June 12, 1962 R. H. POSTAL ET AL 3,039,055

RATIOMETER

Filed Jan. 7, 1959

FIG. 1

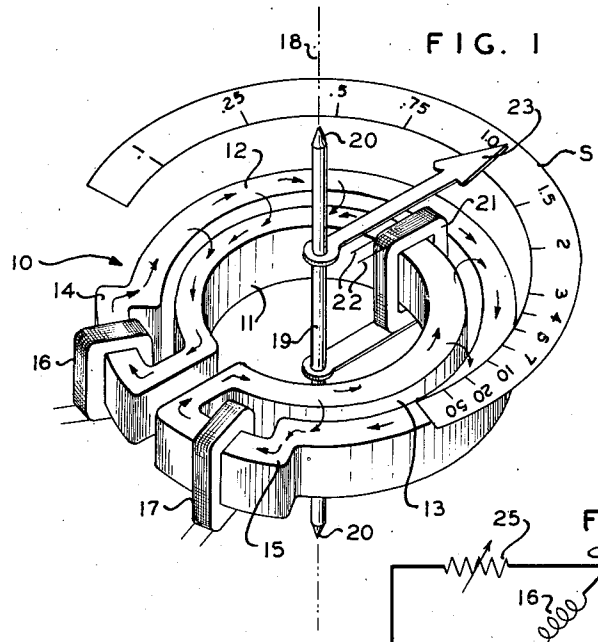


FIG. 2

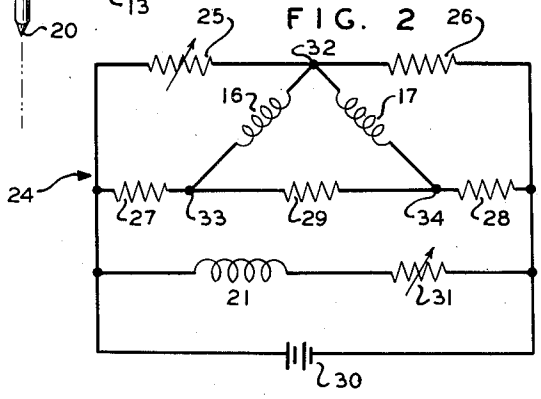
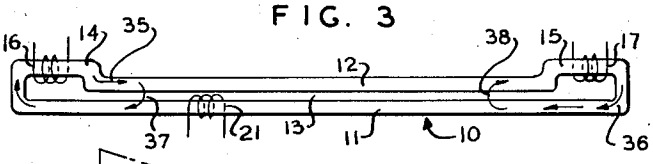


FIG. 3



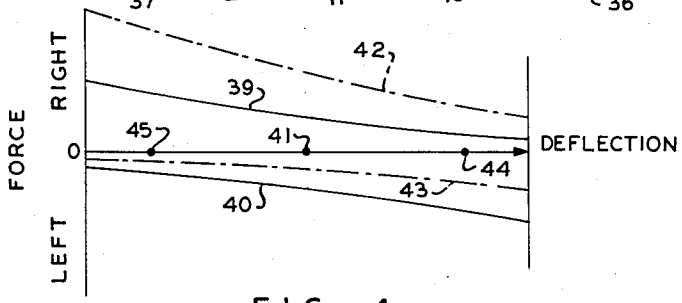


FIG. 4

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RATIOMETER

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This invention relates to a novel ratiometer of the moving coil type.

Objects of the invention are to provide an improved ratiometer having a long scale (greater than 180°) and having a novel construction which is simple and economical to produce.

Another object is to provide such ratiometer which is capable of indicating the ratio of both A.C. and D.C. currents.

A further object is to provide such ratiometer which has a stable operation free of critical tolerances and adjustments.

The present ratiometer operates on the null-balance principle which is that at each indicating position the net torque acting on the armature coil is zero. The net torque may be considered as comprising two opposing torque components dependent respectively on the currents in the field coils. Each torque component varies with deflection of the armature coil such that the armature is propelled always to an indicating position whereat the opposing torques are in balance. If the armature coil is deflected physically from an indicating position the torque exerted in the direction of the deflection is reduced and that in the other direction is increased to restore the armature coil to its original position. The present invention comprehends a novel field structure which makes feasible a practical form of moving coil type of ratiometer operating on the null-balance principle.

In the description of the invention, reference is had to the accompanying drawings of which:

FIGURE 1 is a perspective view of a ratiometer mechanism according to the invention;

FIGURE 2 is a bridge circuit for operating the ratiometer;

FIGURE 3 is a view of the field core structure laid out rectilinearly to better illustrate the operation of the instrument; and

FIGURE 4 is a set of flux density-deflection characteristics taken with reference to the core structure of FIGURE 3.

The present ratiometer shown in FIGURE 1 comprises a core structure **10** of a soft permeable magnetic material having two core members **11** and **12** placed alongside each other at a uniform spacing to provide a narrow air gap **13** therebetween. These core members are joined at their ends by looped portions **14** and **15** of the same material. On these looped portions are respective field coils **16** and **17**. For the usual form of instrument having a pivoted armature the core members are shaped arcuately about a common axis **18**, preferably in concentric relationship with one another as shown. Also, the looped portions **14** and **15** are extended outwardly to provide space between the core members for the field coils and to enable the inner core member to be extended arcuately throughout the widths of the field coils, giving thus an extended range for the moveable armature coil as will appear. At the axis **18** is a shaft **19** with cone shaped pivot ends **20** for journaling in respective jewel bearings not shown. This shaft carries an armature coil **21** which passes through the air gap **13** and surrounds the inner core member at a clearance distance from all adjacent parts of the core structure. The coil has lead wires **22** which are to be connected to the circuit shown in FIGURE 2 as through the usual hair springs not shown, but alternatively these lead wires may be connected together at the coil to short the coil and adapt the ratiometer for A.C. operation as will appear. The core structure is made of solid metal for D.C. operation and is laminated for A.C. operation. Secured to the shaft is a pointer **23** which registers with a suitable scale S graduated in terms of the condition to be measured.

Upon measuring any particular condition such as pressure, temperature, etc. a conversion circuit **24** such, for example, as is shown in FIGURE 2 may be employed. This is a bridge circuit comprising an upper branch with resistance arms **25** and **26** in series and a lower branch having corresponding resistance arms **27** and **28** and an additional central resistor **29**. The cross arm of the bridge is in the form of a delta comprising the field coils **16** and **17** as the opposite sides and the resistor **29** as the bottom. The bridge is connected to a suitable source of voltage **30** which may be a battery as shown for D.C. operation or any suitable source of alternating current for A.C. operation. In either case the voltage source **30** may provide also the energizing current for the armature **21**, as through an adjustable resistor **31** as shown.

One of the bridge arms, say the arm **25**, is of a type responsive to the condition being measured. For example, if temperature is being measured the arm **25** may be a resistor bulb having a resistance variable with temperature such as is well known in the art. As the resistor **25** is varied the potential of the common junction point **32** between the field coils and the upper branch of the bridge circuit is shifted with respect to the potentials at the junction points **33** and **34** in the lower branch, causing the current in one field coil to increase and that in the other coil to decrease in a corresponding manner. The ratiometer **10** measures the ratio of these currents to provide an indication of the temperature to which the variable resistor element **25** is exposed. The advantage of using a ratiometer for such measurements is that the indications are substantially independent of the voltage of the energizing source **30** since any variation in this voltage source varies the currents in both field coils alike without changing their ratio and the resultant indication. The indication becomes therefore a true measure of the condition under measurement.

In measuring systems such as are above described it is highly desirable that the indicating instrument have a long scale—typically about 250° or more—so that the graduations will be spread out to enable the condition being measured to be read more accurately. Many attempts have been made in the instrument field to devise a satisfactory ratiometer of practical construction capable of measuring over a longe scale but these attempts have not been wholly successful. The present instrument **10** is a new form of moving coil ratiometer of simple construction which is largely free of the critical tolerances and adjustments characteristic of prior forms of long scale ratiometers. For a better understanding of the operation of this instrument reference is had next to FIGURE 3 showing the core structure **10** laid out on a rectilinear basis with the armature coil **21** surrounding one of the parallel core members of this structure.

The field coils on the ends of the core structure are poled so that the currents therein set up flux lines **35** and **36** which are additive in the core. As will appear, the leakage flux lines across the air gap are then subtractive as designated at **37** and **38**. Since the core structure is a closed loop as of soft iron comprising adjacent core members **12** and **14** of uniform cross section and uniform spacing along the length of the air gap **13**, the magnetomotive force from each field coil across the gap will decrease substantially linearly proceeding along the gap

from the field coil but will not decrease to zero at the far end of the gap from the coil because of the magnetomotive force drop in the adjacent end loop of the core structure. Since the gap is uniform the density of the flux of each field coil in the gap will likewise decrease substantially linearly proceeding along the gap from the field coil. For any given current in the armature coil, a force is exerted on the armature coil proportional to the density of the flux in the gap. Since the flux lines in the gap from the respective field coils are in opposite directions, one field coil propels the armature coil in one direction and the other propels it in the other direction. If the field coils have equal ampere turns and the current in the armature coil is poled so that each field coil propels it in a direction away therefrom, the forces exerted on the armature coil by the respective field coils will be substantially as shown by the lines 39 and 40 in FIGURE 4. Under these conditions the opposing forces in the armature coil are in balance when the armature coil is at a mid position 41 on the scale. Such position of the armature coil becomes also a stable one because if the coil is deflected to the right or left from this position an unbalance in the opposing forces is developed to restore the armature coil to the position from which it was deflected. If the current in the field coil 16 is doubled and that in the field coil 15 is halved, the respective propelling forces on the armature coil would become as approximately indicated by the dash-dot lines 42 and 43 and the armature coil would seek a new stabilized position as indicated at 44. Similarly, if the currents in the field coils were varied in the inverse manner by the same proportion the armature coil would seek a position near the other end of the scale as at 45.

When a ring shaped core structure is used as shown in FIGURE 1 the same action takes place except that the forces on the armature coil are torque components about the axis 18. However, since the circuit shown in FIGURE 2, is not one which produces a variation of current in each field coil in true linear relation to variations in the resistor arm 25, a measurement of a variable condition with the use of this bridge circuit will result in a non-linear scale expanded at one end and compressed at the other as indicated in FIGURE 1. Such non-linear scale is however often desirable since it enables more accurate reading of variations in a condition throughout its most useful range and enables yet very large, or very small as the case may be, values in that condition to be still registerable on the scale.

The present instrument can be used on A.C. with the same bridge circuit as shown in FIGURE 2 as before explained. Further, it is now possible that the armature coil be disconnected from the voltage source and be shorted. This has the advantage of eliminating the hair-spring connections to the movable armature coil as well as the undesirable torque effects which such springs have on the operation of the ratiometer. Under A.C. operation a voltage component is induced in the armature coil from each field coil. Each voltage component varies according to the linkage of the flux from the respective field coil with the armature coil. When the air gap is substantially uniform as described and the magnetomotive force drop across the gap varies substantially linearly with increasing distance along the gap from each field coil the linkage varies substantially as a quadratic characteristic with deflection from a maximum when the armature coil is adjacent to the field coil to a minimum when it is away at the far end of the core structure with respect to the respective field coil. Since the shorted armature circuit has an inductive reactance the current component resulting from each individual voltage component is in lagging phase relationship to the flux of the air gap to produce a torque component which tends to move the armature coil away from the field coil producing the induced voltage component. Since each torque component is proportional to the product of the induced voltage component and the field flux it will vary sharply with deflection of the armature coil along the gap. But since the torque components from the respective field coils are in opposite directions, the armature coil again seeks always a stabilized position wherein the two torque components are in balance. Therefore when the armature coil is shorted the instrument operates on A.C. in the same manner as it does on D.C. when the armature coil is energized by a D.C. current.

The particular embodiments of our invention herein shown and described are intended to be illustrative and not necessarily limitative of our invention since the same is subject to changes and modifications without departure from the scope of our invention, which we endeavor to express according to the following claims.

We claim:

1. A ratiometer comprising a closed magnetic core having two uniformly spaced opposite sides in close proximity to each other along substantially their full lengths to form a uniform air gap therebetween along the length of said sides, field coils on opposite end portions of said core for providing a magnetic flux in a closed circuit through said core with leakage flux across said gap from each coil of a density which decreases at increasing distances from the respective coil, said coils being energizable by respective currents the ratio of which is to be measured and being poled so that the flux from said coils in said core is aiding and the leakage flux from said coils across said gap is opposing whereby to provide a null flux in said gap at distances along said sides dependent on the relative currents in said coils, and an armature coil surrounding one of said sides at a clearance distance therefrom and freely mounted for translational movement along said side responsive to the opposing torque influences of the flux components of said coils in said gap to cause the armature to seek the point of null flux in said gap and move along said gap as the currents in said coils are varied relatively to each other.

2. The ratiometer set forth in claim 1 including means for supplying a D.C. energizing current in said armature coil of a polarity causing a force to be exerted upon the armature coil from each field coil in a direction away from the respective field coil.

3. A ratiometer comprising a closed magnetic core having two opposite sides in close proximity to each other to form a uniform air gap therebetween along substantially the full length of said sides, field coils on opposite end portions of said core for providing a magnetic flux in a closed circuit through said core with leakage flux across said gap, said coils being energizable by respective currents the ratio of which is to be measured and being poled so that the flux from said coils in said core is aiding and the leakage flux from said coils across said gap is opposing whereby to provide a null flux in said gap at distances along said sides dependent on the relative currents in said coils, and an armature coil passing through said gap in surrounding relation to one of said sides of said core and mounted for translational movement along said one side whereby the net flux threading said armature coil from said field coils is in different directions when the armature coil is respectively at opposite sides of said null flux position, and means for supplying an energizing current to said armature coil causing the armature coil to seek said null position.

4. A ratiometer comprising a closed magnetic core having two opposite sides in close proximity to each other to form an air gap therebetween along substantially the full length of said sides, field coils on opposite end portions of said core for providing a magnetic flux in a closed circuit through said core with leakage flux across said gap, means for supplying respective currents to said field coils of a polarity causing the flux from said coils to be additive in said core and subtractive in said gap, said supplying means including a variable element responsive to a condition to be measured for varying the ratio of

currents in said field coils and causing a position of null flux in said gap to be shifted along said gap in relation to variations in said condition, an armature coil surrounding one of said sides and mounted for translational movement therealong, said core sides and gap being substantially uniform along the length thereof to cause the density of air flux in said gap from each field coil to vary substantially linearly along said gap, and means connecting said armature coil to said current supplying means for feeding a given energizing current to said armature coil of a polarity causing the armature coil to seek always said position of null flux.

5. A ratiometer comprising a closed magnetic core having two opposite sides in close proximity to each other to form an air gap therebetween along substantially the full length of said sides, field coils on opposite end portions of said core for providing a magnetic flux in a closed circuit through said core with leakage flux across said gap, means for supplying respective A.C. currents to said field coils of respective polarities causing the flux from said coils to be additive in said core and subtractive in said gap, said supplying means including a variable element responsive to a condition to be measured for varying the ratio of the currents in said field coils and causing a position of minimum flux in said gap to be shifted along said gap in relation to variations in said condition, an armature coil surrounding one of said sides and mounted for translational movement therealong, and means shorting said armature coil to cause currents to be induced therein from said field coils, said induced currents reacting with the flux from said field coils to cause the armature coil to seek said position of minimum flux.

6. A ratiometer comprising two arcuate core members

of soft permeable magnetic material having a common axis and positioned in proximity to each other to form an air gap about said axis, said core members being joined at their ends to form a closed magnetic circuit, field coils on said end portions energizable by respective currents the ratio of which is to be measured, said coils being poled to cause the flux thereof to be additive in said core and subtractive in said gap, an armature coil surrounding one of said core members and pivoted at said axis for movement along said one core member, and means for supplying a D.C. energizing current to said armature coil of a polarity causing the coil to seek always a position of minimum flux in said air gap.

7. The ratiometer set forth in claim 6 wherein said core members are concentric one within the other about said axis, said armature coil surrounds the inner one of said core members and the end portions of the outer one of said core members are looped outwardly from said axis to provide space for said field coils with arcuate extension of the inner one of said core members past the respective field coils whereby to provide an extended range of movement for said armature coil about said axis.

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