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THERMIONIC ENERGY DETECTOR

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Fig. 1.

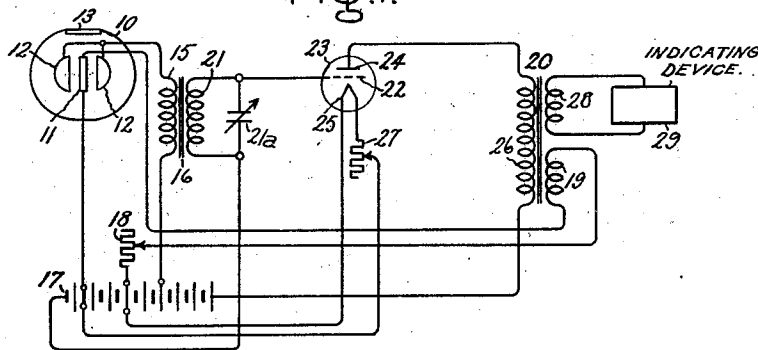


Fig. 2.

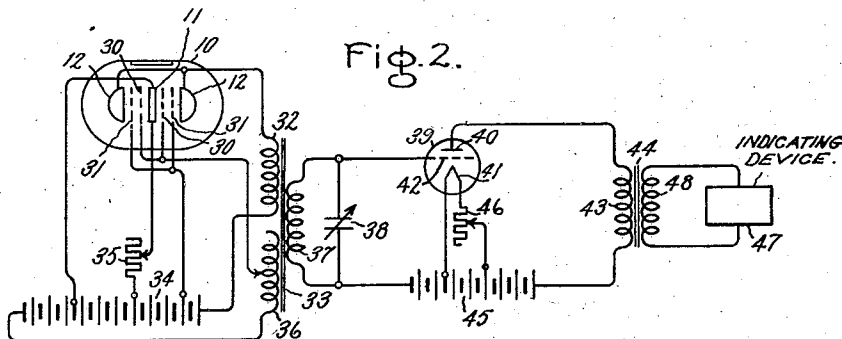
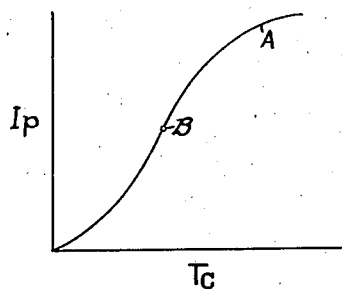


Fig. 3.



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THERMIONIC ENERGY DETECTOR

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My invention relates to thermionic energy detectors and, particularly, to electronic systems and apparatus for measuring the intensity and, if desired, the frequency of pulsating thermionic radiant energy, such as for example the infra-red radiation which is emitted from the exhaust of an internal combustion engine, or through the propeller of an approaching aircraft, or the like.

It is a principal object of my invention to provide a new and improved electronic apparatus for detecting pulsating or periodic thermal transfer.

The invention is particularly concerned with thermionic radiation measurement, and has for a particular object the provision of means for increasing substantially the response of electronic detecting apparatus for such radiation beyond the response of such apparatus heretofore known.

The particular features of novelty characteristic of my invention will be pointed out with particularity in the claims appended hereto. The invention may be more fully understood, however, and its objects and advantages further appreciated by referring now to the following detailed specification taken in conjunction with the accompanying drawings, in which Fig. 1 is a schematic circuit diagram of a thermionic radiant energy detecting apparatus embodying my invention; Fig. 2 is a schematic circuit diagram of another such apparatus embodying my invention in modified form; and Fig. 3 is a graphical representation of the thermal characteristic of the detecting electric discharge device.

Referring now to the drawings, I have shown at Fig. 1 an electric discharge device 10 comprising a thermal sensitive electron emitting cathode 11 positioned between a pair of anodes 12. The electrodes 11 and 12 are enclosed within a suitable evacuated envelope which may be of glass or metal and provided with a suitable window 13 through which thermal radiant energy, such as infra-red rays, may be directed toward the cathode 11. Preferably, such a window is composed of a fusible inorganic salt, such as a halogen salt of sodium or potassium or calcium fluoride. As disclosed in Patent 2,125,113, granted to A. K. Kling on July 26, 1938, such a window may be inexpensively constructed of rock salt.

The cathode 11 is positioned directly in the path of radiant energy entering the rock salt window 13 in the evacuated envelope. Preferably, the cathode is formed of a flat ribbon of thoriated tungsten or a flat ribbon of tungsten coated with a suitable oxide for increasing the electron emis-

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sivity of its surface. Oxides suitable for this purpose are barium oxide, caesium oxide, and the like. Preferably, the anodes 12 comprise flat metallic plates which may be semi-circular in shape and disposed so on opposite sides of the cathode 11 that the planes of the anodes 12 are positioned at a slight angle with respect to each other.

I have shown at Fig. 1 the anodes 12 electrically connected together and to one terminal of a primary winding 15 of a transformer 16. The opposite terminal of the primary winding 15 is connected to a suitable source of positive potential, such as a battery 17. The cathode 11 of the electric discharge tube 10 is also connected to the battery 17 at a point negative with respect to the point of connection of the transformer winding 15, thereby to complete an output or load circuit for the discharge device 10.

The cathode 11 of the discharge device 10 is connected to be heated by current from the battery 17 through a circuit comprising a variable resistor 18, a tertiary winding 19 on a transformer 20, and the cathode 11, all connected in series circuit relation between points of suitable potential difference on the battery 17.

The transformer 16 is provided also with a secondary winding 21 shunted by a tuning capacitor 21a and having one terminal connected to a control grid 22 of a low frequency electronic amplifying device 23. The amplifier 23 comprises also an anode 24 and a cathode 25. The anode 24 is connected to one terminal of a primary winding 26 on the transformer 20, the opposite terminal of which is connected to a suitable source of positive potential on the battery 17. The cathode 25 of the amplifier 23 is also connected to the battery 17 at a point more negative in potential than the point to which the primary winding 26 of the transformer 20 is connected. The transformer winding 21, which supplies the input power for the amplifier 23 and has one terminal connected to the control grid 22, also has its other terminal connected to a point on the battery 17 which is more negative in potential than the point to which the cathode 25 is connected, thereby normally to bias the amplifier 23 negatively. The cathode 25 is heated by current from points of suitable potential difference on the battery 17 through a circuit including a variable resistor 27.

The transformer 20 is provided also with a secondary winding 28 connected to a suitable measuring or indicating device 29, such as an ammeter.

ter, voltmeter, cathode ray tube, loudspeaker, or the like.

The thermal electron emission characteristic of the electric discharge device 10 may be represented by a curve such as the curve A of Fig. 3. This curve represents the relation between plate current, I_p , and cathode temperature, T_c . It will be noted that at some intermediate point, such as B, in the range of temperature values, the rate of change of plate current with temperature is a maximum.

In operation, when potential is applied between the anode and cathode of the discharge device 10 and the electric discharge device 10 is directed so that pulsating thermal radiant energy from a source the temperature or distance of which is to be measured falls upon the cathode 11, a plate current flows having an instantaneous value proportional to the instantaneous temperature of the cathode 11. The temperature of the cathode 11 is determined by the sum of the heating effects of the received radiant energy and the electric heating circuit. Preferably, the variable resistor 18 is so adjusted that the average cathode temperature resulting from the sum of the current heating and the radiant energy heating falls somewhere near the point B on the curve A of Fig. 3. Thus, as the cathode temperature is periodically increased and decreased instantaneously by the pulsation of the received radiant energy, the anode current pulsates and an alternating component of current at the frequency of the radiant energy pulsation flows through the transformer 16. The alternating potentials thus induced in the secondary winding 21 of the transformer 16 are amplified in the discharge device 23 and applied to the output transformer 20. These amplified oscillations appear upon the secondary winding 28 of the transformer 20 and are applied to the indicating or measuring device 29.

For the purpose of increasing the sensitivity of my detecting apparatus to radiated thermionic energy, I provide for regenerative feedback of energy from the output transformer 20 to the cathode heating circuit of the discharge device 10. It is for this purpose that the tertiary winding 19 of the output transformer 20 is connected in series circuit relation in the heating circuit for the cathode 11 of the discharge device 10. To ensure regeneration, rather than degeneration, from the winding 19, it is only necessary to so arrange the circuits that the oscillations appearing across the winding 19 are in phase with the radiant energy pulsations received by the cathode 11 of the discharge device 10. To further ensure maximum response, it will be clear that the tuning condenser 21a should be adjusted so that the parallel resonant circuit comprising the transformer winding 21 and the condenser 21a is tuned to the frequency of the received radiant energy pulsations.

At Fig. 2, I have shown another embodiment of my invention in which the electric discharge device 10 is provided with a control grid and a suppressor grid between the cathode 11 and each of the anodes 12. The control grids are electrically connected together and are identified by the reference numeral 30. The suppressor grids are also electrically connected together and are identified by the reference numeral 31. Furthermore, as at Fig. 1, the anodes 12 are electrically connected together and to one terminal of a primary winding 32 of a transformer 33. The opposite terminal of the primary winding 32 of

the transformer 33 is connected to a point of positive potential upon a battery 34, while the cathode 11 is directly connected to a point on the battery 34 which is relatively negative in potential. Furthermore, between points of suitable potential difference upon the battery 34, is connected a cathode heating circuit including a variable resistor 35 and the cathode 11 connected in series circuit relation. The suppressor grids 31 are connected directly to a suitable point upon the battery 34 positive with respect to cathode potential. In order that the discharge device 10 may be properly biased, the control grids 30 are connected through a tertiary winding 36 on the transformer 33 to a suitable point upon the battery 34 which is slightly more negative in potential than the point to which the cathode 11 is connected. The unidirectional potential applied from the battery 34 to the control grids 30 through the tertiary winding 36 provides a negative bias for the discharge device 10.

The transformer 33 is provided with a secondary winding 37 having connected in parallel circuit relation therewith a tuning capacitor 38. The secondary winding 37 is connected to the input of an amplifying electric discharge device 39 having an anode 40, a cathode 41, and a control electrode 42. The anode 40 is connected to one terminal of a primary winding 43 of an output transformer 44. The other terminal of the winding 43 is connected to a suitable source of positive potential, such as a battery 45. The cathode 41 of the discharge device 39 is connected to a suitable point of negative potential upon the battery 45, and a cathode heating circuit for the cathode 41 is connected through a variable resistor 46 between points of suitable potential difference upon the battery 45. Finally, the transformer winding 37 has one terminal connected to the control grid 42 of the amplifier 39 and the other terminal connected to a point on the battery 45 which is slightly more negative in potential than the point of connection to the cathode 41. The section of the battery 45 between the cathode 41 and the connected terminal of the transformer winding 37 provides a source of negative bias potential for the control grid 42. The amplified signal upon the transformer winding 43 is applied to a suitable measuring or indicating device 47 through a secondary winding 48 upon the output transformer 44.

In the operation of the apparatus of Fig. 2, the cathode heating circuit of the electric discharge device 10 is adjusted in the same manner as described heretofore in connection with Fig. 1. Thus, when pulsating infra-red radiation falls upon the cathode 11, the anode current in the electric discharge device 10 varies periodically thereby to provide an alternating component of current in the transformer 33. The signal thus induced in the transformer 33 is amplified in the discharge device 39 and impressed upon the indicating device 47 through the transformer 44. Simultaneously, also, an alternating potential at the frequency of the received pulses of thermionic energy is induced in the tertiary winding 36 of the transformer 33. The potential induced in the tertiary winding 36 is connected in series circuit relation in the control grid biasing circuit for the electric discharge device 10, whereby this alternating potential is superposed upon the normal unidirectional bias potential of the control grid 30. The alternating potential on the winding 36 will be substantially in phase with the pulsations of thermionic energy to which the cathode 11 is

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exposed, and the winding 36 is so arranged that the potential fed back to the discharge device 10 is regenerative rather than degenerative; that is, whenever the anode current is increased instantaneously by an increase in the radiation falling upon the cathode 11, the tertiary winding 36 instantaneously raises the potential of the control grid 30 in a positive direction, thereby further to increase the anode current and to enhance the response of the apparatus to the radiated thermionic pulsations.

While I have shown only certain preferred embodiments of my invention by way of illustration, many further modifications will occur to those skilled in the art and I, therefore, wish to have it understood that I intend in the appended claims to cover all such modifications as fall within the true spirit and scope of my invention.

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

1. A thermionic radiant energy detecting apparatus comprising an electric discharge device having an anode and a thermo-sensitive electron emissive cathode, electric heating means for said cathode comprising a source of unidirectional potential, means for exposing said cathode to pulsating thermal radiant energy, said cathode controlling the anode current of said discharge device in accordance with instantaneous variations in intensity of said pulsating radiant energy, and means connected in series circuit relation between said cathode and said source of unidirectional potential for deriving from said anode current an alternating potential of like frequency and time phase relation with the pulsations of said radiant energy, thereby regeneratively to increase the response of said discharge device to said radiant energy.

2. A thermionic radiant energy detecting apparatus comprising an electric discharge device having an anode and a thermo-sensitive electron emissive cathode, electric heating means for said cathode connected in circuit with a source of unidirectional potential, means for exposing said cathode to pulsating thermal radiant energy, said cathode establishing electric oscillations in the output of said discharge device in accordance with variations in instantaneous intensity of said pulsating radiant energy, means including a transformer for amplifying said electric oscillations, and a winding inductively associated with said transformer and connected in series circuit relation between said cathode and said source of unidirectional potential for deriving from said output circuit and applying to said cathode heating circuit an alternating potential in aiding time phase relation with the pulsations of said radiant energy, thereby regeneratively to increase the response of said discharge device to said radiant energy.

3. A thermionic radiant energy detecting apparatus comprising an electric discharge device having an anode, a control electrode and a thermosensitive electron emissive cathode, means for exposing said cathode to pulsating thermal radiant energy to control the anode current of said device in accordance with the instantaneous thermal energy level of said cathode, and means for deriving from said anode current and applying to said control electrode a potential in aiding time phase relation with said pulsating radiant energy for increasing the response of said anode current to said radiant energy.

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4. A thermionic radiant energy detecting apparatus comprising an electric discharge device having an anode, a control electrode and a thermoresponsive electron emissive cathode, means for exposing said cathode to periodically pulsating thermal radiant energy, means including a transformer responsive to the anode current of said discharge device for detecting the intensity of said radiant energy, a winding on said transformer for deriving a potential of like time phase relation with said periodic pulsations of radiant energy, and means for applying said potential to said control electrode regeneratively to increase the response of said electric discharge device to said radiant energy.

5. A thermionic radiant energy detecting apparatus comprising an electric discharge device having an anode, a control electrode and a thermoresponsive electron emissive cathode, a source of negative bias potential connected in circuit between said cathode and said control electrode, means for exposing said cathode to periodically pulsating thermal radiant energy, means including a transformer responsive to the anode current of said device for detecting the intensity of said radiant energy, a tertiary winding on said transformer for deriving a potential of like time phase relation with said periodic pulsations of radiant energy, and means for superposing said derived potential upon said grid bias circuit in opposing relation to said negative bias potential regeneratively to increase the response of said electric discharge device to said radiant energy.

6. Apparatus for detecting and measuring the intensity of pulsating heat energy waves comprising an electric discharge device enclosed in an evacuated envelope having a window composed of a fusible inorganic salt, said discharge device having a two-part anode and a thermal responsive cathode, a source of electric energy for heating said cathode to a substantially constant temperature level, said cathode being positioned within said discharge device between the two parts of the anode and opposite said salt window so as to have its temperature level varied by heat waves entering through said window, means connected to said discharge device and responsive to the output thereof for detecting variations of the temperature level of said cathode, means for deriving from the output circuit of said discharge device a potential proportional to such variations, and means for applying said derived potential to the discharge device in adding time phase relation with said variations thereby to increase the response of said device to variations in the heat waves entering through said window.

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