United States Patent [19]

McBroom

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[54] **IMAGE INTENSIFIER COMPENSATED FOR EARTH'S MAGNETIC FIELD**

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[73] Assignee: **General Electric Company**, Schenectady, N.Y.

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[21] Appl. No.: **319,176**

[52] **U.S. Cl.** ..... **250/213 VT**, 313/65 R

[51] **Int. Cl.** **H01j 31/50**

[58] **Field of Search** ..... 250/213 VT, 213 R; 313/65 R, 65 A, 83, 84, 85, 86; 324/44, 45

[56] **References Cited**

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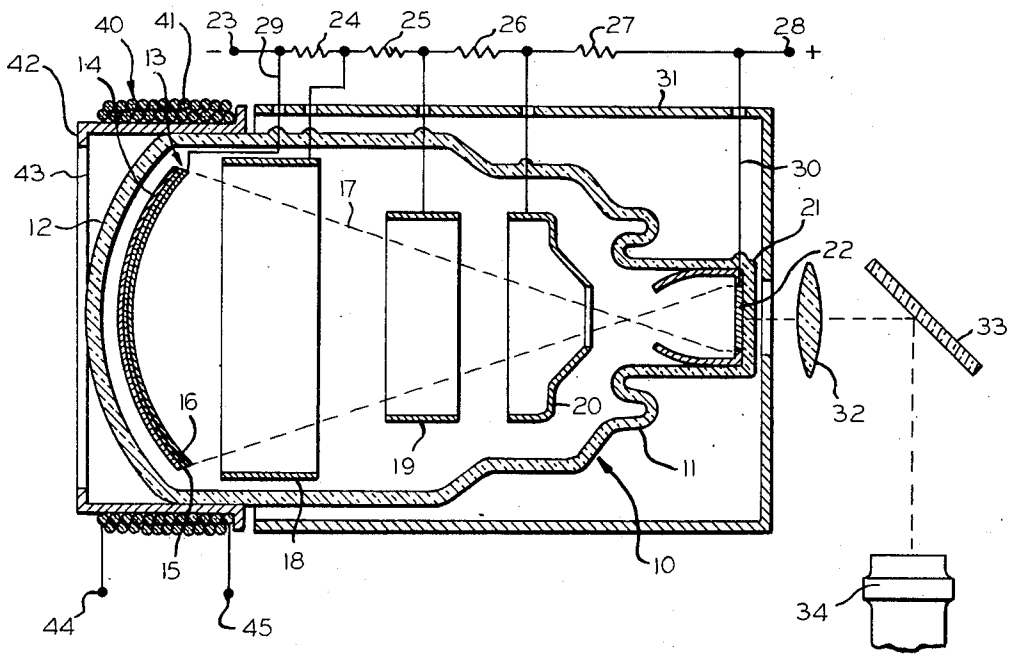
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Primary Examiner—Archie R. Borchelt
Assistant Examiner—D. C. Nelms
Attorney, Agent, or Firm—Ralph G. Hohenfeldt; Fred Wiviott

[57] **ABSTRACT**

The earth's magnetic field influences the electrons emitted from the photocathode of a radiation image intensifier tube such that the optical image formed on the output screen of the tube is often distorted and rotated. The invention involves locating an electromagnet coil in the vicinity of the photocathode of the image tube where emitted electron energy is low, to nullify the effects of the earth's magnetic field. Means are provided for adjusting the field strength of the coil for various orientations of the image tube.

14 Claims, 4 Drawing Figures



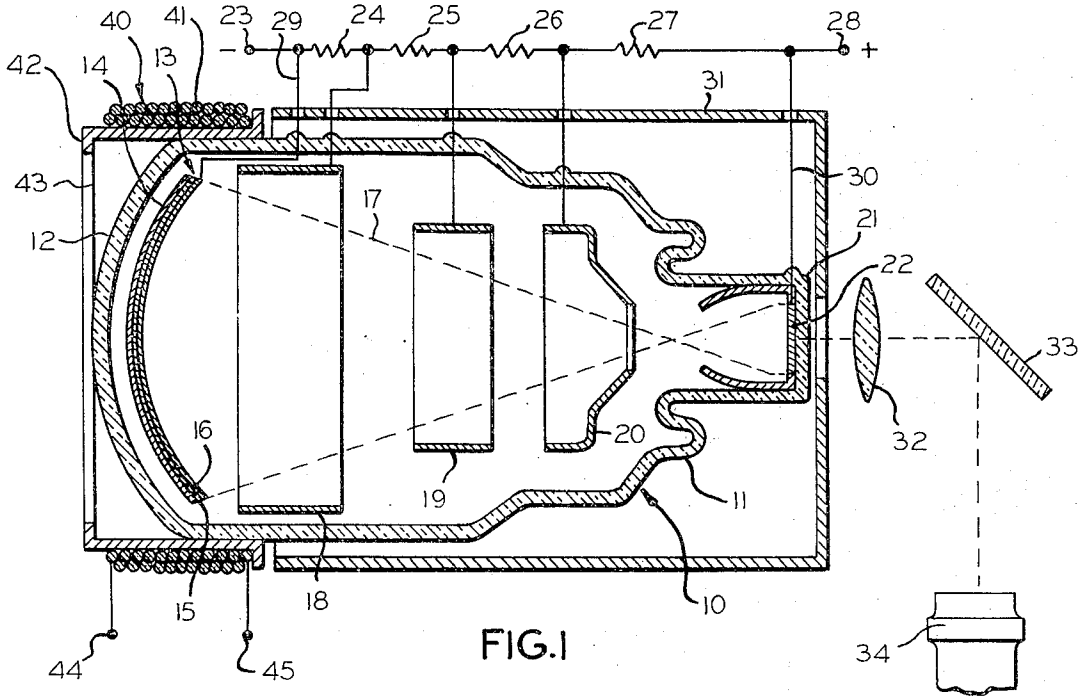


FIG.1

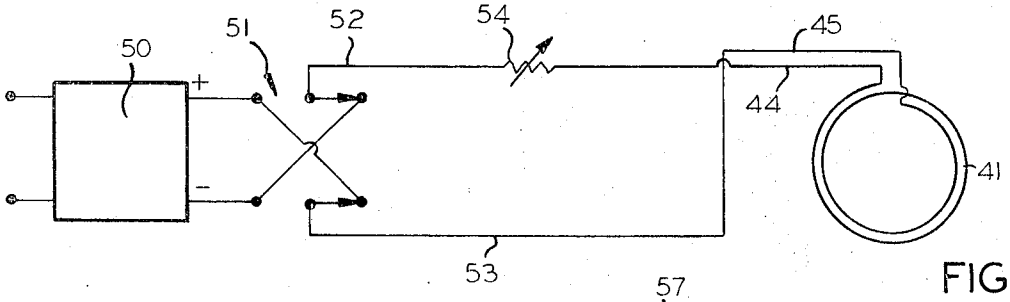


FIG.2

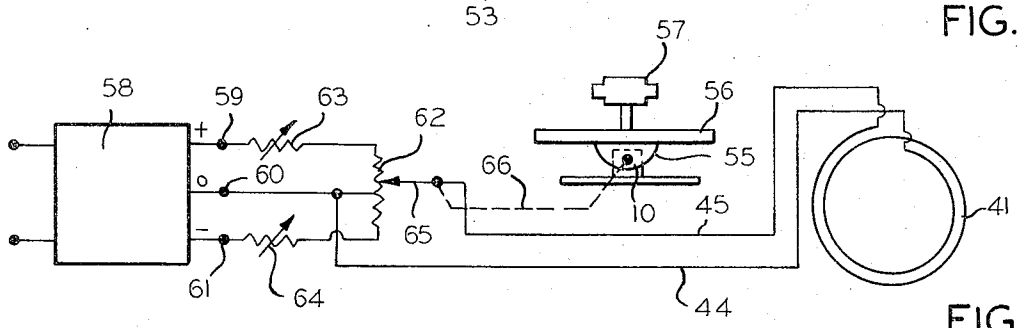


FIG.3

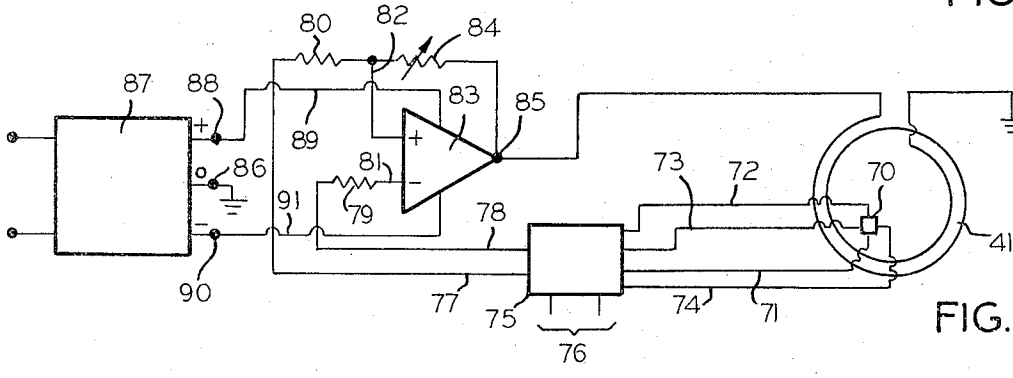


FIG.4

IMAGE INTENSIFIER COMPENSATED FOR EARTH'S MAGNETIC FIELD

BACKGROUND OF THE INVENTION

This invention relates to a method and apparatus for compensating radiation image intensifiers for the adverse influence of the earth's magnetic field. The invention will be illustrated in connection with an x-ray image intensifier tube which will hereinafter be called an image tube for the sake of brevity.

A well known type of X-ray image tube comprises an evacuated generally cylindrical glass envelope. An X-ray image which is to be intensified penetrates the glass face plate or window at the input end of the image tube. Behind the face plate is a fluorescent screen which converts the X-ray image into a light image. A photocathode adjacent the fluorescent screen emits electrons from its surface with density variations corresponding to light intensity variations of the light image. The electron image is focused in a converging manner onto an output screen where it is converted to a bright but minified visible image. It is customary to use a mirror system for directing the optical image selectively to recording cameras and to a television camera, the latter of which permits display of the enlarged image on the screen of a television monitor.

The electron image is usually focused with a series of electrostatic lenses interposed between the photocathode and the phosphorescent output screen. The voltage drop between the photocathode and the output screen is often as high as 30 kilovolts in which case the electron image impinges on the output screen with considerable energy. However, in the region immediately adjacent the photocathode the electrons have low imitial energy and velocity and they can be deviated easily by the earth's magnetic field which invariably permeates an X-ray image tube even though the tube is magnetically shielded. It is well known that when an electron moves under the influence of a magnetic field, it experiences a force at right angles to both the field and its velocity. Thus, the electron follows a helical path when one of its vectorial velocity components is parallel and its other component is transverse to the magnetic flux lines. When considered as the entire flow of electrons making up an image, the result is a rotation of two coordinates of the image. In a typical case, a vertical image line might be rotated about 7° to the right or left. One approach to correcting for this condition was to rotate the video camera and each of the film cameras in their mountings so that vertical lines would appear vertical on the film or display screen and horizontal lines would appear horizontal. This spoils the appearance of the equipment. Despite the inconvenience of this approach and the undesirability of having the user perform makeshift adjustments of the equipment, it has been done regularly because of the paramount importance of having lines and image elements appear in their true attitude and without the image overhanging the field of the recording or visualizing media.

Unfortunately, the stray magnetic field which causes the image distortion is not equally effective in causing rotation of the entire image so that straight lines are not only rotated, but are bent in a serpentine shape. Up to the time of the present invention, this situation has merely been tolerated since it is impossible for a user to make suitable corrections by changing the geometrical relationship of the components of the viewing system. Moreover, if such corrections are made for one orientation of the image tube, they are usually inappropriate for another orientation thereof. For instance, in diagnostic X-ray systems, the image tube is very often mounted for mobility about a room or building and for being aimed at the patient at various angles in which case the effect of the earth's field is different for different orientations.

SUMMARY OF THE INVENTION

A general object of this invention is to provide means for eliminating the adverse effects of the earth's magnetic field on a radiation image intensifier.

More specific objects are to surround the photocathode end of an image tube with an electromagnet coil whose field strength can be adjusted to nullify the effects of the earth's magnetic field regardless of the orientation of the image tube.

How the foregoing and other more specific objects of the invention are achieved will appear in the course of the ensuing description of a preferred embodiment of the invention which will be set forth shortly hereinafter in reference to the drawings.

Briefly stated, a ring or form made of magnetic material is surrounded by a coil to which direct current is applied. The form is fit over the input end of an image tube. The coil preferably encircles the photocathode and a region adjacent thereto wherein the emitted photoelectrons have low initial energy. With a test object in the view of the intensifier, current through the coil and, hence, field strength is adjusted while observing the output screen until rotation, distortion and misalignment of the image on the output screen is minimized. In one embodiment, movements of the image tube drive a potentiometer which effectuates automatic adjustment of the electromagnet coil current. In another embodiment, a magnetic field sensor is located near the image tube and out of its line of sight. The sensor controls a servo system which in turn varies the current to the coil until the stray field is nulled.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of an X-ray image intensifier tube and viewing system, the new stray field compensating coil being affiliated with the image tube;

FIG. 2 is a circuit diagram relating to one method of controlling field compensating current;

FIG. 3 shows a schematic view of an X-ray table together with a circuit diagram wherein a circuit component responds to positions of the X-ray table for adjusting the stray field compensating current; and

FIG. 4 is a circuit diagram for a system wherein a magnetic field sensor effects nullification of any stray magentic field through an image tube.

DESCRIPTION OF A PREFERRED EMBODIMENT

In FIG. 1 an X-ray image tube to which the new magnetic field compensating means may be applied is generally designated by the reference numeral **10.** The illustrative tube comprises a substantially cylindrical vacuum tight glass envelope **11.** An X-ray image to be intensified enters tube **11** through its input end or face plate window **12** and impinges on a composite photocathode **13.** The photocathode usually comprises three

layers. The first layer **14** on which the radiation image impinges is made of fluorescent material and has the property of converting the invisible X-ray image to a corresponding visible light image in a known manner. The fluorescent layer **14** is usually deposited on a thin glass layer **15** on the concave side of which there is a layer of photoemissive material **16.** The photoemissive material emits electrons from its surface corresponding in density with the intensity of light received from corresponding areas of the fluorescent layer as is known. The emitted photoelectron image thus formed is focused toward the glass output end **21** of image tube **10** and an inverted image is formed on an output screen **22** which is an anode and is inside of the image tube and which fluoresces to produce a visible image when impacted by high energy electrons. The electrons desirably maintain their relative positions within the conical beam of electrons, defined by the dashed line **17,** which is focused on the output screen.

The electron image beam **17** is focused conventionally with a series of electrostatic lens electrodes such as **18, 19** and **20.** There is a potential difference between photoemitter **16** and output screen **22** which causes the electrons to be accelerated and thus produces the brightened and minified image on the output screen. The accelerating and focusing potential is derived from a regulated d-c source, not shown, the negative terminal of which may be connected to the terminal **23** of a voltage divider comprising a series of resistors 24–27 which have a terminal **28** that is connected to the positive terminal of the power supply. Photoemitter **16** is connected by means of a suitable conductor such as **29** to the most negative point on the voltage divider and the output screen **22** is connected to the most positive point in the power supply by means of a lead **30.** A thin vapor deposited metal film, not visible, is often used to provide a means for connecting to the photoemissive layer and the output screen to their electric source terminals.

Electrostatic lens electrodes **18, 19** and **20** are at increasing positive potential in the direction away from the photocathode and the velocity of the electrons emitted by the photocathode increases correspondingly as they progress through the lenses. The effect of the earth's magnetic field on the electrons is minimal when they have been accelerated somewhat beyond initial velocity. However, the earth's field is strong enough to deviate the electrons rather randomly immediately adjacent the inside surface of the photoemissive layer **16** where initial electron velocity is low. The direction of the earth's magnetic flux vector through the tube may be longitudinal thereof or at some angle with respect to the axis of the tube depending on how the tube was oriented in the room. This makes the course of the low energy electrons a variable and accounts for defocusing, image rotation shifting and distortion which was mentioned earlier.

It has been found that the adverse effects of the earth's magnetic field cannot be eliminated solely by enclosing the image tube **11** in an open ended cylinder **31** which is made of magnetic shielding material such as iron. There is no practical way to shield a large empty space from this field. At most, the shield **31** only distorts the earth's magnetic field as is evidenced by the fact that a magnetic compass may be calibrated for accurate operation even though it is surrounded by steel as is the case when the compass is in an automobile or a ship. However, a cylindrical soft iron shield **31** can eliminate the adverse effect of electromagnetic fields of an alternating type such as might be produced by a nearby electrical appliance operating at 50 or 60 Hz. A conductive coating on the exterior of image tube **11** effectively vitiates the effects of extraneous electrostatic fields which might adversely affect electron focusing.

The bright minified image appearing on the output screen **22** is usually directed to a collimating lens combination **32** to a mirror **33** which redirects the image to the lens **34** of a television camera, the remainder of which is not shown. Usually in X-ray image viewing systems, mirror **33** is mounted so that it can be pivoted to an angle where it reflects the optical image to a film recording camera, not shown, whose lens axis may be coincident with the axis of the lens **34** of the video camera. Mirror **33** is sometimes semitransparent so it reflects part of the light and transmits the remaining portion to a viewing device or camera, not shown, which is on the axis of the output screen and objective lens **32.** As indicated above, if the image is merely shifted on the output screen due to the earth's magnetic field, it is sometimes possible to realign the lenses and the mirrors so that their centers will coincide with the central ray from the image in which case image shifting may be compensated by misaligning the viewing system components. However, when straight lines in an object appear as serpentine lines or when picture elements are rotated within the boundaries of the intensified image there is no way in which to compensate for this distortion in prior art image systems.

In accordance with the invention, the adverse effects of the earth's magnetic field are compensated in an image tube which is focused electrostatically or electromagnetically by use of a strategically placed auxiliary electromagnet coil which, in FIG. **1,** is designated generally by the reference numeral **40.** The coil is comprised of a multiplicity of wire turns **41** which are wound on and suitably insulated from an annulus **42** made of a magnetically susceptible material such as iron. The annulus and the coil thereon is preferably of such axial length as to be coextensive with the electron accelerating region extending from the input face **12** of the tube to the leading edge of the first electrostatic lens cylindrical electrode **18.** In other words, the design is such that the electromagnetic field produced by the coil will be most influential on those electrons which have just left the photoemissive surface **16** and have not as yet undergone appreciable acceleration. The annulus **42** may be made of such size as to fit snugly on the outer periphery of the tube envelope **11** as suggested in FIG. **1.** In practice it has been found desirable to make the annulus **42** of substantially the same dimensions as the ring, not shown, which retains and supports the input end of the image tube in its housing, not shown, in which case retrofitting of the coil onto existing image tubes in the field is facilitated. The annulus **42** has a central opening **43** which avoids absorption or attenuation of the X-ray image which is incident upon the input face plate **12** of image tube **11.**

By way of example and not limitation, in a practical case the coil **41** having 230 turns of No. 22 A.W.G. insulated wire was used on a 9-inch image tube. For a typical earth's field condition, complete correction is obtained with about 0.1 ampere flowing through the coil. A 6-inch image tube compensating coil uses 350 turns of the same size wire and comparable current to

effect complete correction in most cases. As will be seen, however, current amplitude may be adjusted in accordance with the invention.

In FIG. 1, the terminals of coil 41 are marked with the reference numerals 44 and 45. Various power supply and control circuits for connecting to the coil terminals are shown in FIGS. 2, 3 and 4 which will now be discussed.

The simplest system is shown in FIG. 2 which is satisfactory for those cases in which the X-ray image tube is installed in a fixed location in the radiology room. In such cases, the compensating coil current can be set once to obtain the most faithful reproduction of the straight lines in a test object and the coil current can remain at that setting during future operations of the image tube. Thus, in FIG. 2, energizing current for coil 41 is obtained from a two terminal d-c power supply 50. The output terminals of the power supply connect to a polarity reversing switch 51. The terminals 44 and 45 of the compensating coil 41 are connected to reversing switch 51 by means of conductors 52 and 53. Transfer of reversing switch 51 will, of course, reverse the polarity of the magnetic field developed by coil 41 as is well known. There is a manually operable adjustable resistor 54 in series with the coil. Resistor 54 is used to set the current flow and, hence, the strength of the magnetic field produced by the coil 41. When an X-ray image tube is installed in a substantially fixed position, an initial setting of adjustable resistor 54 will usually suffice for future operations of the image tube. To determine the setting which results in elimination of shifting, rotation and bending of the image of the output phosphor of the image tube an X-ray opaque wire may be interposed between the X-ray tube, not shown, and the input end of the image tube while the axis of the image tube is oriented vertically as is possible when the tube is mounted on an overhead hanger which permits rotation of the tube between vertical and horizontal positions. The image tube is then turned between these alternate positions and the best correction is made for each position by adjusting resistor 54. Finally, a compromise setting may be selected that averages the improvement for both positions. This will yield a considerable improvement in comparison to making no correction.

In the FIG. 2 arrangement, one may transfer reversing switch 51 to change the polarity of coil 41 initially and thereby make a gross determination as to the proper direction for the correcting magnetic flux. The fine adjustments may then be made with the adjustable resistor 54 as described in the preceding paragraph.

In FIG. 3, the X-ray image tube 10 is mounted within the body of an X-ray table 55 which is shown schematically. The subject to be examined rests upon table top 56. The X-ray tube casing 57 from which the X-ray beam is projected through the subject for imaging in image tube 10 is mounted above the table as shown and is adapted to move longitudinally of the table coordinately with the image tube 10 for scanning the patient longitudinally. Tables of this kind may tilt up to 90° from horizontal in either direction in which case the magnetic flux lines of the earth'field will penetrate the image tube at various angles and no single setting of the coil 41 current will suffice for all angles which the table may assume. In this case a three terminal or a two-polarity d-c power supply 58 may be employed. One of its output terminals 59 may be relatively positive with respect to an intermediate terminal 60 and the other of its output terminals 61 may be negative relative to intermediate terminal 60. A tapped resistor 62 is connected across terminals 59 and 61 to provide for voltage division. Adjustable resistors 63 and 64 are also serially connected into the lines as shown. With this arrangement, the wiper 65 may be driven in correspondence with angulation of the table as symbolized by the dashed line 66 which couples table motion to wiper motion. As the wiper moves in correspondence with the table angulation, polarity and intensity of the magnetic field produced by coil 41 is varied. Rotation of table 55 through a 180° total angle will usually require complete reversal of the compensating magnetic vector. When the X-ray table is installed, a test object is interposed between the X-ray source and the image tube as described above and the best image is set with adjustable resistors 63 and 64 at each limit of table angulation. During future operations, all compensation for different table and image tube angles is obtained automatically by variations in polarity and current cuased by wiper 65 moving on resistor 62.

The system shown in FIG. 4 may be used in those cases where the X-ray image tube 10 is installed in a mobile X-ray unit hich may be used in the radiology room and in other rooms of the building as well where the earth's magnetic field is variously distorted or even of different intensity due to the effect of metallic objects or structures in the vicinity of the X-ray equipment.

FIG. 4 illustrates a control system which is usable in all situations but is especially useful in those installations where the X-ray image tube undergoes high mobility under markedly varying magnetic field conditions. In this embodiment, a Hall effect magnetic sensor device 70 is located near the input end 12 of the image tube but out of the image field. As is known, a Hall effect device comprises a prism or chip of n-type semiconductor material. Electron current is conducted through opposite side faces of the prism. Magnetic field vectors which are perpendicular to the top and bottom faces and orthogonal to current flow deflect the electrons toward one face and deplete the region near the other face in which case a potential difference depending on the field strength is produced. This potential difference is a measure of the earth's magnetic field. A pair of conductors 71 and 72 are used to apply a constant current to two terminals of the device. Potential variations due to magnetic field variations are manifested in a pair of conductors 73 and 74. Conductors 71–74 connect to a current source and signal amplifier device which is symbolized by the block marked 75. Power is supplied to device 75 through a pair of lines 76. The output from the device 75 appears on a pair of conductors 77 and 78 which connect through resistors 79 and 80 to the inverting and non-inverting input terminals 81 and 82, respectively, of an operational amplifier 83. The amplifier 83 has a feed back resistor 84 connected between its output terminal 85 and its non-inverting input terminal 82. Coil 41 is connected between the amplifier output terminal 85 and the center tap 86 of a two-polarity d-c power supply 87. The positive terminal 88 of the power supply is connected to amplifier 83 by means of a conductor 89 and the negative terminal 90 of the power supply is connected to amplifier 83 by means of a conductor 91. Center tap terminal 86 may be grounded or connected directly to

terminal 45 of coil 41. The output terminal 85 from the amplifier is connected to terminal 44 of coil 41.

In the FIG. 4 embodiment, as the X-ray image tube 10 is translated or angulated differently, the Hall effect magnetic sensor will produce a varying voltage output signal if the stray magnetic field of the earth varies with respect to the longitudinal axis of the X-ray image tube 10. Such signal variations will control amplifier 83 to vary the polarity and magnitude of its output current in such manner as to correspondingly vary the magnitude and polarity of the coil 41 current and, hence, its compensating magnetic field strength is varied as required. By appropriate control of variable feed back resistor 84, the gain of the amplifier 83 may be calibrated or adjusted so that coil 41 will be caused to produce a compensating magnetic field that is appropriate to all orientations of the image tube 10.

Although one form of compensating coil and several different current control systems have been described in considerable detail, such description is intended to be illustrative rather than limiting for the invention may be variously embodied and is to be limited only by interpretation of the claims which follow.

I claim:

1. For use with a radiation image intensifier having a photocathode for emitting photoelectron image current representative of a radiation image impinging thereon, a light emitting screen spaced from said photocathode, said screen having a high positive potential with respect to said photocathode, and focusing means interposed between said photocathode and light emitting screen for directing said photoelectrons onto said screen to produce a corresponding image thereon, the improvement for reducing the effect of a stray magnetic field permeating said envelope on said electron image current in a region adjacent said photocathode comprising:

a. an electromagnet coil surrounding the exterior of said envelope and said photocathode, the axial length of said electromagent coil and the region of mangetic influence thereof being substantially less than the distance between said photocathode and said screen, said coil being energized with direct current during operation of said intensifier to produce a magnetic field only of sufficient strength to overcome the influence of said stray magnetic field at least in the region within said envelope whereat said emitted electrons have not undergone significant acceleration.

2. The invention set forth in claim 1 wherein:

a. said envelope has a substantially cylindrical portion having an end through which said radiation image is transmitted to said photocathode adjacent thereto,

b. said focusing means including a plurality of electrostatic focusing electrodes disposed coaxially between said screen and photoelectrode, the first of said electrodes being adjacent said photocathode,

c. said coil having an axial length sufficient to embrace between its axial limits said photoelectrode and at least a part of said first focusing electrode.

3. The invention set forth in claim 1 including:

a. an annulus of magnetic metal on which said coil is mounted concentrically, said annulus surrounding said envelope.

4. The invention set forth in claim 1 including:

a. a direct current source having opposite polarity output terminals,

b. an adjustable resistor means connected in a series circuit with said coil, said series circuit being connected to said output terminals,

c. said resistor means being adjustable to establish a current magnitude for said coil to produce a magnetic flux sufficient to substantially nullify any component of said stray field which would influence said photoelectrons near said photocathode.

5. The invention set forth in claim 4 including:

a. a current direction-reversing switch interposed between said source terminals and said coil terminals.

6. The invention set forth in claim 1 including:

a. means supporting said image intensifier, said supporting means being movable to thereby change the orientation of said image intensifier with respect to the magnetic flux of the earth,

b. a direct current source having a first intermediate voltage output terminal and second and third output terminals which are respectively positive and negative relative to said intermediate terminal,

c. a resistor connected between said second and third terminals and having an intermediate point connected to said first terminal,

d. a movable contact element cooperating with said resistor means, said coil being connected to said contact element and said intermediate terminal, and

e. means for moving said contact element in response to movements of said supporting means to thereby alter the current through said coil in correspondence with the position of said supporting means.

7. The invention set forth in claim 1 including:

a. means supporting said image intensifier for undergoing movements which change its orientation with respect to the magnetic flux of the earth,

b. a variable direct current source for supplying current to said coil, and

c. means responding to movement of said image intensifier by varying the current delivered by said source to said coil.

8. The invention set forth in claim 1 including:

a. a direct current supply circuit for supplying current to said coil and including means for varying the output current of said supply circuit, and

b. means responsive to position changes of said intensifier for varying said varying means and the current supplied to said coil so that said coil varies its magnetic flux correspondingly to compensate for variations in the earth's mangetic flux in said intensifier resulting from movement of said intensifier.

9. The invention set forth in claim 1 including:

a. a direct current supply circuit for supplying current to said coil and including means for varying the output current from said supply circuit,

b. sensor means located in proximity with said intensifier means, said sensor means producing a signal which is functionally related to magnetic field intensity in the vicinity of said sensor means,

c. means responsive to signal variations resulting from movement of said intensifier means by vary-

ing said variable means and the current supplied to said coil so that said coil varies its magnetic flux correspondingly to compensate for variations in the magnetic field of the earth in said intensifier resulting from said movement.

10. The invention set forth in claim **9** wherein:

a. said direct current supply circuit includes a two polarity direct current source having a first output terminal and second and third terminals which are respectively positive and negative with respect to said first terminal, said first terminal being connected to said coil,

b. an amplifier connected to said second and third terminals and having an output terminal connected to said coil,

c. means connected to said amplifier for varying the magnitude and polarity of the output current therefrom to said coil in response to and coordinately with signal variations produced by said sensor.

11. The invention set forth in claim **9** wherein said sensor is a Hall effect device.

12. The invention set forth in claim **10** wherein said sensor is a Hall effect device.

13. In combination with an X-ray image intensifier tube including an envelope which has a substantially cylindrical portion and a window at its input end through which said X-ray image is received,

a photocathode at the input end of said envelope excitable by said X-ray image to emit a substantially corresponding electron image beam,

an output screen axially remote from said photocathode in said envelope, said output screen being excited to produce an optical image corresponding with the electron image beam impinging thereon,

a plurality of axially spaced apart annular electrostatic focusing electrodes interposed between said photocathode and output screen in said envelope, and means for applying in respect to said photocathode increasingly more positive potentials to said electrodes and said screen whereby to accelerate and focus said electron beam on said output screen, the improvement comprising:

a) a coil surrounding said envelope in the region of said photocathode, said coil having substantially lesser axial length than both said envelope and the distance between said photocathode and said output screen, means for energizing said coil with direct current to produce a magnetic field of sufficient strength to nullify the effect of the earth'magnetic field on emitted electrons in the vicinity of said photocathode.

14. The invention set forth in claim **13** wherein:

a) said energizing means includes means for varying the current through said coil until it produces said magnetic field of sufficient strength to substantially cancel the effect of the earth'magnetic field in said image tube.

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UNITED STATES PATENT OEFICE

CERTIFICATE OF CORRECTION

Patent No. 3,809,889 Dated May 7, 1974

Inventor(s) Robert C. McBroom

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Claim 1, column 7, line 25, after "intensifier" insert---

including an envelope and---.

Same line, delete "having".

Claim 1, column 7, line 26, after "photocathode" insert---

inside of said envelope---.

Claim 8, column 8, line 56, change spelling of "mangetic"

to---magnetic---.

Signed and sealed this 7th day of January 1975.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

ORM PO-1050 (10-69)

USCOMM-DC 60376-P69
* U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334.