

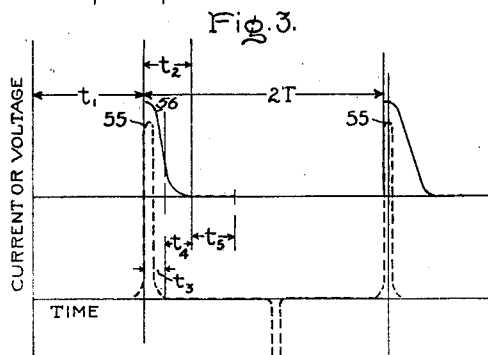
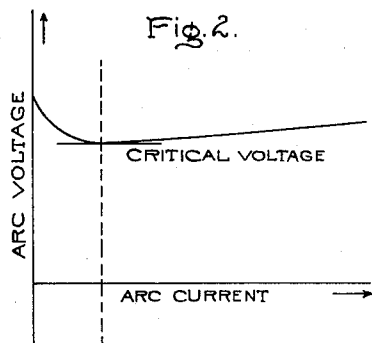
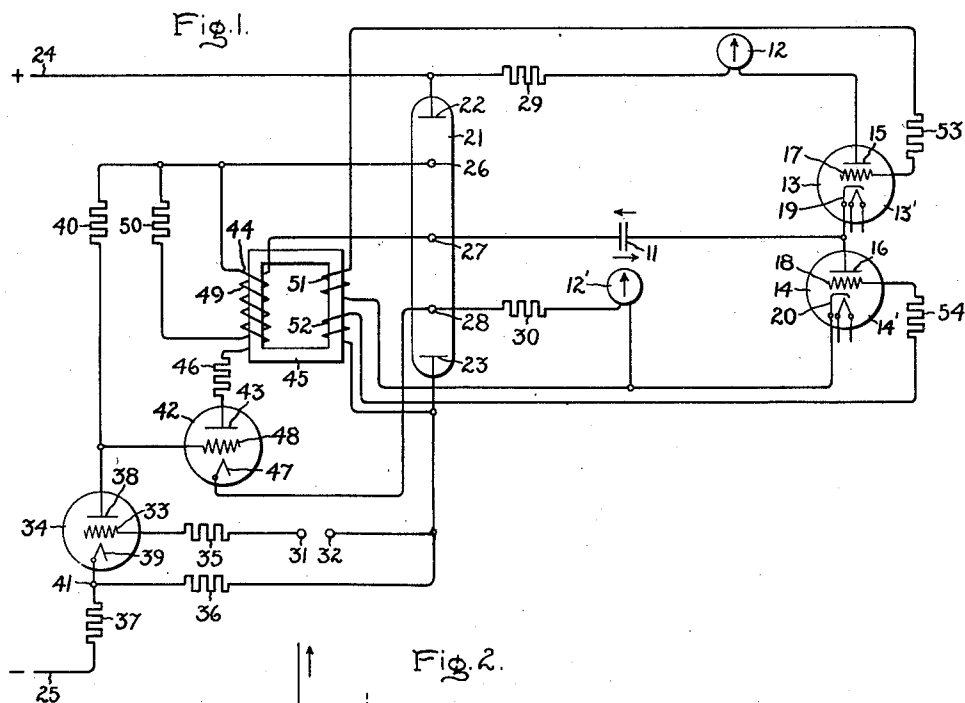
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T. FECKER

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FREQUENCY RESPONSIVE APPARATUS

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Inventor
 Theo Fecker,
 by *Harry E. Junker*
 His Attorney.

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FREQUENCY RESPONSIVE APPARATUS

Theo Fecker, Berlin-Reinickendorf-Ost, Germany, assignor to General Electric Company, a corporation of New York

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10 Claims. (Cl. 175—368)

My invention relates to frequency responsive apparatus and to receivers for telemetric systems of the impulse frequency type.

It is the principal object of my invention to produce frequency responsive apparatus which is unaffected by variations in voltage of the source of current, the frequency of which is to be measured. It is also an object of my invention to produce apparatus responsive to the occurrence of current or voltage impulses but unaffected by variations in the amplitudes thereof. Another object is the precise measurement of high frequencies.

Still another object of my invention is the production of voltage peaks of substantially constant amplitudes in response to predetermined events. Still another object of my invention is the production of voltage impulses of substantially constant amplitudes in response to relatively minute variations of a received current from a predetermined value.

Still another object of my invention is to provide a grid control arrangement for discharge tubes of the grid control type in which the operation of the tube and the amplitude of the discharge are substantially independent of the magnitude of the control voltage.

A further object of my invention is to provide an arrangement for successively charging a condenser to equal voltages after successive discharges in response to impulses, irrespective of variations in strength of said impulses. Other and further objects and advantages of my invention will become apparent as the description proceeds.

In accordance with my invention in its preferred form, current impulses to be received are supplied to the primary winding of a saturable core or peaking transformer which has secondary windings connected in the grid circuits of grid controlled discharge tubes arranged alternately to charge a condenser from a constant voltage source through a current responsive device and to discharge the condenser in response to the impulses. The arrangement is such that the control or igniting voltages of the discharge tubes are of very short duration with respect to the charging and discharging periods so that variations in the strength of the impulses or the igniting voltages are without effect on the magnitudes of the charges stored in the condenser.

The features of my invention, which I believe to be novel and patentable, will be pointed out in the claims appended hereto. A better understanding of my invention, itself, however, may be

obtained by referring to the following description taken in connection with the accompanying drawing in which Fig. 1 is a circuit diagram representing schematically the arrangement of apparatus constituting one embodiment of my invention; Fig. 2 is a curve representing the relationship between arc current and anode voltage of a gaseous or vapor discharge tube; and Fig. 3 is a graph illustrating the time and amplitude relationships between various currents and voltages acting in the apparatus represented in Fig. 1.

In Fig. 1, of the drawing, I have shown apparatus constructed in accordance with one form of my invention, which may be utilized either as the receiver in a telemetric system of the impulse frequency type or simply as a frequency indicator.

In general, the apparatus consists of terminals 31 and 32 through which the apparatus is connected to a transmitting circuit of an impulse frequency telemetering system, discharge tubes 34 and 42 amplifying the received impulses, a saturable core transformer 45 for converting the received impulses into high peak voltage impulses of short duration, a condenser 11, charged and discharged in response to said impulses, a current responsive device 12 carrying the condenser charging current and giving the desired meter indications, a glow tube 21 with intermediate electrodes for supplying various voltages to charge condenser 11 and to operate the tubes, and grid controlled discharge tubes 13 and 14 which control the charging and discharging of the condenser 11 and are triggered by the high peak voltage impulses produced by the transformer 45.

Considering the apparatus, now more in detail, it will be seen that I have represented the application of my invention to an arrangement in which a condenser 11 is charged and discharged in response to each of the successive cycles or in response to each of the received impulses of a given polarity, the frequency of which is to be determined and the frequency measurement is made or the response to frequency is obtained by means of a current responsive device 12 through which the currents flow which successively charge the condenser 11.

The charging and discharging of the condenser 11 are controlled by means of a pair of grid controlled discharge tubes 13 and 14, consisting respectively of suitable envelopes 13' and 14' containing anodes 15 and 16, control electrodes or grids 17 and 18, and cathodes 19 and 20, which may if desired be of the indirectly heated type. The envelopes 13' and 14' also contain suitable

gaseous or vaporous material serving to impart to the tubes 13 and 14 the property of conducting current after a discharge has been initiated, without the continued application of voltage to the control grids 17 and 18. Any suitable gas or vapor may be employed but, where the apparatus is to be used in connection with the measurement of high frequencies, care should be taken to employ tubes having relatively short deionization times. I have found that tubes containing a light gas, such as hydrogen may satisfactorily be employed for high frequency work.

The requisite auxiliary potentials for the operation of the apparatus may, if desired, be obtained from a high resistance element, such as, for example, a glow discharge tube 21, having electrodes 22 and 23 connected to the positive terminal 24 and the negative terminal 25, respectively, of a source of current preferably one substantially free from variations in voltage, although my arrangement tends to overcome the effect of voltage variations. The discharge tube 21 also contains the auxiliary electrodes 26, 27, and 28 spaced between the electrodes 22 and 23 and serving to provide points of intermediate potential.

The discharge tube 13 controlling the charging of the condenser 11 has its anode 15 connected in series with the current responsive device 12 and a resistor 29 to the positive terminal 24 of the direct current source, and has its cathode 19 connected to one plate of the condenser 11, the other plate of the condenser 11 being connected to the electrode 27 of the glow discharge tube 21. The discharge tube 14, controlling the discharge of the condenser 11, has its anode 16 connected to the cathode 19 of discharge tube 13 and to one plate of the condenser 11, and has its cathode 20 connected in series with a resistor 30 to the electrode 28 of the glow discharge tube 21.

Discharges are initiated in the discharge tubes 13 and 14 by positive potential impulses impressed upon the grids 17 and 18 in response to impulses received by the apparatus in a manner which will be described more in detail in connection with the specific apparatus shown by way of example.

The voltage impulses or cycles of alternating voltage received by the apparatus, the frequency of which is to be determined, are applied to terminals 31 and 32 which are connected, respectively, to the grid 33 of a discharge tube 34 through a current limiting resistor 35 and to the negative terminal 25 of the auxiliary source of current through resistors 36 and 37.

The presence of the resistor 35 reduces the internal power of the apparatus in cases where high voltages may at times be applied to the terminals 31 and 32, thereby making the apparatus applicable to the frequency measurement of either high or low voltage impulses, and preventing the withdrawal of appreciable power from a transmission circuit.

The discharge tube 34 has an anode 38, and a cathode 39, connected in series with a resistor 40 between the electrode 26 of the glow discharge tube 21 and the common terminal 41 of resistors 36 and 37. A second discharge tube 42 has its anode 43 connected to the electrode 26 of the glow discharge tube 21 in series with the primary winding 44 of a saturable core transformer 45 and a resistor 46, and has its cathode 47 connected to the electrode 28 of the glow discharge tube 21. The control grid 48 of the discharge

tube 42 is connected to the anode 38 of the discharge tube 34. The discharge tubes 34 and 42 may be of any desired type but are preferably of a type providing high amplification.

In order to compensate for the magnetomotive force or the ampere turns of the winding 44 of the saturable core transformer 45 produced by the normal anode or plate current of the discharge tube 42, a compensating winding 49 is also wound on the core of the transformer 45 and is so connected between the electrodes 26 and 27 of the glow discharge tube 21 that it produces a flux opposing that of the winding 44. A resistor 50 is connected in series with the winding 49 and has a resistance of such a value that the windings 44 and 49 are balanced in a desired portion of the characteristic curve of the discharge tube 42. The windings 44 and 49 are preferably wound upon the same portion of the core of the transformer 45.

The saturable core transformer 45 is also provided with secondary windings 51 and 52 for controlling the discharge tubes 13 and 14 respectively. The windings 51 and 52 are preferably wound upon a different portion of the core of the transformer 45 from the windings 44 and 49 in order to magnify the effect of saturation by allowing leakage flux to cross the air space between the two wound portions of the core of the transformer 45. The grid 17 of the discharge tube 13 is connected in series with a current limiting resistor 53, the secondary winding 51 of transformer 45, and the resistor 30 to the electrode 28 of glow tube 21. Similarly, the control grid 18 of the discharge tube 14 is connected in series with a current limiting resistor 54, and the secondary winding 52 of transformer 45 to the electrode 23 of the glow discharge tube 21.

In the operation of the apparatus, the received voltage impulses applied to the terminals 31 and 32 are amplified by the discharge tubes 34 and 42 to produce current impulses in the primary winding 44 of the saturable core transformer 45. Owing to the characteristics of the transformer 45, current reversals in the winding 44 produce voltage peaks of high amplitudes and short duration in the secondary windings 51 and 52 which are impressed upon the grids 17 and 18 of the discharge tubes 13 and 14. The connections are such that positive voltage peaks are impressed alternately upon the grids 17 and 18 so that, in the case of receiving alternating voltages, in response to one received half cycle, the discharge tube 13 becomes conducting and permits condenser 11 to be charged while tube 14 is held non-conducting and, in response to the next received half cycle, the discharge tube 14 becomes conducting while the discharge tube 13 remains non-conducting and the condenser 11 is discharged. The frequency of the received cycles or impulses, obviously, determines the number of charges applied to the condenser 11, and consequently the average value of the current traversing the windings of the current responsive device 12 which, therefore, is responsive to the frequency of the received impulses. The apparatus obviously may be used to determine the frequency of fluctuation of pulsating direct current or the frequency of intermittent impulses as well as the frequency of alternation of alternating current. Although the polarity of a direct-current circuit remains unchanged, each impulse in such a circuit corresponds to a cycle of an alternating-current circuit since, in each case, the alternate rise and fall of current or voltage result in the

successive voltage peaks produced by the transformer 45 and in the charge and discharge of the condenser 11. If desired, a frequency determination may also be made by means of a current responsive device 12' connected so as to carry the successive discharging currents of the condenser 11.

Since the grid 17 of the discharge tube 13 is connected to the electrode 28 of the glow tube 21, it is normally at a negative potential with respect to the cathode 19 of the discharge tube 13 which is connected to one plate of condenser 11, the opposite plate of which is connected to the electrode 27 of the glow tube 21. Consequently, the potential of grid 17, being negative, normally has no effect upon the magnitude of the discharge current in the tube 13. The magnitude of the positive peak potential impulse impressed by the winding 51, is such as to overcome this negative bias and to permit the discharge tube 13 to become conducting in response to alternately received impulses.

The extinguishing of the discharge in the tube 13, however, is controlled by the potential difference between the electrodes 15 and 19. As the charge on the condenser 11 increases, the potential of the cathode 19 rises until the potential difference between electrodes 16 and 19 falls to the critical value at which a discharge can no longer be maintained. Expressing the operation in another way, as the charge on the condenser 11 increases, the charging current gradually decreases in accordance with the well known nature of condenser charges until the current in the discharge tube 13 falls to the minimum value at which it can be maintained. The critical values of current and voltage are shown in the curve of Fig. 2 in which arc voltage, or the voltage between electrodes 16 and 19, is plotted against discharge or arc current. It is seen, therefore, that after the arc current falls to the critical value represented by the intersection of the dashed line with the curve, an increase in arc voltage would be necessary to maintain the discharge. The voltage, however, is determined by the charge upon the condenser 11 and consequently, when this critical point is reached, the discharge is extinguished, the condenser being charged during each charging period to a voltage determined by this critical voltage so that equal charges are stored in the condenser during successive periods and the response of the current responsive device 12 is dependent wholly upon the number of impulses received and not upon the voltage of the received impulses.

In like manner, since the control grid 18 is connected to the electrode 23 whereas the cathode 20 of discharge tube 14 is connected to the electrode 28 of the glow tube 21, the control grid 18 is normally definitely negative with respect to the cathode 20 and its potential is then without effect upon the discharge in the tube 14. However, when the positive peak potential occurs in the winding 52, the control grid 18 momentarily becomes positive in order to initiate a discharge. As will be explained hereinafter, the positive impulses are of such short duration as to be without effect upon the magnitude of the discharges in tubes 13 and 14.

The constants of the transformer 45 are so chosen that the core becomes saturated at a predetermined value of resultant primary ampere turns or magnetomotive force so that further increases in the primary current cause substantially no further increase in flux. The material of

which the core is composed is one having a high permeability at low magnetization, the permeability of which decreases rapidly at the saturation point so that the flux of the transformer tends to increase rapidly as the primary current increases up to the point of saturation and also tends to decrease rapidly as the primary current decreases below the point of saturation. Consequently, sharp voltage peaks of short duration are produced in the secondary windings 51 and 52 as illustrated by the curves 55 in Fig. 3.

Owing to the fact that the core of the transformer 45 may be premagnetized by the windings 44 and 49, i. e., may be normally magnetized to a value bearing any desired relationship to the critical value at which the core of transformer 45 becomes saturated, the tube 42 may be operated at the steepest portion of its characteristic curve so that very slight variations in the anode current of the tube 42 produce appreciable variations above or below the primary current at which the core of the transformer 45 saturates. Consequently, specially high sharp voltage peaks are obtained from secondary windings 51 and 52 giving greater sensitivity and independence of the apparatus from the magnitude of the voltages received at the terminals 31 and 32.

The grid voltage of the tube 42 is determined by the anode current of the tube 34, and, preferably, this grid voltage is so selected that the working range of the tube 42 lies within the straight line portion of the tube characteristic. Owing to the presence of the resistor 40 in the anode circuit of the discharge tube 34, the potential variations of the control grid 48 produced by variations in anode current of the discharge tube 34 are further amplified. The magnitude of the resistor 36 may be so selected that the discharge tube 34 is also operated in the steepest part of its characteristic so as to obtain a further amplifying effect. If desired, additional amplifying tubes may be cascaded in this manner in order to make the apparatus responsive to frequencies of very minute alternating voltages or to minute voltage impulses applied to the terminals 31 and 32.

The time relationship between the events occurring in the apparatus of Fig. 1 is illustrated graphically in Fig. 3, where curves 55 represent the high peak secondary voltages induced in windings 51 and 52 of transformer 45 plotted against time. At the instant t_1 , the voltage 55 produced by the secondary winding 51 exceeds the negative bias of the control grid 17 of discharge tube 13 produced by the negative voltage from electrode 27 to electrode 28 of the glow tube 21. At this instance, anode current 56 starts to flow in the discharge tube 13, charging the condenser 11 and gradually falling off as the potential difference between the plates of the condenser 11 increases. The constants of the circuit are so chosen that the duration of the time period t_3 in which the peak voltage 55 falls to zero and the control grid 17 regains its full negative bias is less than the time period t_2 during which the charging of the condenser 11 continues so that the momentary positive potential of the control grid 17 is wholly without effect upon the magnitude of the current 56 charging the condenser 11. The last part of the charging of the condenser 11 takes place during the time period t_4 when the grid bias is wholly negative. t_5 represents the deionization time of the discharge tube 13 and $2T$ represents the minimum interval between successive impulses to be received. It will be understood that the constants of the discharge tube 75

13 must be so chosen that the time period t_2 plus t_3 is less than the period $2T$ in order that the ionization of the tube 13, that is its tendency to conduct, will have completely disappeared before the reception of the succeeding impulses. Likewise, the constants of the charging circuit of the condenser 11 will be so chosen that the time period t_2 is less than the half cycle T of the received impulses in order that the charging of the condenser 11 will have been completed within the half cycle during which discharge tube 13 is permitted to conduct and before the discharge tube 14 becomes conducting in order to discharge the condenser 11.

In accordance with the provisions of the patent statutes, I have described the principle of operation of my invention together with the apparatus which I now consider to represent the best embodiment thereof, but I desire to have it understood that the apparatus shown is only illustrative and that the invention may be carried out by other means.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. An impulse responsive device comprising in combination a source of direct current, a discharge tube having a plurality of electrodes including two electrodes connected to said source of current and an intermediate electrode providing a point of intermediate potential, a condenser having a pair of plates one of which is connected to said intermediate electrode, means for alternately connecting the second plate of said condenser to electrodes at higher and lower potentials than said intermediate electrode, and current responsive means connected in series with one of said latter electrode connections.
2. An impulse responsive apparatus comprising in combination a source of direct current, a discharge tube having a plurality of electrodes including two electrodes connected to said source of current and at least one intermediate electrode providing a point of intermediate potential, a condenser having a pair of plates one of which is connected to said intermediate electrode, a grid controlled discharge tube having an anode connected to one of the electrodes of said first mentioned discharge tube at a higher potential than said intermediate electrode, a cathode connected to the second plate of said condenser and a control grid, a second grid controlled discharge tube having an anode connected to the second plate of said condenser, a cathode connected to one of the electrodes of said first mentioned discharge tube at lower potential than said intermediate electrode and a control grid, a current responsive device connected in series with one of said grid controlled discharge tubes, and means for impressing positive potentials on each of said control grids successively in response to each successive impulse of a given polarity, thereby rendering said tubes alternately conducting, alternately charging said condenser in reverse directions, but causing a unidirectional current to flow in said current responsive device.
3. In an impulse responsive device the combination of a saturable core transformer having primary and secondary windings, a source of direct current, a grid controlled discharge tube having a plate circuit connected to said current source in series with the primary winding of said transformer, and having a control grid energized by impulses to be received, said tube being so adjusted that the normal plate current of said tube premagnetizes said transformer, whereby weak

impulses applied to said control grid result in large changes in plate current producing abrupt saturation of said transformer and inducing high sharp voltage peaks in the secondary winding of said transformer.

4. An impulse responsive device comprising in combination a condenser, a source of direct current, a grid controlled discharge tube having a control grid and having a pair of electrodes connecting said condenser to said source of current, a second source of current having a polarity opposite to that of the first mentioned source, a second discharge tube having a control grid and having a pair of electrodes connecting said condenser to said second mentioned source of current, a current responsive device connected in series with one of said discharge tubes, and means for impressing positive voltage impulses upon each of said control grids successively in response to each successive impulse of a given polarity, thereby rendering said tubes alternately conducting, alternately charging and discharging said condenser and causing said current responsive device to carry an average current dependent upon the frequency of said impulses.

5. An impulse responsive device comprising in combination a source of current, a grid controlled discharge tube having an anode connected to one terminal of said source, a cathode and a control grid, a condenser connected between said cathode and the remaining terminal of said current source, a second discharge tube having an anode connected to one side of said condenser, a cathode and a control grid, a current source connected to the remaining side of said condenser and to the cathode of said second discharge tube, a current responsive device connected in series with one of said discharge tubes, and means for impressing positive potentials upon each of said control grids successively in response to each successive impulse of a given polarity, thereby rendering said tubes alternately conducting, alternately charging said condenser in reverse directions and causing said current responsive device to carry an average current dependent upon the frequency of said impulses.

6. An impulse responsive device comprising in combination a saturable core transformer having primary and secondary windings, a current responsive device in circuit with said secondary winding, a discharge tube having a plate circuit in series with said primary winding, and having a control grid energized by impulses to be received, said plate circuit being so adjusted that the normal plate current of said tube magnetizes said transformer to a value approaching that producing saturation, whereby weak impulses applied to said grid result in large changes in plate current producing abrupt saturation of said transformer and inducing high sharp voltage peaks in the secondary winding of said transformer.

7. An impulse responsive device comprising in combination a saturable core transformer having a main primary winding, a primary compensating winding and a secondary winding, a current responsive device in circuit with said secondary winding, a source of current and a discharge tube in series with said main primary winding, a source of current energizing said compensating winding, said discharge tube having a control grid energized by impulses to be received, said primary windings being so proportioned that their net effect causes said trans-

former to become saturated with a value of current in said tube coming within the steep portion of its characteristic curve.

5 8. In combination, a saturable core transformer having a main primary winding, a primary compensating winding and a secondary winding, a source of current, and a variable impedance discharge tube in series with said current source and said main primary winding
10 and serving to control the current in said winding, said discharge tube having a normal impedance at which normal plate current flows, said compensating winding being so connected as to oppose said main primary winding and
15 serving to neutralize the ampere turns produced by the normal plate current of said tube flowing through said main primary winding.

9. A telemetering system of the impulse frequency type having a receiver comprising in combination a condenser, a source of direct current,
20 a grid controlled discharge tube having a control grid and having a pair of electrodes connecting said condenser to said source of current, a second source of current having a polarity opposite
25 to that of the first mentioned source, a second discharge tube having a control grid and hav-

ing a pair of electrodes connecting said condenser to said second mentioned source of current, a current responsive device connected in series with one of said discharge tubes, and means for impressing positive voltage impulses
5 upon each of said control grids successively in response to each successive impulse of a given polarity transmitted through the said system, thereby rendering said tubes alternately conducting, alternately charging said condenser in
10 reverse directions and causing said current responsive device to carry an average current dependent upon the frequency of said impulse.

10. In an impulse responsive device, the combination of a condenser, a source of current, an
15 arc-discharge tube connected in series with said condenser and said source and having a control grid, a second arc-discharge tube connected in a circuit across said condenser for discharging it
20 and having a control grid, and a saturable core peaking transformer having secondary windings energizing said control grids with opposite polarities and having a primary winding adapted
25 to receive electric impulses.

THEO FECKER.