curve diagram showing the relation between the voltages impressed across the terminals of the variable capacity element, as ordinates, and the charges on the electrodes contained therein, as abscissæ.

Fig. 3 is a series of curve diagrams explaining the theory of operation of the frequency-doubler system of Fig. 1.

Fig. 4 is a cross-sectional view of the tube shown in Fig. 1, illustrating the direction of the electron path when the transverse magnetic field is substantially zero, and

Fig. 5 is a similar view showing the effect of a relatively large transverse magnetic field upon the electron path.

The operation of the variable-capacity element embodying my invention is based upon the effect of a transverse magnetic field upon the path of an electron emitted from a hot cathode. In a vacuum-tube device 1, such, for example, as that shown in Fig. 1 and comprising a central cathode 2 and a coaxially mounted anode in the form of a split cylinder 3, the electrons emitted from the cathode travel in substantially straight lines to the anode. Such condition is illustrated in Fig. 4, the dotted lines 4 representing the paths of the electrons.

However, upon the application of a magnetic field transverse to the paths of the electrons, it is found that the paths become curved or cycloidal in shape and that the degree of curvature depends upon the intensity of the transverse magnetic field. Upon the application of a magnetic field of sufficient intensity, the electrons may be caused to move around the hot cathode 2 in curved paths without reaching the anode, such condition being illustrated by dotted lines 5 in Fig. 5.

The expression "space current path" has been used herein to designate the space between the cathode and the anode through which ordinarily space current flows. It should be remembered, however, that in this device the current across this space is very small, if not zero. The paths of the several electrons being curved do not cross this space. The "space current path" therefore, is not the actual path of the electrons when this device is in operation.

With the transverse magnetic field substantially zero, there exists, between the electrodes of the tube 1, a definite capacity which is fixed by the particular construction of the tube. When the transverse magnetic field, however, is adjusted to some such value that the electrons are prevented from reaching the anode, as illustrated in Fig. 5, it is found that the capacity between the electrodes is increased by reason of an increase in the effective diameter of the cathode. The increase in the effective diameter of the cathode is due, as explained above, to the space charge. When the difference of potential between the cathode and the anode increases, the radial velocity of the electrons due to the electrostatic field increases, and the geometrical envelope of the curved paths of the electrons comes nearer to the anode. This increases the capacity. The capacity of the device, therefore, increases with increasing voltage. As can readily be seen, the increase in the effective diameter of the cathode is caused by the electrons which are moving around the cathode.

Since the diameter of the curved electron paths 5 and so the diameter of the geometrical envelope of these paths is dependent upon the intensity of the transverse magnetic field and upon the voltage impressed across the terminals of the tube, it follows that the capacity between the electrodes may be readily controlled.

In Fig. 1, I have shown one application of the variable-capacity element embodying my invention, as applied to a frequency-doubler system, although it is not to be limited to such system. A primary circuit 6 of the frequency-doubler system comprises a source of alternating currents (not shown), a primary winding 7 of a coupling transformer 8 and the variable-capacity element 1. The hot cathode 2 may be energized, by means of a source of energy 9, through a resistor 11. A source of direct-current energy 12, which serves as a biasing voltage, may be impressed across the hot cathode 2 and the anode 3 through a pair of radio-frequency choke coils 13.

A substantially constant transverse magnetic field is produced by means of a magnetizing winding 14 which is wound around the tube and which may be energized from a source of direct-current energy 15 through a resistor 16 and a radio-frequency choke coil 17.

An outgoing circuit 19 comprises a secondary winding 21 of the coupling transformer 8 and a condenser 22 which is connected in shunt relation to said secondary winding, the circuit formed by said shunt connection being tuned to the double-frequency harmonic which is introduced into the primary circuit 6 by the variable-capacity element 1, as will be explained hereinafter.

In Fig. 2, is shown a curve indicating the relation between the voltage impressed across the terminals of the variable-capacity element, as ordinates, and the charge on the electrodes contained therein, as abscissæ. It will be noted that the general shape of the curve is similar to the well known saturation curve of an iron core. It is important to notice that this curve does not show the relation between the voltage and the current. Such relation is shown by the usual characteristic curve for a vacuum tube. In this tube the magnetic field is strong enough to prevent electrons from reaching the anode and, therefore, the current is always very small, the device acting in this respect like a true condenser except that it may have a somewhat greater leakage.

Since this curve has a very marked knee, it is evident that at a characteristic potential the rate of change of the charge upon the electrodes with changing potential will alter abruptly. In order to avoid lengthy expressions in the specification and claims, this value of the potential is called the critical potential. The value of the biasing voltage of the direct-current source 12 is such as to adjust the constants of the tube to a point where operation may be effected upon the knee of the curve shown in Fig. 2.

The operation of my device, as a frequency-doubler, may be more readily explained by referring to the curves shown in Fig. 3, wherein curve *a* shows the sinusoidal wave form of the primary voltage impressed across the terminals of the variable-capacity element 1, and curve *b* represents the variations in the charge on the electrodes corresponding to the variations in voltage, as shown in curve *a*.

The reason for the variations in curve *b* may be explained by referring to Fig. 2. Since the biasing voltage is of such value as to adjust the charge upon the electrodes to a value corresponding to the knee of the curve, the effect of positive half cycles of the voltage wave upon the charge is many times greater than for negative half cycles, thereby inducing a double-frequency harmonic voltage in the secondary circuit, as shown in the current curve *c*. The latter curve is obtained from curve *b* by taking the derivative thereof with respect to time.

In view of the foregoing description, it can readily be seen that, upon adjusting the biasing voltage to the knee of the curve shown in Fig. 2, double-frequency currents are introduced in the primary circuit 6 which may be absorbed by the double-frequency circuit 19.

An advantage of my invention is the provision of a simple, efficient and easily constructed variable-capacity element, the operating characteristics of which are such that it may be employed either as a frequency multiplier or as an amplifier.

While I have shown the variable-capacity element embodying my invention constructed according to a special design and employed in a specific circuit arrangement, it is not to be limited thereby and I desire that only such limitations shall be imposed thereon as are indicated in the prior art or are specifically set forth in the appended claims.

I claim as my invention:

1. A variable-capacity element comprising an evacuated electric device having a space-current path therein, electrodes individual to said space-current path and means associated with said device for producing a magnetic field transverse to said space-current path and of sufficient strength to prevent the electrons from completely traversing the space between said electrodes.

2. A variable-capacity element comprising an enclosed envelope, a space-current path, electrodes individual to said space-current path and means for producing a substantially constant magnetic field transverse to said space-current path and of sufficient strength to prevent the electrons from completely traversing the space between said electrodes.

3. A variable-capacity element wherein are combined a hot cathode, an anode and means for producing a magnetic field substantially constant in value, said magnetic field being transverse to said space-current path and of sufficient strength to prevent the electrons from completely traversing the space between said electrodes.

4. In an electrical system, a variable-capacity element wherein are combined a containing envelope, a hot cathode, an anode disposed in symmetrical relation thereto and magnetizing windings symmetrically disposed with respect to said anode and included in a circuit containing a direct-current source of energy, said direct current being sufficient to produce a magnetic field of the strength that will prevent the electrons from completely traversing the space between said electrodes.

5. In an electrical system, a variable-capacity element consisting of a hot cathode, an anode, means for producing an electron stream from said hot cathode toward said anode and means for producing a magnetic field transverse to said electron stream, whereby said electrons are caused to assume curved paths, the capacity of said element being a function of the diameter of said curved paths.

6. A condenser drawing leading wattless currents having a non-rectilinear voltage-current characteristic comprising a pair of conductors, means for establishing, between said conductors, a space-current discharge having a critical-potential condition, and means for applying a biasing component unidirectional potential approximating said critical potential.

7. An electrical condenser comprising a pair of separated conducting media, at least one of said media having a relatively small diameter of cross-section as compared to its length, and means for rendering the effective diameter of said medium variable in accordance with the magnitude of the impressed potential.

8. A device having a variable electrical capacity, which capacity is a function of the voltage impressed thereon, which comprises an envelope having electrodes at the ends of a space-current path, and means for producing a unidirectional magnetic field transverse to said path and of sufficient strength to prevent any electrons from completely traversing the space between said electrodes.

9. A variable-capacity element comprising a hot cathode, a co-axially mounted anode, and means for producing a magnetic field substantially constant in value, said magnetic field being transverse to the current path between said cathode and anode and of sufficient strength to prevent any electrons from completely traversing the space between said electrodes.

10. The method of varying the electrostatic capacity of an evacuated electric device having an electron-emissive cathode and another electrode therein which comprises impressing a transverse magnetic field between said electrodes of such strength that substantially none of said electrons reach said other electrode, and varying the potential impressed between said electrodes.

11. The method of varying the electro-

static capacity between an electron-emissive cathode and another electrode which comprises impressing upon the space between said electrodes a magnetic field of such intensity as to cause electrons emanating from said cathode to traverse curved paths which do not intersect the other electrode, and varying the voltage impressed between said electrodes.

In testimony whereof, I have hereunto subscribed my name this 16th day of August, 1921.

CHESTER T. ALLCUTT.