Dec. 14, 1937. H. T. FAUS 2,102,409

ELECTRIC MEASURING INSTRUMENT

Filed June 19, 1936

Fig. 1.

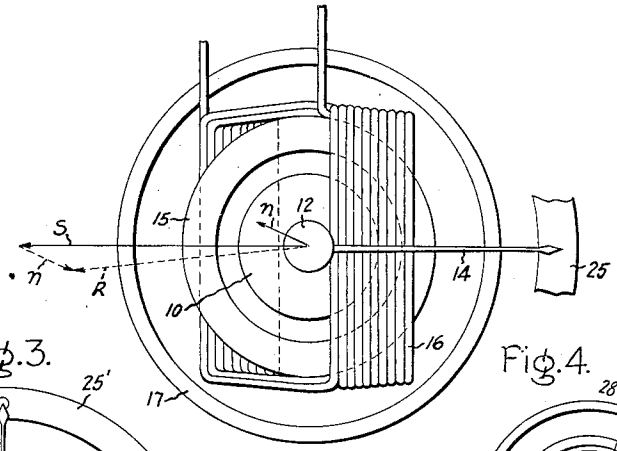


Fig. 3.

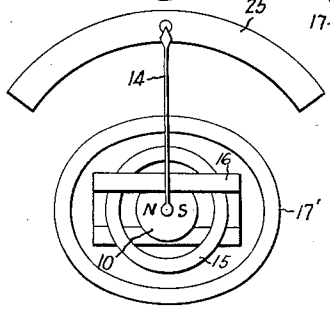


Fig. 4.

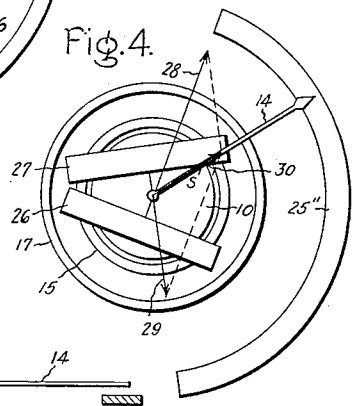
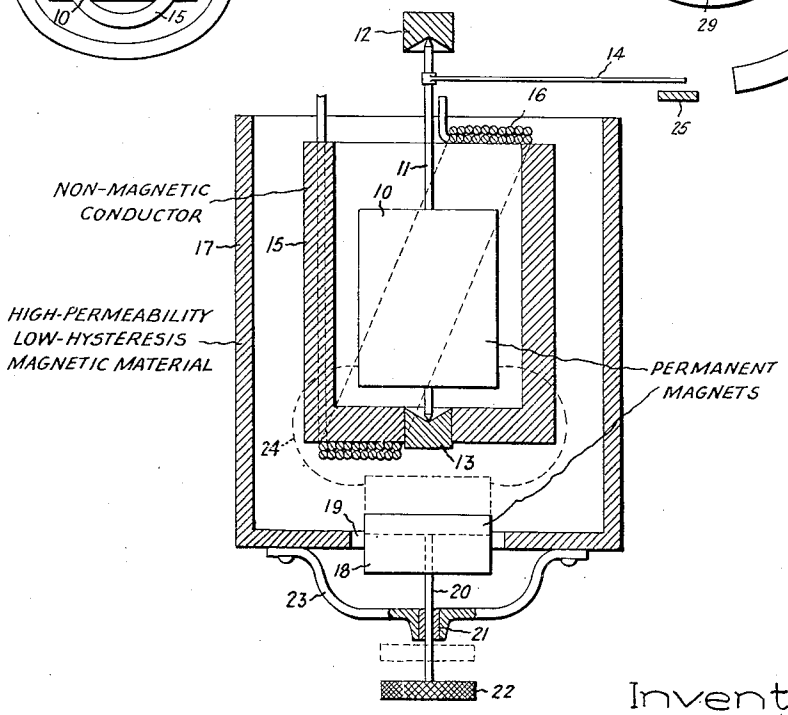


Fig. 2.



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UNITED STATES PATENT OFFICE

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ELECTRICAL-MEASURING INSTRUMENT

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Application June 19, 1936, Serial No. 86,109

7 Claims. (Cl. 171—95)

My invention relates to electric-measuring instruments and its object is to provide a reliable direct-current measuring instrument having many of the desirable performance characteristics of the d'Arsonval type of instrument but being more rugged in construction and less costly to manufacture.

In carrying my invention into effect in its preferred form, I employ a moving armature consisting of a light-weight permanent magnet. This is surrounded by a stationary damping shell of conducting material and by a stationary coil carrying the current to be measured. The instrument is preferably shielded from stray fluxes by placing it in an enclosure of magnetic material and, where a magnetic zero adjuster is used, it cooperates with such shield.

The features of my invention which are believed to be novel and patentable will be pointed out in the claims appended hereto. For a better understanding of my invention, reference is made in the following description to the accompanying drawing in which Fig. 1 represents a top view, Fig. 2 a sectional side view of the main portions of an instrument embodying my invention; Fig. 3 is a plan view of an instrument having an elliptical instead of a circular magnetic shield; and Fig. 4 is a showing of a two coil ratio instrument embodying my invention.

The moving armature 10 of the instrument consists preferably of an unlaminated cylinder of light-weight magnetic material capable of being permanently magnetized and which is polarized across a diameter thereof. A material which I have used for this purpose is prepared and magnetized as follows:

Mix together finely powdered magnetite, ferric oxide, and cobaltic oxide in the proportion of 43.6 per cent of magnetite, 30.1 per cent of ferric oxide, and 26.3 per cent of cobaltic oxide. Mold the mixture in the shape desired under pressure of from three to five tons per square inch. Remove from the mold and heat in an atmosphere of nitrogen or air for two to three hours at about 1020° C. and allow to cool. Then reheat to about 520° C. in a special furnace placed in the air gap of a direct-current electromagnet with a field of about 3000 H. With the field on, lower the temperature to about 300 or 320° C. and hold in the field within this range of temperature for about three quarters of an hour. Then allow to cool in the field to below 100° C. The material may then be machined or ground to shape if necessary.

The material first described after being magnetized, in addition to being a permanent magnet of exceptionally high coercive force and low residual induction, has other remarkable properties. It has a resistance between 600,000 and 1,000,000 ohms per centimeter cubed and is thus practically an insulator. It is hard and of a grey slate color. It is very light in weight as compared to other magnetic materials, having a specific gravity of approximately one half that of ordinary steel. The coercive force of the material prepared as previously described is between 700 and 1,000 oersteds and it has a residual induction of about 2,200 lines per square centimeter.

The line of polarization is very definite and fixed and does not shift. The behavior of the cylindrical magnet in this respect is just as if it were a compass needle. The material may be polarized after heat treatment, but in such case, the resulting permanent magnet is not so strong.

The permanent magnet strength of this material is several times that of permanent magnet steel for the same size and shape of magnet and the material is only about half the weight of such steel. Due to its high coercive force, the sintered oxide permanent magnet can be made very short in its polarized axis and is thus suitable for the armatures of small instruments.

The armature 10 is thus a light-weight, small diameter cylinder polarized across a fixed diameter. It is mounted on a nonmagnetic shaft 11 passing through its central axis. The shaft is mounted in suitable bearings 12 and 13 and carries a pointer or recording arm 14. No leads to the moving element are required.

Fifteen represents a cup of conducting material such as copper. It serves as a support for the bearing 13 and for the stationary coil 16. Its main purpose is that of a damper to damp the oscillations of the armature 10 when it changes its rotary position in response to a sudden change of current in coil 16.

Coil 16 is shown as wound in an inclined position with respect to the shaft 11. This arrangement permits the coil to avoid the shaft. The coil might be wound coaxial with the shaft but this would make assembly more difficult and expensive.

The part 17 is a cup-shaped shield of high permeability, low hysteresis magnetic material. It serves several purposes as follows:

It serves to magnetically shield the instrument from external stray flux fields; it serves as a partial magnetic return for the flux of the permanent magnet armature 10 and for the flux

produced by stationary coil 16; and, where as here a magnetic zero adjuster and restoring force means 18 is used, the cup-shaped shield 17 cooperates therewith for adjustment purposes as will be explained.

The zero adjuster and restoring force means 18 is also a permanent magnet and is preferably made of the sintered oxide material used in the armature. It is cylindrical in shape and is polarized across a diameter thereof but is made considerably shorter in axial length than the armature 10. Consequently, a correspondingly smaller flux emanates therefrom.

The bottom of the cup-shaped shield 17 has a central circular opening 19 appreciably larger than cylinder 18 and in which the cylinder 18 is located. As shown, all of the instrument parts are concentric to the axis of shaft 11. The magnetic zero adjuster is fixed on a shaft 20, which passes through a bearing 21 with a sufficiently tight fit to hold the part 18 in any desired position of axial and rotational adjustment. A thumb nut or other means 22 is also fixed to shaft 20, by means of which the zero adjuster magnet 18 may be rotated and moved axially in the opening 19. The supporting arms 23 for bearing 21 will be of nonmagnetic material when fastened, as shown, to the shield 17.

It is evident that, in the position shown, the bottom portion of magnetic cup 17 serves as a magnetic return for substantially all of the flux of the magnetic-restoring part 18. However, as part 18 is moved axially towards armature 10, as indicated in dotted lines, it will divert more and more of the flux from the permanent magnet armature 10, as indicated by dotted line 24, and the shield will shunt less and less of the flux from both permanent magnets and, when no current flows in coil 16, the armature 10 will rotate into and be held in a position determined by the rotary position of the adjustably fixed magnet 18. This will be the zero position of armature 10, which can be adjusted to any desired rotary position by turning magnet 18. This magnetic force serves to restore armature 10 and pointer 14 to the zero position when deflected therefrom, and the magnitude of this force may be adjusted by moving magnet 18 axially.

In Fig. 1, let us assume that the magnet 18 is adjusted with its north pole in the direction indicated by the small arrow *n*. With no current in coil 16, the zero position of armature 10 will be that where its south pole lines up with arrow *n*. Now, assume that direct current flows in fixed coil 16 and produces a south pole field in the direction of large arrow S. The field S will tend to rotate armature 10 clockwise and, if it were not for restoring force *n*, the north pole of armature 10 would rotate into line with arrow S. If we assume that the lengths of arrows *n* and S represent the relative influence of the restoring and deflecting forces on armature 10 and that the *n* force is negative with respect to S, then the armature 10 will take up a position with its north pole in line with the resultant force R. This represents a deflection of 180° less the angle between *n* and R. If we attempt to use so great a deflection as here indicated, the scale, indicated at 25, becomes unduly congested at the upper and lower ranges. It is preferable, therefore, not to attempt to use more than about a 90° deflection range and scale with the structure shown.

The magnetic shield 17 is shown exactly circular and concentric with respect to armature 10 in Fig. 1. The magnetic attraction between armature 10 and shield 17 will, therefore, be the same in all rotative positions of the armature. In some cases, I may wish to otherwise shape the shield 17, for example, make it elliptical, so that the magnetic poles of the armature approach more closely thereto in certain rotary positions than in others to modify the scale distribution. An example of this is indicated in Fig. 3 showing a zero center scale instrument where the magnetic poles of armature 10 approach more closely to the elliptical shield 17' as the pointer 14 approaches the upper end of scale 25' in either direction from zero. This will make the upper ends of the scale less congested.

In Fig. 4 I have shown the essential parts of a ratio instrument employing an armature 10 of polarized sintered oxide. The damping cylinder 15 and magnetic shield 17 are in general similar to these parts in Fig. 1, except that the bottom end portion of the shield may be omitted as in this instrument no zero restoring means is essential although a weak armature bias may be provided, as in some ratio instruments, if desired. The instrument is provided with two stationary energizing coils 26 and 27 arranged at an angle to each other such that coil 26 produces a flux in the direction of arrow 28 and coil 27 produces a flux in the direction of arrow 29. If we assume that the length of these arrows indicate the magnitudes of the fluxes produced by these coils for a given ratio measurement the resultant flux will correspond in magnitude and direction to arrow 30. The line of polarization of armature 10 will, therefore, align with the resultant flux 30, and the pointer 14 will be positioned accordingly. The scale 25'', may therefore, be calibrated in the ratio of currents in coils 26 and 27. It will be evident that with no current in coil 26 and with current in coil 27 the pointer 14, as mounted in the illustration will point along the line of arrow 29. Also that with current in coil 26 and none in coil 27 the pointer will point along arrow 28. These arrows thus define the limits of the scale 25'' for the particular angle shown between the coils 26 and 27. A scale having an arc of 180° less the arc formed by the angle between the coils is thus obtained.

It will be seen that I have provided an instrument of rugged construction having no moving coil and requiring no flexible leads. It is protected from external magnetic influences by reason of the magnetic screen 17, which serves for other purposes as described. It has good damping by reason of the stationary cup of conducting material 15, which is cut by the flux between the permanent magnet 10, and the surrounding shield 17. The part 15 also serves as a form of support for the energizing winding 16, which is stationary. The moving armature is made of comparatively light weight material, which is beneficial.

The instrument where required is provided with a simple and effective zero adjustment which serves also as a means for adjusting the magnitude of the restoring force. However, these adjustments can be made independently of each other. For example, rotating the magnet 18 changes the zero-indicating position but does not modify the magnitude of the restoring force. Moving the magnet 18 towards or away from armature 10 changes the magnitude of the restoring force but not the zero-indicating posi-

tion. This permanent magnet adjuster is also protected from stray fields by the surrounding portion of the magnetic screen 17. Such an instrument has damping, responsiveness, and scale distribution characteristics which compare favorably with d'Arsonval instruments. It is not so sensitive as the d'Arsonval instrument but it is more rugged and its cost is materially less.

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

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

1. A direct current electrical measuring instrument comprising an armature consisting of a permanent magnet mounted for rotation on an axis perpendicular to its line of polarization, a stationary cylinder of conducting material surrounding the armature so as to intercept the flux from said armature to damp oscillatory movements thereof, a stationary coil supported by said cylinder for producing a measurement flux across the axis of rotation of said armature, a cup-shaped member of high-permeability low-hysteresis magnetic material surrounding said coil and armature for protecting the instrument from external stray fluxes, said cup-shaped member being provided with an opening in its bottom portion coaxial with the axis of rotation of said armature, and a second permanent magnet serving to produce a zero return torque on said armature and adjustable towards and away from said armature along its axis of rotation through the opening in the bottom portion of the cup-shaped magnetic shield.

2. An electrical measuring instrument comprising a movable armature consisting of a permanent magnet polarized in a direction perpendicular to its axis of rotation, a stationary member of conducting material partially surrounding said armature and serving to damp the oscillations thereof, a stationary coil surrounding said armature and damping member for directly producing a flux in, and at an angle to the axis of rotation of, said armature and a shield of high-permeability, low-hysteresis magnetic material surrounding said armature and stationary coil to the extent necessary to protect the instrument from external stray fluxes.

3. A direct current electrical measuring instrument having a movable armature consisting of a magnetic cylinder of sintered oxide material of about half the weight of steel and polarized across a diameter thereof through its axis of rotation, stationary energizing winding means surrounding the armature for directly producing flux across the axis of rotation of said armature and a magnetic shield of high-permeability low-hysteresis magnetic material surrounding the flux axes of said coil and armature for protecting the instrument from stray fluxes and serving as a magnetic return for fluxes of the instrument.

4. A direct current electrical measuring instrument comprising a permanent magnet armature pivoted to rotate on a line perpendicular to its line of polarization, a stationary coil for producing a measurement flux across the axis of rotation of said armature, a stationary magnetic shield surrounding said armature and coil for protecting the same from external stray fluxes, and a second permanent magnet serving to produce a zero return torque on said armature, said second permanent magnet being mounted for adjustment about the axis of rotation of said armature and movable towards and away from said armature along said axis, said magnetic shield serving as a flux return for a portion of the fluxes of said two permanent magnets, which portion is adjustable by movement of the second permanent magnet towards and away from the armature.

5. A direct current electrical measuring instrument comprising a cylindrical permanent magnet polarized across a diameter thereof and pivoted for rotation on its axis, a cup of conducting material coaxial with said armature and supporting a bearing for said armature in the bottom wall thereof, a stationary coil for producing a measurement flux across the axis of rotation of said armature, a cup-shaped magnetic shield for said instrument enclosing the cup of conducting material coaxial therewith, said shield having an opening in its bottom portion coaxial with the axis of rotation of the armature and a permanent magnet rotatively and axially adjustable in said opening for producing an adjustable zero return torque for the armature.

6. An electrical measuring instrument comprising a permanent magnetic armature, inner and outer cup-shaped members enclosing said armature with their open ends upward, said armature being mounted on a shaft coaxial with said cups and extending out of the upper ends of said cups and being provided with a pointer extending over the upper end portions of said cups, the inner cup being of conducting material for damping the oscillations of said armature and supporting a bearing for the armature shaft in its bottom portion and also supporting a stationary coil for producing a measurement flux through the armature, said outer cup being of a high-permeability low-hysteresis magnetic material for protecting the instrument from external stray fluxes, said outer cup being provided with a central opening in its bottom portion and a permanent magnet rotatively and axially adjustable in said opening for providing a zero return torque for the armature.

7. A ratio instrument comprising an armature consisting of a cylinder of a sintered magnetic oxide polarized across a diameter thereof and pivoted for rotation on its cylindrical axis, a stationary cylinder of non-magnetic conducting material surrounding said armature for damping said armature, a pair of stationary coils positioned to produce fluxes across the axis of said armature at an angle to each other such that the armature is positioned by the resultant flux of said coils and a cylindrical magnetic shield surrounding said instrument, said coils being positioned between the cylinder of conducting material and magnetic shield.

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