March 29, 1949. L. E. NORTON 2,465,743

DETECTOR

Original Filed June 11, 1945 4 Sheets-Sheet 1

Fig 1

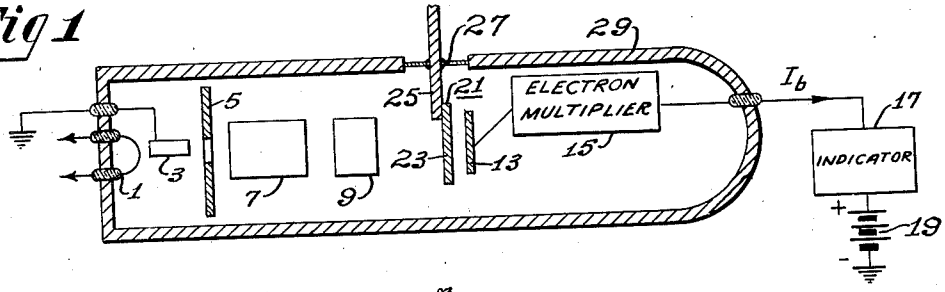
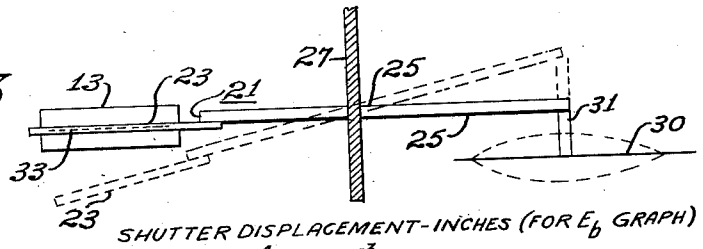


Fig. 3



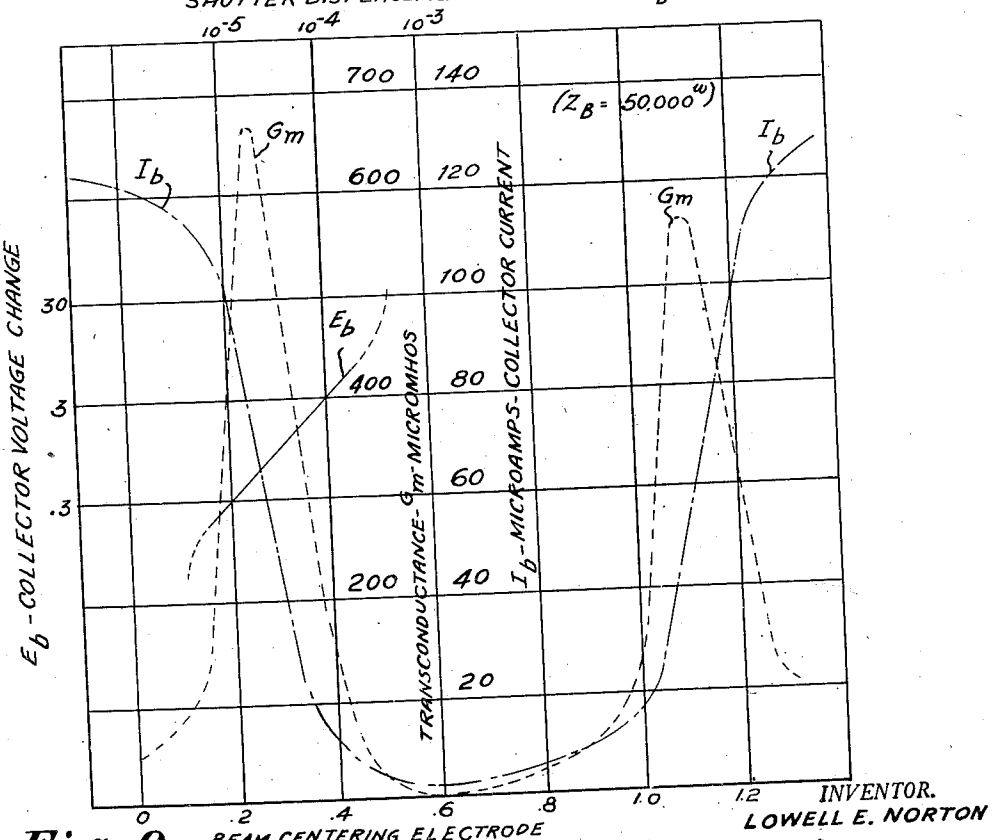


Fig. 9 BEAM CENTERING ELECTRODE POTENTIAL IN VOLTS (FOR I_b AND G_m GRAPHS)

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Fig 7

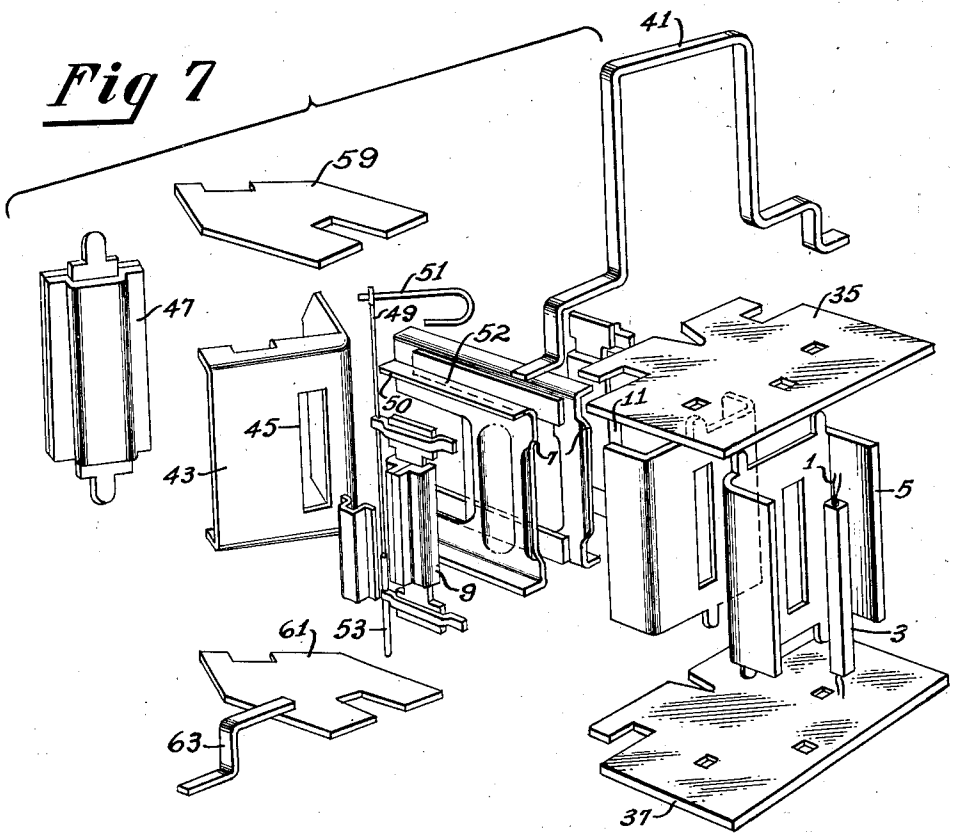
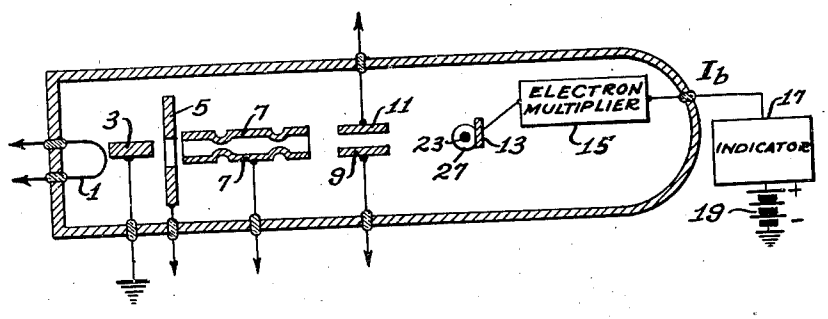


Fig 2



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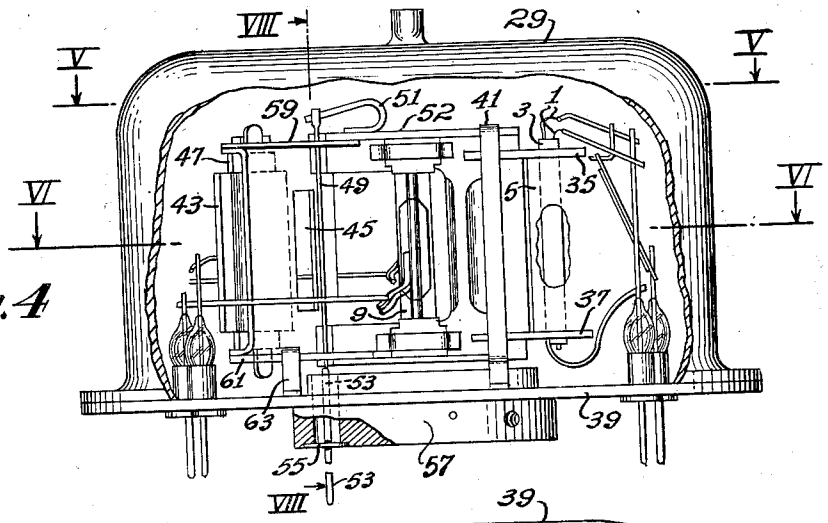


Fig. 4

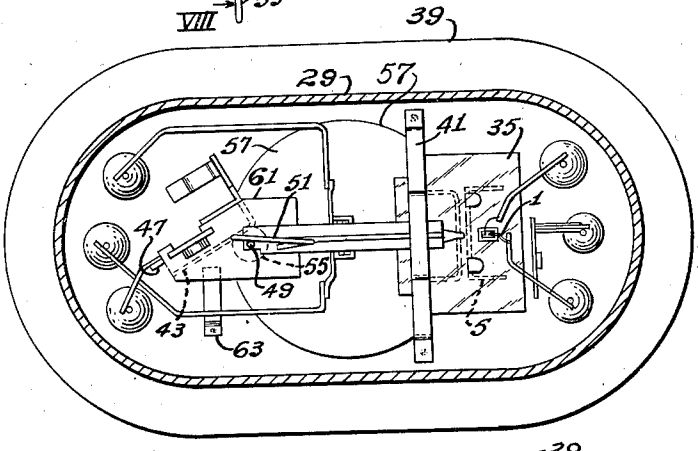


Fig. 5

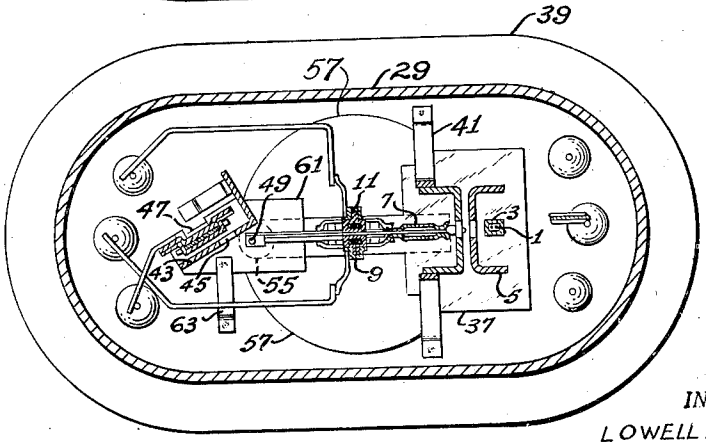


Fig. 6

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Original Filed June 11, 1945 4 Sheets-Sheet 4

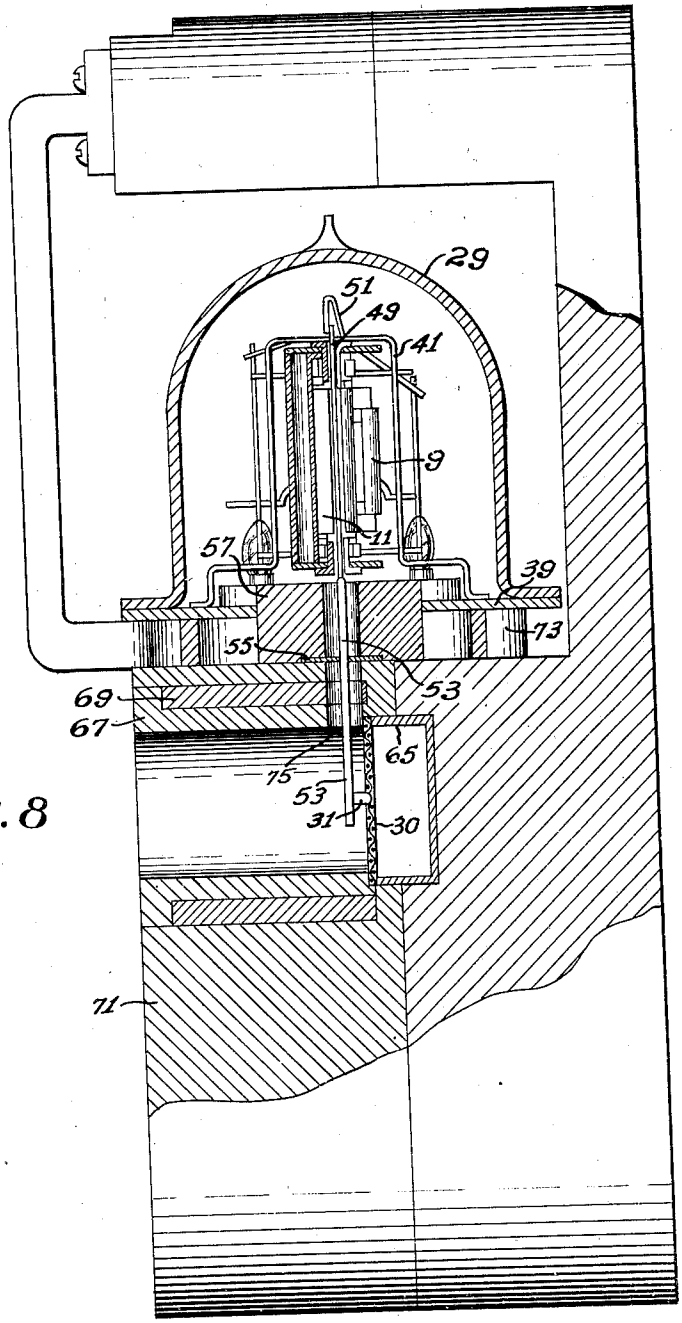


Fig. 8

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Patented Mar. 29, 1949

2,465,743

UNITED STATES PATENT OFFICE

2,465,743

DETECTOR

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Original application June 11, 1945, Serial No. 598,740. Divided and this application March 29, 1946, Serial No. 657,975

3 Claims. (Cl. 250—27.5)

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This application is a division of applicant's copending application Serial No. 598,740, filed June 11, 1945, entitled "Detector" and assigned to the same assignee as the instant application. This application has become Patent Number 2,451,769 granted October 19, 1948.

This invention relates generally to electronic detectors and more particularly to an improved device for detecting and measuring extremely small mechanical displacements or vibrations.

Briefly, the instant invention comprises an improved electronic detector comprising a thermionic discharge tube having means for generating a thin sheet of electrons which is focused upon a secondary-electron-emissive collector electrode, and in which a light movable shutter is interposed between the focused electron source and the electron collector. The movable shutter is mechanically coupled to an external device, of which the mechanical displacement is to be detected, by means of a flexible diaphragm set into the evacuated envelope of the tube. Since the electron beam is focused to an extremely thin sheet, and since the shutter when at rest normally interrupts substantially all electron transmission to the collector electrode, very slight displacements of the shutter provide relatively high collector current and collector voltage variations.

One application of the invention is in the detection of mechanical vibrations of small magnitude. Another application is in seismographic measurements wherein the discharge tube envelope is suspended and cushioned in a high inertia support in a manner whereby earth vibrations are transmitted substantially only to the movable shutter. A third application of the invention is in the detection and measurement of microwave transmission through wave-guides or coaxial transmission lines in combination with the devices disclosed in applicant's copending application Serial No. 598,739, filed June 11, 1945. This application has become Patent Number 2,453,532 granted November 9, 1948. In said copending application the microwave fields propagated along a waveguide or coaxial line provide mechanical displacement of a thin conductive diaphragm forming a portion of the guiding means. The improvement comprising the instant invention includes the combination of such a wave responsive diaphragm with the vibration detecting tube disclosed herein for measuring in an extremely sensitive and efficient manner the energy propagated along said guiding means.

Among the objects of the invention are to provide improved methods of and means for measuring minute mechanical displacements or vibrations. Another object is to provide an improved vibration detector comprising a thermionic tube having a movable shutter enclosed within the tube envelope and coupled through a flexible diaphragm in said envelope to an external source of vibrations for interrupting the tube electron beam as a function of the vibration amplitude. A further object of the invention is to provide an improved method of and means for measuring microwave energy propagated along a waveguide or coaxial transmission line by utilizing a flexible conductive element forming a portion of the wave guiding means and responsive to the microwave fields and an electron discharge tube having an electron shutter responsive to displacement of said diaphragm for generating an electric current proportional to the magnitude of said microwave fields. An additional object of the invention is to provide a more efficient and sensitive means for detecting and measuring mechanical vibration. A still further object of the invention is to provide an improved vibration detector adaptable to seismographic measurements.

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The invention will be described in greater detail by reference to the accompanying drawings of which Figure 1 is a schematic cross-sectional elevational view showing the basic components of the vibration responsive thermionic tube, Figure 2 is a schematic cross-sectional plan view of said basic features of said tube, Figure 3 is an enlarged schematic diagram of the vibration-responsive movable mechanical elements of said tube, Figure 4 is a partially cross-sectional, elevational view of a preferred embodiment of said tube, Figure 5 is a cross-sectional plan view of said preferred embodiment of said tube taken along the section line V—V, Figure 6 is a cross-sectional plan view of said preferred embodiment of said tube taken along the section line VI—VI, Figure 7 is an exploded perspective view of the principal elements of said preferred embodiment of said tube, Figure 8 is a partially cross-sectional view of a second embodiment of the invention adapted to measurements of microwave energy propagated along a waveguide, and Figure 9 is a family of graphs illustrative of the operating characteristics of the invention. Similar reference characters are applied to similar elements throughout the drawings.

Referring to Figures 1, 2 and 3, a thermionic heater element 1 supplied by currents derived from an external source, not shown, energizes an indirectly-heated cathode 3 which emits electrons. The electrons from the cathode 3 are formed into a constricted beam by means of an apertured limiting electrode 5 and thence are focused into an extremely thin flat beam by means of focusing electrodes 7 which, if desired, may be biased by a source of potential, not shown. The focused beam of electrons impinges upon a collector electrode 13 which, in conjunction with an electron multiplier 15 of any known type, provides an output current I_b through an indicator 17 connected to a source of collector voltage 19.

A movable shutter 21 comprising a fine wire 23, which is normally disposed in the path of the electron beam intermediate the electron beam focusing means and the collector electrode, includes a relatively heavier portion 25 which passes through a flexible diaphragm 27 forming a portion of the envelope 29 of the thermionic tube. The heavy portion of the shutter external of the diaphragm may be coupled to any external device providing a source of vibrations to be measured. The focused electron beam derived from the focusing electrodes 7 passes between beam deflecting electrodes 9 and 11 which may be biased for centering the electron beam upon the thin wire portion 23 of the shutter 21, whereby the electron beam is normally shielded from the collector electrode 13. It should be understood that the thin wire portion 23 of the shutter 21 should have a cross-section slightly larger than the cross-section of the focused electron beam at the plane of the shutter.

Figure 3 is an enlarged view of the movable shutter 21 and the diaphragm 27 showing the movement of the fine wire portion 23 of the shutter 21 with respect to the collector electrode 13 in response to displacement of an external diaphragm element 30 which is coupled through a linkage 31 to the external end of the heavy shutter portion 25. The portion of the figure shown in dash lines indicates the relative displacement of the elements in response to vibrations of the external diaphragm or element 30. The fine dotted line 33 shown on the fine wire portion 23 of the movable shutter and coinciding with the center of the collector electrode 13 indicates the focused electron beam which is normally shielded from the collector electrode 13.

Figures 4, 5, 6 and 7 show the construction of a preferred embodiment of the vibration-responsive tube wherein the indirectly heated cathode 3, beam limiting electrode 5, beam focusing electrode 7 and beam deflecting electrodes 9 and 11 are supported by upper and lower brackets 35 and 37 which are held to a base 39 by means of a U-shaped strap 41. A V-shaped vertical shield electrode 43 having a rectangular aperture 45 is located adjacent to the end of the beam deflecting electrodes 9 and 11 remote from the cathode 3. The rectangular aperture 45 exposes a secondary-electron-emissive collector electrode 47 to electron irradiation when the vibration-responsive shutter is deflected.

The shutter comprises the fine wire 49 which is supported at its upper end by means of a spring 51 fastened to the upper side of one of the brackets 50, 52 which project from the focusing electrodes 7 and which support and align the beam deflecting electrodes. The lower end of the fine wire shutter 49 is fastened to a heavier wire portion 53 which passes through, and is sealed to, a thin metallic diaphragm 55 which is sealed into a heavy center portion 57 of the base 39. The fine wire portion 49 of the shutter is centered in alignment with the aperture 45 of the shield electrode 43 by preliminary adjustment of the supporting spring 51 and it is maintained under constant tension by means of said spring. The secondary-electron-emissive collector 47 and the shield electrode 43 are held in relatively fixed positions by means of a top plate 59 and bottom plate 61 to which the electrodes are crimped. The bottom plate 61 is held to the base plate 39 by means of an angle bracket 63 which is spot welded thereto.

The secondary-electron-emissive collector 47 and the shielding electrode 43 comprise a single stage electron multiplier which increases the electron efficiency of the tube by a factor of about 4. After preliminary adjustment of the position and tension of the supporting spring 51, the assembly of the tube is completed and it is evacuated. Subsequent adjustment of the tube is obtained by varying the deflection voltage applied to the deflection electrodes 9 and 11 for centering the focused electron beam upon the fine wire portion 49 of the shutter when it is at rest. External terminals in the base of the tube are provided for the heater 1, the cathode 3, the beam deflecting electrodes 9 and 11, and the secondary-electron-emissive collector 47 for applying suitable operating voltages thereto. If desired, other terminals may be provided for the limiting electrode 5 and focusing electrodes 7. However, the limiting, focusing and apertured shield electrodes have been found to operate satisfactorily when grounded to the base plate 39.

In Figure 8 the vibration detecting tube described heretofore by reference to Figures 4, 5, 6 and 7 is shown coupled by means of the external shutter portion 55 and coupling link 31 to a thin metallic diaphragm 30 forming a portion of one of the wide faces of a conventional rectangular waveguide 65. The diaphragm 30 comprises, for example, a circular screen of the order of 1000 mesh and having a thickness of .2 mil. For some applications the diaphragm may be a solid thin film. The diaphragm 30 is stretched at one end of a pair of telescopic supporting rings 67 and 69 which fit into a heavy bracket 71 which supports both the waveguide 65 and the vibration detecting tube. The heavy base portion 57 of the tube is fitted into a conventional tube socket 73 which also is supported by the heavy bracket 71. For the sake of simplicity the socket connections or contacts are not shown. An aperture 75 in the side of the telescopic rings 67 and 69 and bracket 71 permits the heavy external portion 53 of the tube shutter to be coupled to the linkage 31 fastened to the center of the waveguide diaphragm 30.

As explained in applicant's copending application identified heretofore, the microwave fields of the wave propagated along the waveguide 65 provide mechanical displacement or deformation of the thin waveguide diaphragm 30 thereby providing vibrations responsive to the microwave pulses or modulation which are transmitted through the elements 31, 53, 55 to displace the fine wire shutter 49 with respect to the electron beam normally focused thereon. The displacement of the shutter permits the beam to reach the secondary-electron-emissive collector electrode 47 and provides a collector current or voltage which is a function of the microwave energy propagated along the waveguide.

Since the vibration-detecting tube with its built-in electron multiplier is extremely sensitive, the collector current I_b will probably be of sufficient magnitude to actuate directly the indicator 17 connected in series with the collector voltage supply. However, since the tube impedance is relatively high, for example 50,000 ohms, the output voltage also will be sufficiently high to actuate efficiently subsequent amplifiers or voltage responsive indicating devices of known types.

Figure 9 is illustrative of the operating characteristics of the tube. The dash line graph G_m illustrates the collector-to-cathode transconductance as a function of the beam deflecting voltage applied to the deflecting elements 9 and 11.

The broken line curve I_b shows the corresponding variation in collector current. It is seen that a variation of one-tenth volt in beam deflection potential provides a change of 65 microamperes in collector current. Since the beam deflection sensitivity of tubes of this type is of the order of .004 inch per volt, a collector current change of 65 microamperes is provided by a corresponding deflection of the electron beam of .0004 inch. It follows that if the electron beam is not deflected, but if the fine wire shutter **23** is mechanically displaced a distance of .001 inch, a collector current change of 163 microamperes will result. Since the single stage electron multiplier disclosed herein provides a gain of the order of 4, the total current sensitivity will be of the order of 650 microamperes per .001 inch of displacement of the fine wire shutter **23**.

Since a tube of this type may be readily constructed to operate with a collector impedence Z_b of the order of 50,000 ohms, it follows that that the output voltage sensitivity of the device will be of the order of 30 volts per .001 inch deflection of the fine wire shutter **23**. The voltage sensitivity v. shutter displacement is indicated by the solid line graph E_b which indicates a collector voltage change of .3 volt for a shutter displacement of .00001 inch.

Due to the extremely high sensitivity of the device, it is desirable that its frequency characteristics as determined by the shutter size, tension, and mass and by the natural period of the envelope diaphragm and the external linkage, be such that its response is highly selective to the vibration frequency to be detected in order that other spurious or factitious frequencies may provide a minimum of noise signal output. The device, however, is not unusually sensitive to operating voltage variations since it is the relative mechanical displacement of the electron beam and the fine wire shutter which provides the remarkable vibration sensitivity.

In the application of the device to seismographic measurements it would be desirable to mount the vibration detecting tube in a cushioned mounting having relatively high inertia. Also the coupling between the vibration responsive shutter and the earth should be sufficiently heavy and should be sufficiently damped to minimize undesirable high frequency vibrations which would provide factitious indications.

Thus the invention disclosed comprises a novel vibration indicator and an improved method of and means for detecting and indicating either external vibrations or microwave energy propagated along a guided wave transmission system.

I claim as my invention:

1. An electro-mechanical device comprising an evacuated envelope, said envelope enclosing an electron source, an anode means disposed intermediate said source and said anode for focusing electrons from said source to form a flat beam, a fixed apertured shielding electrode disposed between said focusing means and said anode, the aperture of said electrode being in the plane of said beam, a movable electron shutter element disposed between said focusing means and said apertured electrode in the plane of said beam for selectively shielding said anode from electron irradiation, and electron beam deflecting means disposed adjacent the path of said beam between

said source and said shutter element for providing adjustment of the plane of said beam, and means disposed externally of said envelope and operative upon said element for moving said element to selectively expose said anode to said electron irradiation whereby the anode current is a function of the displacement of said externally disposed means, and means for connecting said anode to an external device.

2. An electro-mechanical device comprising an evacuated envelope, said envelope enclosing an electron source, an anode, means disposed intermediate said source and said anode for focusing electrons from said source to form a flat beam, a fixed apertured shielding electrode disposed between said focusing means and said anode, the aperture of said electrode being in the plane of said beam, a movable electron shutter element disposed between said focusing means and said apertured electrode in the plane of said beam for selectively shielding said anode from electron irradiation, and electron beam deflecting means disposed adjacent the path of said beam between said source and said shutter element for providing adjustment of the plane of said beam, and means disposed externally of said envelope and coupled to said element to selectively expose said anode to said electron irradiation whereby the anode current is a function of the displacement of said externally disposed means, and means for connecting said anode to an external device.

3. An electro-mechanical device comprising an evacuated envelope, said envelope enclosing an electron source, an anode, means disposed intermediate said source and said anode for focusing electrons from said source to form a flat beam, a fixed apertured shielding electrode disposed between said focusing means and said anode, the aperture of said electrode being in the plane of said beam, a movable electron shutter element disposed between said focusing means and said apertured electrode in the plane of said beam for selectively shielding said anode from electron irradiation, and electron beam deflecting means disposed adjacent the path of said beam between said source and said shutter element for providing adjustment of the plane of said beam, and means including a flexible diaphragm forming a portion of said envelope coupled to said element and to means disposed externally of said envelope for moving said element to selectively expose said anode to said electron irradiation whereby the anode current is a function of the displacement of said externally disposed means, and means for connecting said anode to an external device.

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