

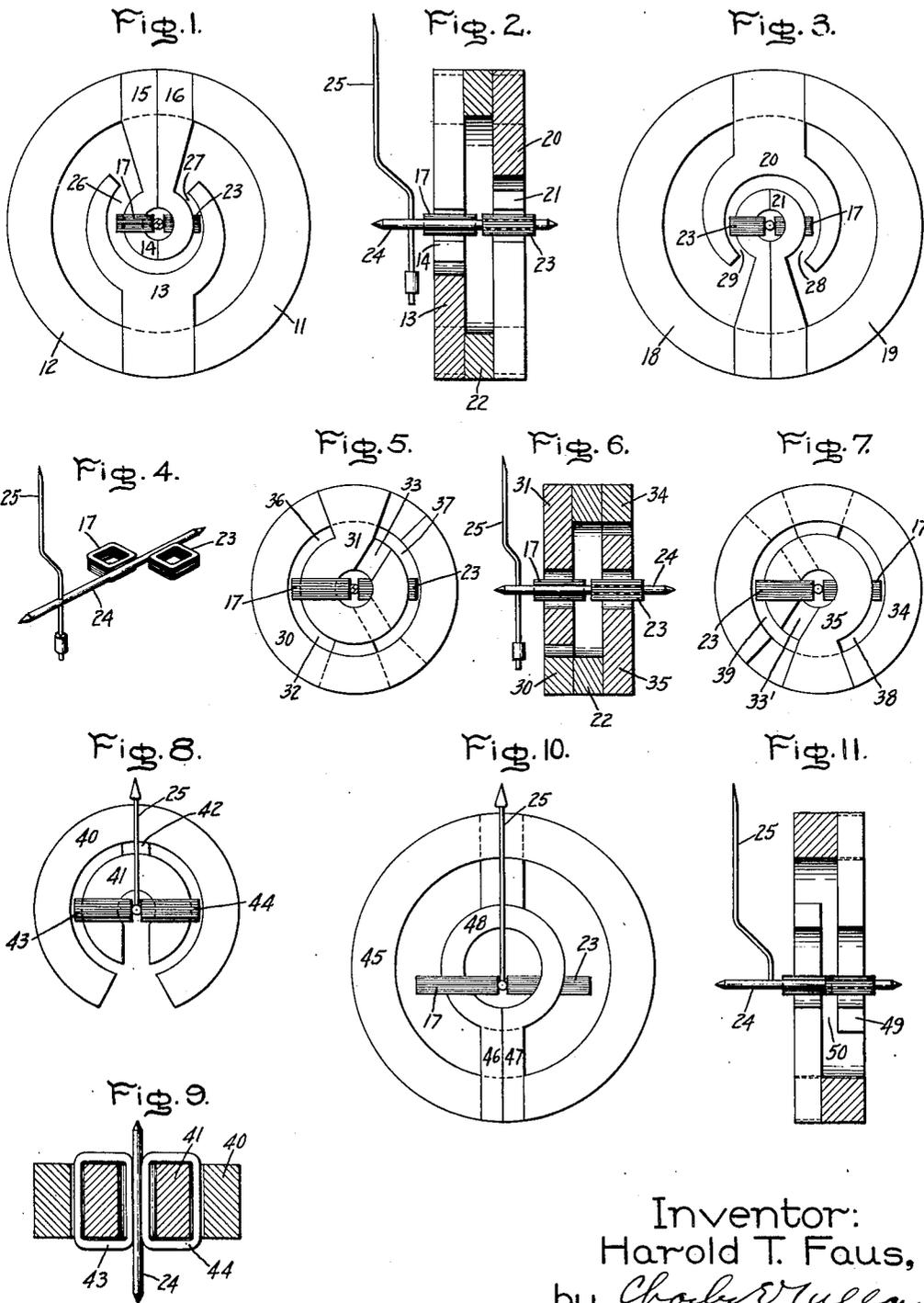
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ELECTRICAL INSTRUMENT

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UNITED STATES PATENT OFFICE

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ELECTRICAL INSTRUMENT

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My invention relates to electrical instruments and in particular to instruments of the ratio measuring type. The principal object of my invention is to provide a compact sensitive instrument having a long scale range. Other objects will become apparent as the description proceeds.

In accordance with my invention I obtain a scale range greater than that obtainable from crossed coil ratio instruments of the ordinary type by providing two eccentrically mounted coils coacting with magnetic fields set up between pole pieces made substantially annular in shape to permit a wide angle of deflection. The torque acting upon one coil is made to increase with the deflection while the opposing torque acting upon the other coil is made to decrease as in ratio instruments heretofore used. The features of my invention which I believe to be novel and patentable will be pointed out in the claims appended hereto.

To afford a more complete understanding of my invention reference is made in the following description to the accompanying drawing in which Fig. 1 is a face view of one of the magnetic field producing elements showing its relation with the current conducting coils; Fig. 2 represents partly in cross-section an embodiment of my invention in which the flux density is made to vary from one portion of the air gap to another by tapering the air gap; Fig. 3 is a rear view of the other magnetic field producing element of the device of Figs. 1 and 2; Fig. 4 represents the moving element of the instrument shown in Fig. 1; Fig. 5 represents a modification in which variation in flux density is produced by changing the magnetomotive force across the gap from one end of the air gap to the other; Figs. 6 and 7 are a sectional view and a view of the opposite side of the embodiment shown in Fig. 5; Figs. 8 and 9 are plan and sectional views of an arrangement in which the current conducting coils are mounted directly opposite each other on the shaft; Figs. 10 and 11 represent a modification in which the torque acting upon each coil varies with the deflection as a result of

the eccentric mounting of the pivot with respect to the pole pieces.

In accordance with one embodiment of my invention I provide a pair of field producing elements shown in Figs. 1 and 3, respectively. The front field element consists of a ring-shaped permanent magnet composed of segments 11 and 12 forming parallel magnetic circuits and having one pole piece with a C-shaped or open annular portion 13 and another pole piece with a closed annular portion 14. The pole piece 14 is split into two parts 15 and 16 to facilitate the assembly of the instrument with a current conducting coil 17 surrounding a portion of the annular pole piece 14. The coil 17 and the annulus 14 may be said to be linked mechanically but the flux flows radially between the pole pieces 13 and 14 rather than axially through the coil 17. The rear field producing element consists of the permanent magnet segments 18 and 19, the C-shaped pole piece 20, and the annular pole piece 21.

Although the two field producing elements are similar the relative positions of the C-shaped portions 13 and 20, and the closed annular portions 14 and 21 are interchanged. The field elements are sufficiently spaced from each other to minimize the magnetic flux flowing from one to the other by any suitable means such as a ring 22, preferably of non-magnetic material. A second current conducting coil 23 surrounds a portion of the annular pole piece 21 and is connected to act in opposition to coil 17. The coils 17 and 23 are eccentrically mounted on the shaft 24 of the moving element, angularly displaced 180 degrees and axially displaced a sufficient amount to permit one coil to coact with annular pole piece 14 and the other to coact with the annular pole piece 21. The shaft 24 also carries an indicating pointer 25.

An air gap is formed between pole pieces 13 and 14 which decreases from a maximum length at portion 26 to a minimum at portion 27. A similar tapered air gap is also formed between pole pieces 20 and 21 decreasing in length from the portion 28 to the portion 29. The spacing of the pole pieces is such that when the coil 17 is in the por-

tion of its air gap having the greatest length the coil 23 will be in the portion of its air gap having the least length and vice versa. Since the magnetomotive forces acting across the air gaps are substantially constant, but the reluctances across the air gaps vary from one portion to another the flux density in the air gap will vary. Consequently, the torques acting upon the two coils for given currents increase progressively for one coil and decrease progressively for the other coil as the moving element deflects until a position of balance is found at which the two torques are equal and opposite. The position of the pointer 25 then indicates the ratio of the currents flowing in the coils 17 and 23 in a manner well understood to those skilled in the art. It will be seen that in this form of my device a scale range of over 270 degrees is obtainable. Obviously the necessity for supporting the pole pieces 14 and 21 somewhere along their annular periphery precludes permitting the coils 17 and 23 to make a full revolution.

In Figs. 5 to 7, I have shown an arrangement of annular pole pieces and coils in which the torque acting upon each coil is made to vary with the deflection by varying the magnetomotive force so as to vary the flux density from one portion of the air gap to the other. In this arrangement an open annular or C-shaped permanent magnet 30 is attached to a hook-shaped soft iron core 31 having an annular portion concentric with the magnet 30 so as to form a uniform air gap 32 between the magnet 30 and the core 31. The magnetic potential will be a maximum at the portion 37 of the air gap and will gradually fall, reaching a minimum at the portion 36. The flux density in the air gap will likewise decrease uniformly from the portion 37 to the portion 36. A similar ring-shaped magnet 34 and a hook-shaped core 35 spaced from parts 30 and 31 are provided, forming an air gap in which the flux density increases from a minimum at 38 to a maximum at 39. Coils 17 and 23 surround portions of the cores 31 and 35 respectively and are connected in opposition. Consequently the coils 17 and 23 will be acted upon by opposing torques varying in relative magnitude in the manner explained in connection with the embodiment shown in Fig. 1.

The openings 33 and 33' in the cores 31 and 35 facilitate the assembly of the instrument and permit the coils 17 and 23 to be placed around the cores 31 and 35 respectively.

In the arrangement shown in Fig. 8 a single C-shaped or open annular permanent magnet 40 is provided which is joined to a soft iron annular core 41 by a member 42. The air gaps between the members 40 and 41 may be uniform but owing to the fact that the magnetomotive forces acting across the

air gaps increase from the portion near the member 42 to the open portions of the C-shaped members 40 and 41, the flux densities will increase likewise. Consequently as the moving element deflects coils 43 and 44 surrounding the core 41 will be acted upon by relatively varying torques in the manner hereinbefore described.

Although I have shown arrangements for varying the torque of the moving element with position by varying the flux density in the air gap it will be understood that I am not limited to these exact arrangements. The same result might be accomplished in other ways; for example, by causing the radius of action of the flux to vary with the position of the coil. Such an arrangement is illustrated by the instrument shown in Figs. 10 and 11, the specific structure of which is not my invention. In this form of the device a magnet 45 is provided with a pole piece having split portions 46 and 47 which when joined form an annular portion 48 linked with one of the coils 17 of the moving element. A similar pole piece having an annular portion 49 linked with coil 23 is attached to the magnet on the opposite side and displaced 180 degrees from the point of attachment of pole piece 48. An air gap 50 is formed between annular pole pieces 48 and 49 which is substantially uniform in length and in which the flux density is substantially uniform. The shaft 24 carrying the coils 17 and 23 is mounted eccentrically with respect to the pole pieces 48 and 49 so that the distance between the portion of the coil acted upon and the axis of rotation varies as the moving element is deflected. The variation in the lever arms being opposite for the two coils, the relative torques acting upon the coils vary with the deflection to accomplish the result sought in the other embodiments described.

Although I prefer for the sake of space economy and convenience in manufacture to use pole pieces having rectangular cross sections cut by a plane through their axes, it will be understood that I am not limited to this exact shape. The term "annular" as used in the appended claims is meant to refer to structures having substantially the shape of either a closed ring or a segment of a ring.

I have herein shown and particularly described certain embodiments of my invention and certain methods of operation embraced therein for the purpose of explaining its principle and showing its application but it will be obvious to those skilled in the art that many modifications and variations are possible and I aim therefore to cover all such modifications and variations as fall within the scope of my invention which is defined in the appended claims.

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

1. An electrical ratio instrument comprising a magnet, a pair of pole pieces therefor having substantially annular portions with a varying air gap therebetween, one pole piece substantially surrounding the other, a current conducting coil mounted to permit a portion thereof to move through said air gap, a rotatable shaft carrying said coil, a second current conducting coil mounted on said shaft and axially offset from said first coil and a second magnet, a pair of pole pieces therefor with a varying air gap through which the second coil moves, the arrangement being such that one coil moves through its air gap in the direction of increasing gap length while the other coil moves through its air gap in the direction of decreasing gap length.

2. An electrical ratio instrument comprising a pair of pole pieces having substantially annular portions between which an air gap is formed in which the magnetic field strength varies progressively from one portion to another, one pole piece substantially surrounding the other, a movable current conducting coil cooperating with said pole pieces, a second current conducting coil mechanically connected to said first mentioned coil and axially offset from said first coil, and a second pair of pole pieces having substantially annular portions between which an air gap is formed in which the magnetic field strength varies progressively, the arrangement being such that one of said coils travels through a magnetic field of increasing strength from one pair of pole pieces while the other coil travels through a field of decreasing strength from the other pair of pole pieces.

3. An electrical instrument comprising two pairs of pole pieces each of which forms a portion of an annulus arranged so that for each pair of pole pieces an air gap is formed between the inner surface of one pole piece and the outer surface of the other in which gaps the magnetic field strength varies progressively from one portion to another, and a pair of mechanically connected axially offset rotatable current conducting coils each arranged to move through one of said air gaps, said pole pieces being arranged so that one coil moves in a direction of increasing field strength while the other moves in a direction of decreasing field strength and each of said inner pole pieces being linked by one of said coils and forming a substantially complete annulus supported at only one portion of its circumference, thereby extending the angular range of the instrument by permitting said coils to move along the entire unsupported circumference of said inner pole pieces.

4. An electrical ratio instrument comprising

a pair of magnetic pole pieces having substantially annular and approximately concentric portions with a varying airgap therebetween and each having a portion projecting from said annular portion, the annular portion of one of said pole pieces being closed to form a complete annulus and being surrounded by the annular portion of the other pole piece, a pair of permanent magnets in the form of circular segments joining the projecting portions of said annular pole pieces to form a circular stationary member, a current-conducting coil linking said closed annular pole piece and mounted to permit a portion thereof to move through said air gap, a rotatable shaft carrying said coil, a second current-conducting coil mounted on said shaft and axially offset from said first coil, said coils being eccentrically mounted and angularly displaced 180 degrees, a second pair of pole pieces, and a second pair of circular segmental permanent magnets similar to said first-mentioned pole pieces and magnets forming a second circular stationary member co-axial with said first-mentioned stationary member and having a varying airgap through which said second coil moves, the arrangement being such that one coil moves through its airgap in the direction of increasing gap length while its other coil moves through its airgap in the direction of decreasing gap length.

5. An electrical ratio instrument comprising a pair of circular co-axial stationary members and a pair of eccentrically mounted axially offset rotating coils angularly displaced 180 degrees, each of said stationary members comprising an inner completely closed substantially annular pole piece mechanically linking one of said rotating coils, and an outer substantially annular pole piece surrounding said inner pole piece to form an airgap therebetween within which a portion of said rotatable coil is free to move and in which the field strength varies circumferentially along said airgap, the arrangement being such that one of said coils moves in a field of increasing strength, whereas the other of said coils moves in a field of decreasing strength as said coils are deflected in a given direction.

6. An electrical instrument comprising two pairs of pole pieces each of which forms a portion of an annulus arranged so that for each pair of pole pieces an airgap is formed between the inner surface of one pole piece and the outer surface of the other, in which airgaps the magnetic field strength varies progressively from one portion to another, said outer pole pieces comprising C-shaped permanent magnets and said inner pole pieces comprising hooked-shaped members composed of permeable material with the substantially annular hooked portion substantially concentric with the permanent magnet

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surrounding said hooked portion and with the projecting portion abutting an end of the surrounding C-shaped permanent magnet, and a pair of mechanically connected axially off-set rotatable current-conducting coils each arranged to move through one of said airgaps, said pole pieces being arranged so that one coil moves in a direction of increasing field strength while the other moves in a direction of decreasing field strength and each of said inner pole pieces being linked by one of said coils.

7. An electrical ratio instrument comprising a C-shaped permanent magnet forming a substantially annular outer pole piece, a hooked-shaped member of relatively permeable magnetic material having a substantially annular hooked portion substantially concentric with said C-shaped permanent magnet and a projecting sector-shaped stub portion of less angular width than the open portion of the C formed by said permanent magnet, said projecting stub portion abutting at one side against one end of said permanent magnet so as to produce a magnetic field in the air gap formed between said inner pole piece

and said outer permanently magnetized pole piece in which the field strength gradually increases from the end where said projecting portion of the inner pole piece abuts the outer pole piece to the end of the airgap between the free end of the C-shaped outer pole piece and the free end of the hooked portion of the inner pole piece, a current-conducting coil linking said inner pole piece eccentrically mounted for rotation about an axis substantially coaxial with said pole pieces, a second current-conducting coil axially off-set from said first-mentioned current-conducting coil, and a second pair of pole pieces similar to said first-mentioned pair of pole pieces, cooperating with said second-mentioned coil and so arranged with respect to said first-mentioned pair of pole pieces that one current-conducting coil moves in a direction of increasing field strength while the current-conducting coil moves in a direction of decreasing field strength for rotation in a given direction.

In witness whereof, I have hereunto set my hand.

HAROLD T. FAUS.

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