

June 27, 1961

J. C. ARNOLD
MAGNETOMETER

2,990,513

Filed Sept. 2, 1958

2 Sheets-Sheet 1

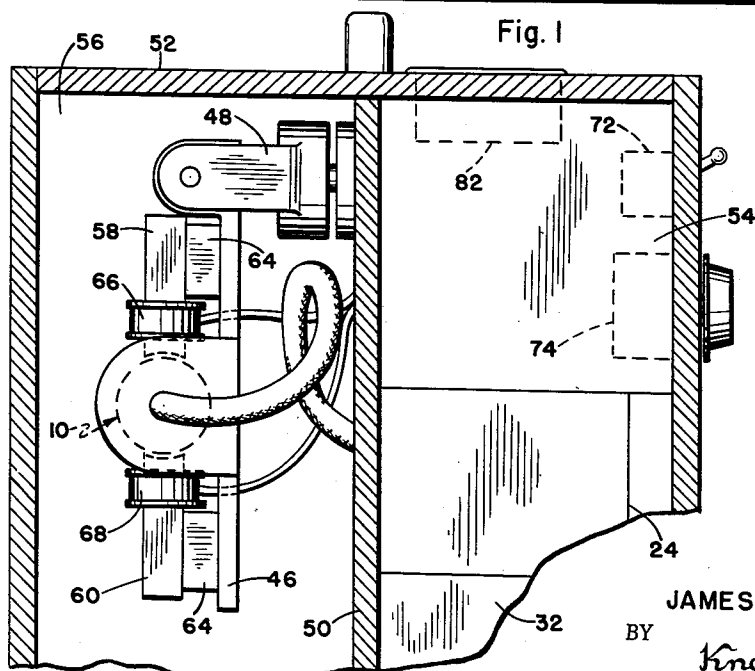
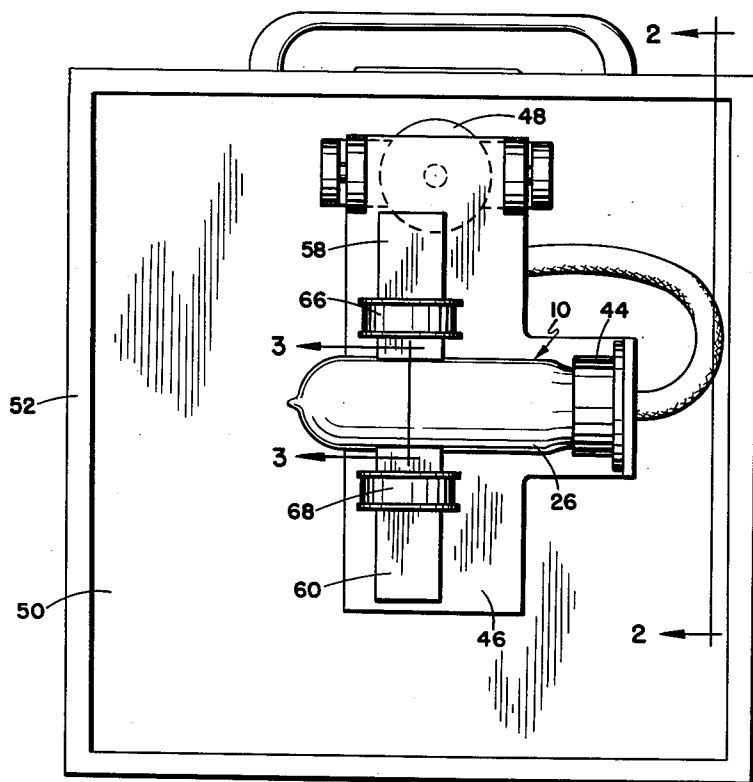


Fig. 2

Fig. 1

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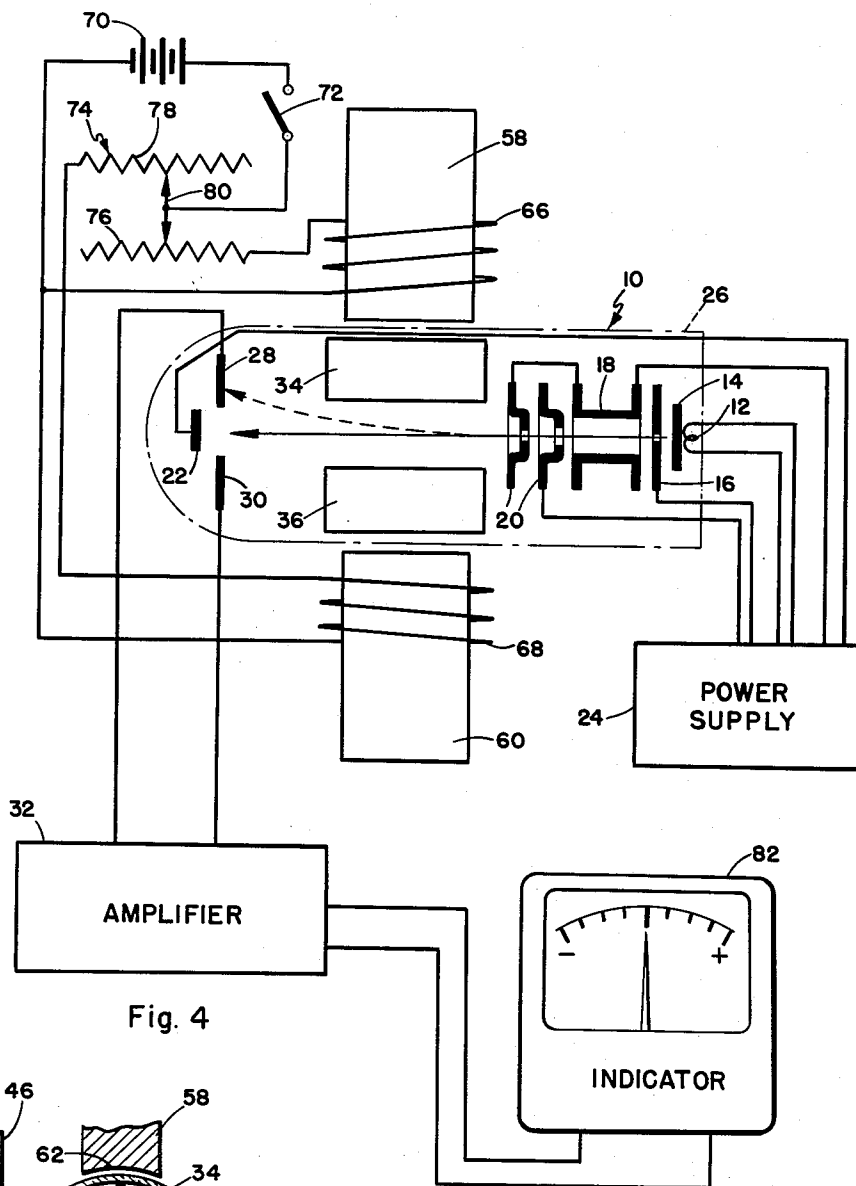


Fig. 4

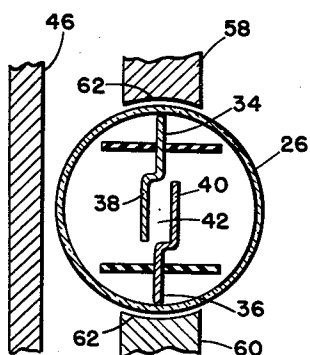


Fig. 3

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Filed Sept. 2, 1958, Ser. No. 758,238

8 Claims. (Cl. 324-43)

The present invention relates generally to magnetic field detection apparatus and more particularly to a magnetometer.

The primary object of this invention is to provide a magnetometer in which a novel type of cathode ray tube of simple construction is used as a signal producing element to operate a magnetic field indicator.

Another object of this invention is to provide a magnetometer in which the signal producing element is controlled by permeable bars which are oriented to detect a magnetic field in a selected plane.

Still another object of this invention is to provide a magnetometer in which an initial variable magnetic field may be introduced adjacent the signal producing element to adjust the instrument to a zero indication as a starting reference.

A further object of this invention is to provide a magnetometer which can be completely enclosed in a compact, portable case to be carried in one hand, or mounted on a support such as a tripod.

Finally, it is an object to provide a magnetometer of the aforementioned character which is simple and convenient to use and which will give generally efficient and durable service with consistently accurate readings.

With these and other objects definitely in view, this invention consists in the novel construction, combination and arrangement of elements and portions, as will be hereinafter fully described in the specification, particularly pointed out in the claims, and illustrated in the drawings which form a material part of this disclosure, and in which:

FIGURE 1 is a front elevation view of the magnetometer with the cover removed;

FIGURE 2 is a fragmentary sectional view taken on the line 2-2 of FIGURE 1;

FIGURE 3 is an enlarged fragmentary sectional view taken on the line 3-3 of FIGURE 1; and

FIGURE 4 is a diagram showing the electrical circuitry of the complete instrument.

Similar characters of reference indicate similar or identical elements and portions throughout the specification and throughout the views of the drawings.

The magnetometer is based on a cathode ray type electronic tube 10 in which is a conventional electron gun having a heater 12 to energize a cathode 14, the electrons emitted by the hot cathode being concentrated by a grid 16 and focused into a narrow beam through focusing anodes 18 and 20, the beam being directed at a cap anode 22 at the end of the tube remote from the cathode. The electron gun assembly is operated by a suitable power supply 24, the circuit involved being well known. The electron gun assembly is, of course, enclosed in an evacuated glass envelope 26. Adjacent the cap anode 22 and spaced on opposite sides thereof are two targets 28 and 30 which are connected to a differential amplifier 32. Between the targets 28 and 30 and the anodes 20 are two generally rectangular deflecting channel portions 38 and 40, defining between them a flat rectangular channel 42 elongated in the plane of the targets 28 and 30, as in FIGURE 3.

The tube 10 is mounted in a socket 44 containing the necessary electrical connections, said socket being secured

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to a mounting plate 46 which is pivotally suspended from a gimbal assembly 48, said gimbal assembly being of any suitable design to enable the mounting plate to hang plumb at all times. The gimbal assembly 48 is fixed to the partition 50 of a case 52 in which the complete magnetometer is contained, said case having a battery compartment 54 on one side of said partition together with the amplifier 32 and power supply 24. On the other side of the partition 50 is an open chamber 56 to allow freedom of movement for the mounting plate 46. It should be understood that the case 52 and arrangement of its contents as illustrated are merely an example, the specific configuration of the instrument as a unit being unimportant to the present disclosure.

As illustrated, the tube 10 is disposed in a horizontal position on the mounting plate 46 and is oriented so that the deflecting plates 34 and 36 are parallel to the mounting plate in a vertical plane. Fixed to the mounting plate 46 on opposite sides of the tube 10 are two vertically opposed permeable bars 58 and 60, coplanar with the deflecting plates 34 and 36 and having arcuate ends 62 to fit closely against said tube, as in FIGURE 3. The permeable bars 58 and 60 are mounted on suitable support blocks 64 in correct alignment, and fitted around said bars are balancing coils 66 and 68, which are connected in parallel to a battery 70, or similar source of D.C. power through a switch 72. Connected between the battery 70 and the coils 66 and 68 is a balancing control 74 containing inversely proportionally variable resistors 76 and 78 having a common tap 80, that is, any suitable arrangement wherein the current in one balancing coil is increased while the current in the other coil is decreased.

In operation, the instrument is normally used to detect anomalies in the magnetic field of the earth for subsurface surveying, an anomaly usually indicating the presence of an ore body or other significant strata. The instrument is placed at a chosen location and the local magnetic field, or the vertical component of the field induces a magnetic flux in the permeable bars 58 and 60. The electron beam from the cathode 14 normally strikes the cap anode 22, as indicated by the solid line directional arrow in FIGURE 4. However, the magnetic field of the permeable bars 58-60 and the deflecting plates 34 and 36 deflects the electron beam, indicated by the dash line arrow. The electron beam, being confined in the channel 42, is subject to deflection only in the plane of the targets 28 and 30 and, when deflected, strikes one or the other of the targets. After initial balancing, the degree and direction of deflection of the electron beam are directly proportional to the intensity and polarity of the local, natural magnetic field causing the deflection. Thus the energy imparted to the target bombarded by the beam is a direct indication of the strength of the local, natural magnetic field, while the particular target bombarded denotes the field polarity. The signal energy from the targets 28 and 30 is amplified by the amplifier 32 which is arranged to differentiate between the signals from both targets, the circuitry of such an amplifier being well known. The output of the amplifier 32 is fed to a meter or indicator 82 which provides a visual indication of the magnetic field strength on a graduated scale, either positive or negative according to polarity.

In recapitulation, since a point of reference is necessary to compare successive readings, the instrument must be adjusted to a zero reading initially. This is accomplished by means of the balancing control 74 which controls the current flow in balancing coils 66 and 68, the initial magnetic field induced in the permeable bars 58 and 60 causing a deflection of the electron beam. By adjusting the balancing control 74, this initial field can be made to coun-

teract the earth's magnetic field at another location, by centering the electron beam and causing a zero reading on the indicator 82. Thereafter, the readings obtained at subsequent locations can be compared to the initial zero reading and the results plotted to indicate the presence and extent of magnetic anomalies.

The instrument as illustrated is of simple form using a single tube 10 with the permeable bars 58 and 60 disposed to detect a vertical magnetic field. However, by orienting the permeable bars to a horizontal position, the horizontal field can be measured, the instrument being rotated in the desired direction. Alternatively, three complete assemblies of tubes 10 with their respective permeable bars may be used and aligned in three axes normal to each other to provide a total field reading, the amplifying means being modified to suit. It is obvious that this instrument can be used to delineate and measure magnetic fields other than the earth's magnetic field. The term deflecting element employed in the original claims is proposed as including all such means as coils, permeable bars or coils with permeable bars as cores.

In contrast to other types of magnetometers utilizing alternating current of various frequencies with the associated complex and bulky equipment, the present instrument uses a small variable direct current source and simple circuitry. The electron beam is highly sensitive to deflection and renders the instrument extremely sensitive to magnetic field variations.

It is understood that minor variation from the form of the invention disclosed herein may be made without departure from the spirit and scope of the invention, and that the specification and drawings are to be considered as merely illustrative rather than limiting.

I claim:

1. In a magnetometer: a source of electrons; a pair of spaced targets disposed essentially in one plane; means for directing a beam of electrons from said source in a path normally extending between said targets; plates having channel portions restricting directional variation of said electrons in said path to variation in substantially said plane only; deflecting elements disposed on opposite sides of the electron beam path; said deflecting elements being capable of being influenced by the local natural magnetic field to deflect said beam toward one or other of said targets; and indicator means connected to said targets to indicate the reception of electrons by the targets corresponding to changes in the polarity and intensity of the natural magnetic field as the magnetometer is travelled.

2. In a magnetometer: an electronic tube containing a source of electrons at one end thereof; a pair of spaced targets at the other end of said tube and disposed essentially in one plane; an anode disposed between said targets; means for directing a beam of electrons from said source toward said anode; plates having channel portions between said source and said anode and defining a restricted channel substantially limiting directional variation of the electrons to variation in said plane; deflecting elements disposed on opposite edges of the electron beam path, said deflecting elements having their axes in said plane; said deflecting elements being capable of being influenced by the local magnetic field to deflect said beam toward one or other of said targets; and indicator means connected to said targets to indicate the reception of electrons by the targets corresponding to changes in the polarity and intensity of the magnetic field.

3. In a magnetometer: an electronic tube containing a source of electrons at one end thereof; a pair of spaced targets at the other end of said tube and disposed essentially in one plane; an anode disposed between said targets; means for directing a beam of electrons from said source toward said anode; plates having channel portions between said source and said anode and defining a re-

stricted channel substantially limiting directional variation of the electrons to variation in said plane; deflecting elements disposed on opposite edges of the electron beam path, said deflecting elements having their axes in said plane and comprising a pair of permeable bars mounted on opposite sides of said tube, whereby a magnetic field induced in said permeable bars acts through said channel portions to deflect the electron beam to one or other of said targets; and indicator means connected to said targets to indicate the reception of electrons by the targets corresponding to the polarity and intensity of the magnetic field in said permeable bars.

4. In a magnetometer: an electronic tube containing a source of electrons at one end thereof; a pair of spaced targets at the other end of said tube and disposed essentially in one plane; an anode disposed between said targets; means for directing a beam of electrons from said source toward said anode; plates having channel portions between said source and said anode and defining a restricted channel substantially limiting directional variation of the electrons to variation in said plane; deflecting elements disposed on opposite edges of the electron beam path, said deflecting elements having their axes in said plane; a mounting plate; said tube being fixed on said mounting plate; said deflecting elements comprising a pair of permeable bars secured to said mounting plate on opposite sides of said tube in said plane, whereby a magnetic field induced in said permeable bars acts through said channel portions to deflect the electron beam to one of said targets; said mounting plate being freely pivotally suspended and gravity controlled to maintain said permeable bars normally vertical; and indicator means connected to said targets to indicate the reception of electrons by the targets corresponding to the polarity and intensity of the magnetic field in said permeable bars.

5. In a magnetometer: an electronic tube containing a source of electrons at one end thereof; a pair of spaced targets at the other end of said tube and disposed essentially in one plane; an anode disposed between said targets; means for directing a beam of electrons from said source toward said anode; plates having channel portions between said source and said anode and defining a restricted channel substantially limiting directional variation of the electrons to variation in said plane; deflecting elements disposed on opposite edges of the electron beam path, said deflecting elements having their axes in said plane and comprising a pair of permeable bars mounted on opposite sides of said tube with their axes in said plane, whereby a magnetic field induced in said permeable bars acts through said channel portions to deflect the electron beam to one or other of said targets; balancing coils wound on each of said permeable bars; a source of D.C. voltage connected to said coils; balancing means for varying the voltage in each of said coils in inverse proportion to the other; and indicator means connected to said targets to indicate the reception of electrons by the targets corresponding to the polarity and intensity of the magnetic field in said permeable bars.

6. In a magnetometer: an electronic tube containing a source of electrons at one end thereof; a pair of spaced targets at the other end of said tube and disposed essentially in one plane; an anode disposed between said targets; means for directing a beam of electrons from said source toward said anode; means for deflecting said electron beam, said means comprising deflecting plates having overlapping offset portions defining a flat, narrow width beam restricting channel therebetween, said channel being aligned in said plane and a pair of permeable bars mounted on opposite sides of said tube and having their axes in said plane, whereby a magnetic field induced in said permeable bars acts through said channel portions to deflect the electron beam to one of said targets; and indicator means connected to said targets to indicate the reception of electrons by the targets corresponding to

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the polarity and intensity of the magnetic field in said permeable bars.

7. In a magnetometer: an electronic tube containing a source of electrons at one end thereof; a pair of spaced targets at the other end of said tube and disposed essentially in one plane; an anode disposed between said targets; means for directing a beam of electrons from said source toward said anode; plates having channel portions disposed on opposite sides of the electron beam path and parallel to said plane; said channel portions defining a thin, flat beam restricting channel therebetween; a pair of permeable bars mounted on opposite sides of said tube and having their axes in said plane, whereby a magnetic field induced in said permeable bars acts through said channel portions to deflect the electron beam to one of said targets; balancing coils wound on each of said permeable bars; a source of D.C. voltage connected to said coils; means for varying the voltage in each of said coils in inverse proportion to the other; and indicator means connected to said targets to indicate the reception of electrons by the targets corresponding to the polarity and intensity of the magnetic field in said permeable bars.

8. In a magnetometer: an electronic tube containing a source of electrons at one end thereof; a pair of spaced targets at the other end of said tube and disposed essentially in one plane; an anode disposed between said tar-

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gets; means for directing a beam of electrons from said source toward said anode; plates having channel portions disposed on opposite sides of the electron beam path and parallel to said plane; said channel portions defining a thin, flat beam restricting channel therebetween; a mounting plate; said tube being fixed on said mounting plate; a pair of permeable bars secured to said mounting plate on opposite sides of said tube and having their axes in said plane, whereby a magnetic field induced in said permeable bars acts through said channel portions to deflect the electron beam to one of said targets; said mounting plates being freely pivotally suspended to maintain said permeable bars normally in a predetermined plane; balancing coils wound on each of said permeable bars; a source of D.C. voltage connected to said coils; means for varying the voltage in each of said coils in inverse proportion to the other; and indicator means connected to said targets to indicate the reception of electrons by the targets corresponding to the polarity and intensity of the magnetic field in said permeable bars.

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