

Oct. 3, 1961

G. SMITH

3,003,128

POSITION MEASURING APPARATUS

Original Filed March 4, 1959

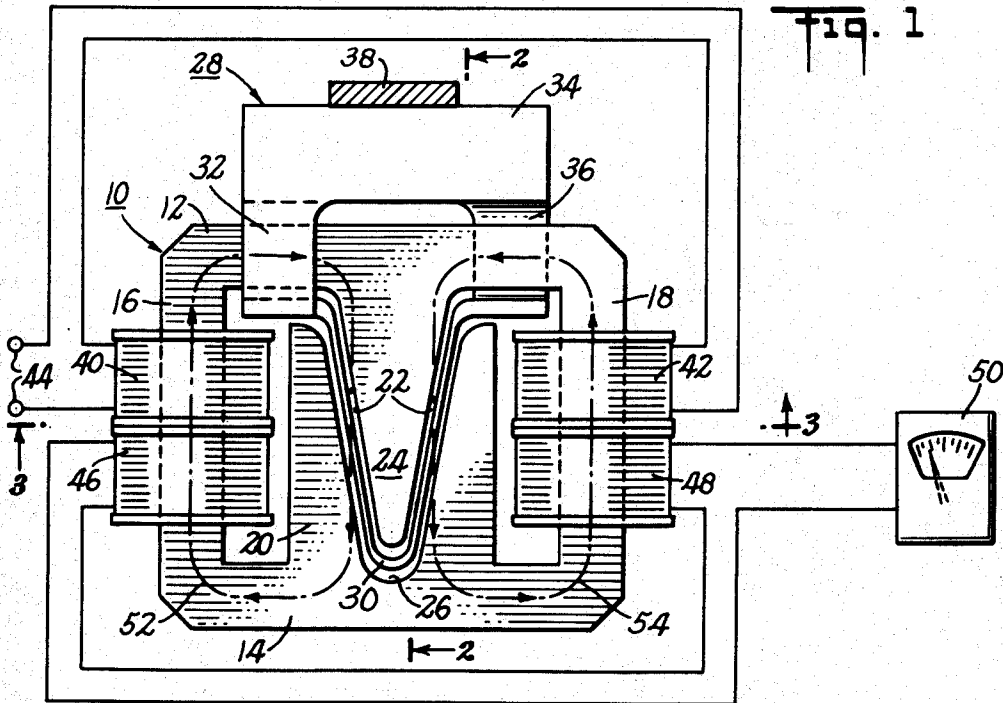


Fig. 1

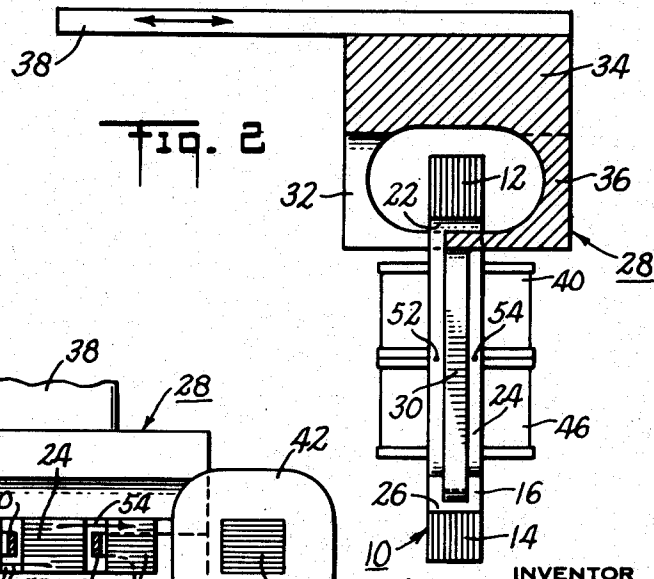


Fig. 2

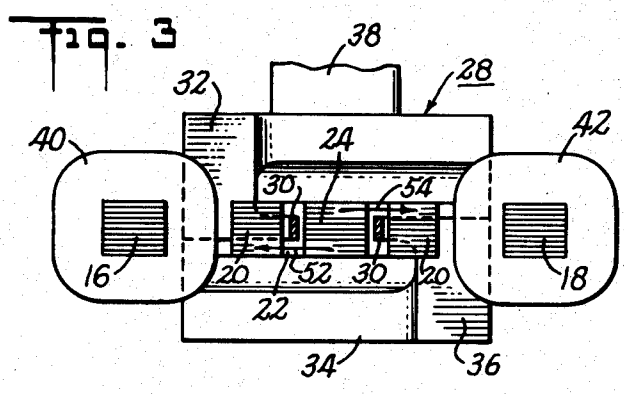


Fig. 3

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3,003,128

POSITION MEASURING APPARATUS

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Continuation of application Ser. No. 797,078, Mar. 4, 1959. This application Apr. 7, 1960, Ser. No. 20,786
6 Claims. (Cl. 336—75)

This invention relates to electrical position-measuring devices adapted to produce and transmit an electrical measurement signal directly corresponding to the position or location of a physically movable element; an example of a measuring device of this general character is described in detail in copending application Serial No. 690,363, filed October 15, 1957. More in particular, this invention relates to improvements adapted to provide electrical position-measuring devices that are highly compact and efficient in operation, and inherently less subject to the effects of variations in ambient temperature.

Prior devices of the general type described in the above copending application comprise a three-legged magnetic core structure having a primary winding wound on the center leg to produce flux around the two magnetic circuits formed by the outer legs. The relative distribution of the flux in the outer legs is controlled by a movable "flux-barrier" consisting of an electrically-conductive closed loop positioned to extend into an air-gap formed in the center leg. Secondary windings are mounted on the outer legs and arranged to produce an electrical output signal in accordance with the relative amounts of flux passing through these outer legs.

In devices of this character, the presence of the air-gap substantially increases the reluctance of the magnetic circuits through which the flux passes, and this in turn reduces the inductive impedance of the windings relative to their effective resistance. As a result, any change in the effective resistance of these windings, due for example to a change in ambient temperature, may alter the output signal to an undesired extent. Moreover, the relatively high reluctance of the air-gap makes it possible for some of the flux to pass through closed paths which do not include the air-gap. This "leakage" effect reduces the amount of flux controlled by the flux-barrier and thus reduces the efficiency of operation.

In accordance with the present invention, however, these adverse effects are minimized by a construction which is compact and yet arranged to provide a relatively low air-gap reluctance. Thus, the inductive impedance of the windings is substantially increased over prior devices of the same overall physical size, and a larger percentage of the flux is controlled by the flux-barrier so as to assure good sensitivity. Other objects, advantages and aspects of the present invention will be in part apparent from, and in part pointed out in, the following description considered together with the accompanying drawings, in which:

FIGURE 1 is a plan view of a position-measuring device constructed in accordance with the present invention;

FIGURE 2 is a cross-section taken along line 2—2 of FIGURE 1; and

FIGURE 3 is a longitudinal section taken along line 3—3 of FIGURE 1.

Referring now to FIGURE 1, the device includes a three-legged magnetic core structure 10 having elongated top and bottom members 12, 14 with a pair of outer legs 16, 18 and a center leg 20 extending therebetween. Between the center leg and the top member is a V-shaped air-gap 22 formed by a wedge-like section 24 and a deep mating trough 26. This air-gap has a "lengthwise" dimension, defined herein as the lineal distance between the remote ends of the air-gap (i.e. as measured

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between the upper tips of the V in the disclosed embodiment), that is substantially greater than the corresponding lateral dimension of the center leg 20, as measured from left-to-right in FIGURE 1.

Referring also to FIGURE 2, an electrically-conductive flux-barrier generally indicated at 28 is positioned about the magnetic core structure 10 and includes an elongated control element 30 which extends lengthwise through the air-gap. This control element is V-shaped to conform to the air-gap configuration, and it lies in a plane that is parallel to the effective plane of the core structure. The left-hand end of the control element is integral with an arm 32 which extends along one side of the top core member 12 and forms part of a base member 34 of the flux-barrier. The right-hand end of the control element is integral with another arm 36 which extends along the other side of top member 12 to the base member 34. Secured to the top of the base member is a support plate 38 which is movable (in the direction indicated by the arrow in FIGURE 2) to vary the positioning of the control element 30 with respect to the air-gap 22.

The outer legs 16, 18 are provided with respective identical primary windings 40, 42 which are energized in series by a source of alternating current indicated by terminals 44. Respective identical secondary windings 46, 48 also are wound on these legs and are connected in series-opposition to an electrical-sensing unit diagrammatically indicated at 50 as a volt meter adapted to indicate the magnitude of the output signal. The particular winding arrangement shown herein also is described and discussed in detail in copending application Serial No. 768,730, filed October 21, 1958 by the present applicant.

As indicated by the dashed lines 52, 54 in FIGURE 1, the magnetic core 10 forms two magnetic circuits both passing through a common core portion including the center leg 20 and wedge-like section 24. The left-hand one of these magnetic circuits 52 passes beneath the flux-barrier arm 32 and crosses the air-gap (see also FIGURE 3) beneath the control element 30. The right-hand magnetic circuit 54 passes above the other flux-barrier arm 36 and crosses the air-gap above the control element 30. Since no net flux can pass through the closed electrically-conductive loop represented by the flux-barrier 28, these two magnetic circuits are effectively isolated from each other. That is, all the flux (except leakage flux) produced by the left-hand primary winding 40 crosses the air-gap 22 below the control element 30, and similarly all the flux produced by the right-hand primary winding 42 passes across the air-gap above this control element.

Referring now to FIGURE 2, when the flux-barrier 28 is positioned with its control element 30 in the center of the air-gap 22 (as shown), the area of the air-gap to the left of the control element will be equal to the area to the right of this element. Hence, the magnetic reluctances of the two circuits 52, 54 will be equal and the two primary windings 40, 42 will present equal impedances to the source of current 44. In that case, the voltages across the primary windings will be equal and consequently the flux produced around the respective magnetic circuits 52, 54 by these windings will be equal. Thus, equal voltages will be induced in the series-opposed secondary windings 46, 48 with the result that no net voltage will be transmitted to meter 50.

If the flux-barrier 28 is moved by the support plate 38 to the left (FIGURE 2), the air-gap area to the left of control element 30 will decrease while the area to the right will increase. Therefore, the reluctance of magnetic circuit 52 will decrease while the reluctance of magnetic circuit 54 will increase, so that the impedance of primary winding 40 is increased and the impedance of

primary winding 42 is decreased. Consequently, the voltage applied across winding 40 will go up, while the voltage applied across winding 42 will go down, and the flux through the left-hand outer leg 16 thus will increase while the flux through the right-hand outer leg 18 will decrease.

With these changes of flux in the outer legs 16 and 18, the voltages induced in the secondary windings 40, 42 will be correspondingly unbalanced so that a net output voltage will be transmitted to meter 50. The magnitude of this voltage is proportional to the extent of movement of the flux-barrier 28, and the phase of this voltage is determined by the direction of flux-barrier movement away from its center position, i.e. either left or right as viewed in FIGURE 2.

Because the air-gap 22 extends down the center leg 20 for a substantial distance, rather than directly across this leg, the lengthwise dimension of the air-gap is substantially increased over prior devices of this general class of the same overall size. Accordingly, the effective area of the air-gap is increased thereby reducing the reluctance of the magnetic circuits traversing the gap. With a lowered magnetic reluctance, the inductive impedances of the windings are increased relative to the winding resistances, thereby reducing any variations in the output signal resulting from changes in winding resistance such as might be caused by changes in ambient temperature. In addition, the lowered reluctance of the air-gap tends to reduce the relative amount of stray flux, i.e. flux which does not cross the gap, and thus increases the efficiency of operation.

Although in the specific preferred embodiment described herein the air-gap is in the shape of a V, other gap shapes can be utilized to achieve at least some of the advantages of the present invention. In any event, the core should be arranged in such a manner that at least a part of the gap, as viewed in a sectional plane through the gap, extends in a direction that is non-perpendicular to the "flux-axis" (that is, the principal direction of the flux) of the magnetic material adjacent the air-gap. For example, in the described embodiment as viewed in the plane of FIGURE 1, both sides of the V extend in directions that are non-perpendicular to the average direction of the flux passing longitudinally (i.e. axially) through section 24 and center leg 20.

When the air-gap is elongated in this manner, the flux crossing the gap should be controlled by a flux-barrier having a control element which extends parallel to the air-gap direction that is non-perpendicular to the flux-axis of the adjacent magnetic material. In addition, this element should be movable in a direction having at least a component that is perpendicular to the longitudinal axis of the control element; e.g. in the preferred embodiment, element 30 moves at right angles to a plane passing through the two arms of the V defined by this element. The air-gap, as viewed in any vertical cross-sectional plane through FIGURE 1, extends parallel to this direction of movement. Thus, regardless of the particular contour or shaping selected for the gap, a mating flux-barrier element can be provided which is freely movable through the gap to control the relative amounts of flux passing through the two separate magnetic circuits 52, 54.

Accordingly, there has been provided a position-measuring device having important advantages as compared to prior constructions. Although a specific preferred embodiment of the invention has been set forth in detail, it is desired to emphasize that this is not intended to be exhaustive or necessarily limitative; on the contrary, the showing herein is for the purpose of illustrating the invention and thus to enable others skilled in the art to adapt the invention in such ways as meet the requirements of particular applications, it being understood that various modifications may be made without departing from the scope of the invention as limited by the prior art.

This application is a continuation of my application Serial No. 797,078, filed March 4, 1959.

I claim:

1. In a position-measuring device adapted to produce an electrical measurement signal for transmission to a remote electrical sensing or indicating means; apparatus comprising a core structure including magnetic material arranged to form two magnetic circuits having a common portion, primary winding means wound on said core structure to produce flux around said two magnetic circuits, said core structure being provided with air-gap means in series with both of said magnetic circuits; the magnetic material of said core structure being shaped to define a configuration for said air-gap means wherein at least a part of said air-gap means extends in a direction that is non-perpendicular to the flux-axis of the magnetic material adjacent said air-gap means on at least one side thereof; electrically-conductive flux-barrier means mounted about said core structure and forming a closed conductive loop adapted to control the relative division of said flux between said two magnetic circuits, said flux-barrier means including a control element positioned in said part of said air-gap means and extending essentially parallel to said direction thereof; support means mounting said flux-barrier means for movement effectively at right angles to said direction of said part of said air-gap means; and secondary winding means coupled to said core structure for producing a signal in accordance with the relative distribution of said flux between said two magnetic circuits.

2. In a position-measuring device adapted to produce an electrical signal for transmission to a remote electrical-sensing means; apparatus comprising, in combination, a three-legged core structure including magnetic material arranged to form two magnetic circuits wherein the center leg is common to both of the circuits, primary winding means wound on said core structure to produce flux around said two magnetic circuits, said core structure being formed with an air-gap in series with said center leg, at least a substantial part of said air-gap extending in a lengthwise direction that is non-perpendicular to the axis of said center leg; an electrically-conductive flux-barrier mounted about said core structure to control the relative division of said flux between said two magnetic circuits, said flux-barrier including an elongated control element positioned in said air-gap and extending longitudinally along the lengthwise direction thereof, said control element being shaped to conform to the contour of said air-gap in said lengthwise direction; support means mounting said flux-barrier for movement in a direction that is perpendicular to said lengthwise direction of said air-gap; and secondary winding means coupled to said core structure for producing a signal in accordance with the relative distribution of said flux between said two magnetic circuits.

3. In a position-measuring device adapted to produce an electrical signal for transmission to a remote electrical sensing means; apparatus comprising, in combination, core structure including magnetic material arranged to form two magnetic circuits having a common portion, first and second primary windings wound on said core structure remote from said common portion to produce flux around said two magnetic circuits, said primary windings being connected in series, said core structure being formed with an air-gap in series with both of said magnetic circuits, at least a substantial part of the lengthwise dimension of said air-gap extending in a direction that is non-perpendicular to the flux-axis of the magnetic material adjacent said air-gap; electrically-conductive flux-barrier means positioned adjacent said air-gap to control the relative division of said flux between said two magnetic circuits; said flux-barrier means including an elongated control element positioned in said air-gap and extending along the lengthwise dimension thereof, said control element being shaped to conform to the shape of the lengthwise dimension of said air-gap; support means for mounting said flux-barrier means for movement in a direction having at least a component that is perpendicular to said

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lengthwise dimension of said air-gap; and first and second secondary windings coupled to said core structure remote from said common portion for producing a signal in accordance with the relative distribution of said flux between said two magnetic circuits.

4. In a position-measuring device adapted to produce an electrical signal for transmission to a remote electrical-sensing means; apparatus comprising, in combination, a three-legged core structure including magnetic material arranged to form two magnetic circuits and wherein the center leg is common to both circuits, primary winding means wound on said core structure to produce flux around said two magnetic circuits, said core structure being formed with a V-shaped air-gap in series with said center leg, at least a substantial part of the long arms of said V-shaped air-gap extending in directions that are non-perpendicular to the longitudinal axis of said center leg; electrically-conductive flux-barrier means positioned in said air-gap to control the relative division of said flux between said two magnetic circuits, said flux-barrier means including an elongated V-shaped control element positioned in said air-gap and extending along the lengthwise dimension thereof; support means for mounting said flux-barrier means for movement in a direction that is perpendicular to said lengthwise dimension of said air-gap; and secondary winding means coupled to said core structure for producing a signal in accordance with the relative distribution of said flux between said two magnetic circuits.

5. In a position-measuring device adapted to produce an electrical signal for transmission to electrical-sensing

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means; apparatus comprising, in combination, a three-legged magnetic core structure including top and bottom members joined by a pair of outer legs and a center leg, said structure being arranged to form two magnetic circuits with the center leg common to both circuits, primary winding means wound on said core structure to produce flux around said two magnetic circuits, said core structure being formed with an air-gap in series with said center leg; electrically-conductive flux-barrier means positioned adjacent said core structure to control the relative division of said flux between said two magnetic circuits, said flux-barrier means including an elongated control element positioned in said air-gap and extending parallel to the effective plane of said core structure; said flux-barrier means further including a base member positioned adjacent said core structure top member and having a pair of arms extending down along opposite sides of said top member to the respective ends of said control element, thereby to establish an electrically-conductive closed loop surrounding said top member; support means for mounting said flux-barrier means for movement in a direction that is perpendicular to the longitudinal dimension of said control element; and secondary winding means coupled to said core structure for producing a signal in accordance with the relative distribution of said flux between said two magnetic circuits.

6. Apparatus as claimed in claim 5, wherein said air-gap is at least approximately V-shaped with the tips of the V immediately adjacent said top member.

No references cited.