May 9, 1950 W. D. MACGEORGE 2,507,344

DIFFERENTIAL TRANSFORMER

Filed Jan. 9, 1948

Fig. 1.

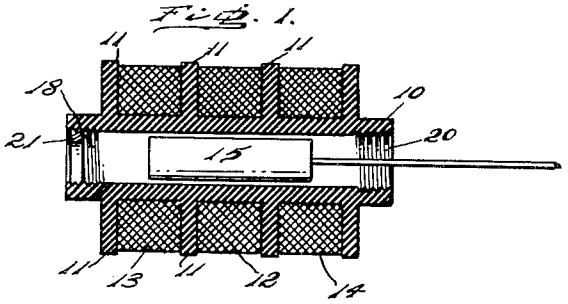


Fig. 2.

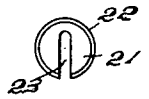


Fig. 3.

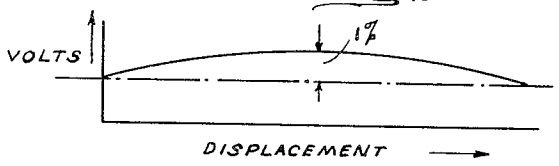


Fig. 5.

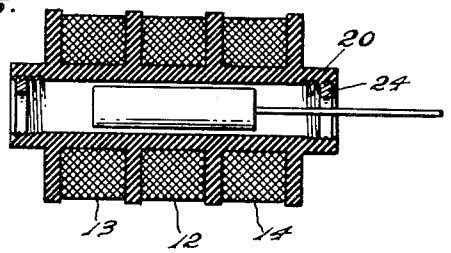


Fig. 4.

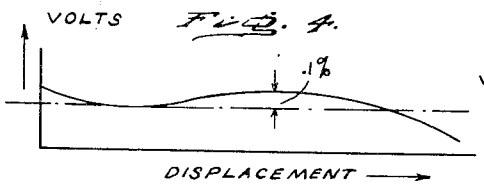


Fig. 6.

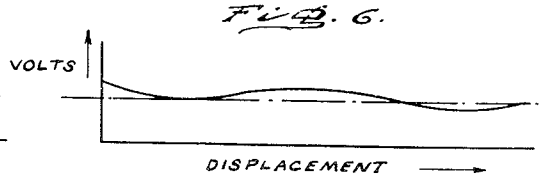
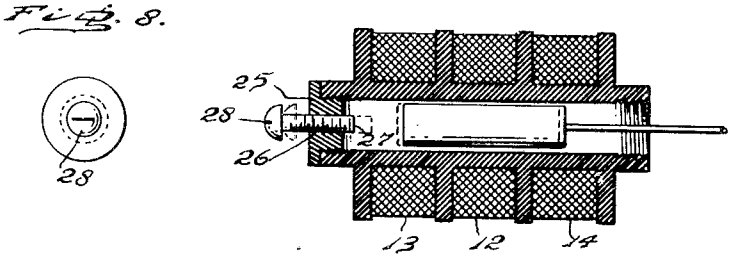


Fig. 7.

Fig. 8.



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DIFFERENTIAL TRANSFORMER

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Application January 9, 1948, Serial No. 1,347

1 Claim. (Cl. 171—119)

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This invention relates to differential transformers, and particularly to means and methods of enhancing the linearity of response and to adjust the zero or null point thereof.

Movable core differential transformers, as typified, for instance, by the transformer disclosed in Patent No. 2,427,866, have as a stator a pair of co-axial secondary coils coupled in bucking series, symmetrically disposed in axially spaced relation on opposite ends of and relative to a common exciting primary. As the relatively movable armature passes from asymmetry with the primary in one sense through symmetry to asymmetry with the primary in the opposite sense, while the primary is energized by a suitable A. C. source, the output of the secondaries varies from a voltage of A phase, through a null output, to a voltage of B phase. The output of such transformers is generally considered to be substantially linear, and for many purposes is sufficiently close to linear as to be adequate. However, it is found that the actual curve of the voltage output varies as much as perhaps one percent more or less from the truly linear.

It will be understood further of such transformers that the range of relative axial motion of the armature thereof is very minute indeed in securing the desired change in output as a measurement, for instance, of such microscopic motion. With such minute armature motion (which may be of the order of .00002") it will be seen that the adjustments of the stator coils relative to the armature or of the armature relative to the actuating device for moving the armature in order to accurately position the armature at the exact symmetrical point in the stator at which null output is attained, as a starting point for the measurement, will be very delicate indeed. In fact, so delicate that accurate mechanical adjustments are all but impossible, or so complicated as to negative or restrict their use.

It is among the objects of this invention to improve the performance characteristics of differential transformers; to provide means and methods for enhancing the linearity of performance of differential transformers; to provide means for electromagnetically adjusting the coils and the armature of movable armature differential transformers; to provide adjuncts for differential transformers; to obviate or minimize some of the objections to prior art differential transformers; and other objects and advantages will become more apparent as the description proceeds.

In the accompanying drawings forming part of this description:

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Fig. 1 represents more or less schematically a longitudinal vertical section through the differential transformer according to a preferred but illustrative form thereof, showing a slug or disc or magnetizable material adjustably positioned on one end thereof to enhance the linearity of the output thereof;

Fig. 2 represents an illustrative side elevation of the adjustable slug or disc of the invention;

Fig. 3 represents an illustrative highly exaggerated curve of the output of a typical illustrative differential transformer such, for instance, as is shown in Fig. 1, prior to or without the addition of the metal slug or disc of the invention;

Fig. 4 represents a similar exaggerated curve of the same transformer after the insertion of the metal slug of the invention as shown in Fig. 1;

Fig. 5 represents a similar sectional view of the transformer of Fig. 1, showing two slugs or discs of magnetic material mounted therein respectively at opposite ends thereof to still further flatten the curve of the output thereof;

Fig. 6 represents an illustrative exaggerated curve of the output of the transformer as illustrated in Fig. 5;

Fig. 7 represents a schematic longitudinal section through a still further modified form of the transformer, showing an axially adjustable magnetizable metal element for effecting substantially vernier adjustments of the armature of the transformer in the establishment of a zero or null output thereof, without changing the adjustment of the armature relative to its causative moving device, or the adjustment of the stator relative to the armature;

Fig. 8 represents an end elevation of the insert device of Fig. 7.

The illustrative transformer of Figs. 1, 5 and 7 comprises preferably, although clearly not essentially, an insulating central supporting form, illustratively of a ceramic or like nature, for instance, comprising a cylinder 10 having a plurality of radial annular fins 11. The fins form partitions to separate a central primary coil 12 from the concentric secondary coils 13 and 14. The latter are coupled in series opposition or bucking relation. The primary coil 12 is arranged for coupling to a source of A. C. A movable core or armature 15 is coupled by a link 16 to a suitable source of relatively slight movement (not shown), such, illustratively as shown in said patent, or as shown in Hornfeck Patent No. 2,420,539, or in any of applicant's co-pending applications. Obviously, any desired actuating device may be associated with the link 16 as the moving element,

the motion of which is to be measured or signalled. It is desired that the motion of the link 19, and thus of the armature 15 be utilized to develop a potential or a null in the output of the secondaries, which is a function of the motion of the armature or core. Preferably, the ends of the insulating cylinder 10 are internally threaded, as at 18 and 20 respectively.

In the curve of Fig. 3 in a highly exaggerated way, the theoretical linear response of the transformer of Fig. 1, as so far described, is indicated by the dot and dash line, and this is supposed to represent the change of voltage as a function of armature displacement. The departure from the truly linear in the actual output voltage of the transformer is indicated by the exaggerated solid line curve above it. It is exaggerated to indicate, by the wide deviation shown from the linear, an actual deviation of approximately 1%, which, if drawn to actual scale might be unnoticeable. As usually but one end of the curve is used, the deviation from linearity from the start of the curve to the substantial center thereof, starting at the left end of the curve, for instance, is appreciable.

The deviation from the truly linear, that is the deviation from linear of the ratio of the change in induced voltage to the change in armature position, is probably due to the fact that the advancing end of the armature moving away from the null symmetrical position toward an asymmetrical position of a potential output from the bucking secondaries is moving away from the most intense field of magnetic flux. This invention contemplates the provision of an additional path of flux with which the advancing end of the armature has increasing response even though leaving or advancing beyond the most intense field centered in the primary coil and in the adjacent mass of the armature. Such deviation being the ratio heretofore recited.

To secure the additional flux path in an efficient and precise way, a slug or disc 21 is provided, of magnetic material having the external threads 22, and also having internally the substantially diametrical slot or other recess opening at one edge in order to reduce eddy currents. The slug 21 is threaded into the threads 18 at the end of the cylinder 10 of the transformer, adjacent to the free end of the armature, and lies in a plane diametrical of the cylinder, parallel to the transverse extent of the armature. The magnetic disc or slug forms an auxiliary or supplemental path for magnetic flux developed in the armature from the primary coil, and forms with the armature a generally closed loop flux circuit so as to maintain an effective field on the advancing end of the armature. The disc is screwed into the cylinder, using the slot 23 for a tool if desired, until the maximum desired effect is secured, as a function of the proximity of the disc or slug to the armature, as it is adjusted inwardly in the cylinder 10. The effect of the properly positioned slug 21 upon the output of the transformer is indicated in Fig. 4, in a flattening of the actual output curve, with a sharp reduction of the previously existing deviation from the truly linear output. This effective change in output, in contrast to the linear, is indicated in an exaggerated way in said figure. The previous deviation of the illustrative 1% of the voltage from the truly linear is reduced to an illustrative substantially .1% of the voltage. This, as indicated, is most evident at the left end of the curve. The reference to linear deviation means the ratio of the change in induced voltage to the change in armature position.

If it is desired to have a similar result at the other end of the curve, a second disc 24, of the same general characteristics as the first, is screwed into the threads 20 at the right end of the cylinder 10, utilizing the slot or recess in the disc or slug as the passage for the motion transferring link 19, as will be clear. This double disc association effects the smoothed and substantially linear path of voltage output as exaggeratedly indicated in Fig. 6, in which both ends of the curve have been affected by the slugs or discs. The improved functioning of the transformer of this invention for delicate and accurate testing and like responsiveness to small motions, by effecting a sharper linearity, will be understood.

It sometimes happens that when the core 15 is coupled rigidly to an actuating source of extremely small range of motion and the stator coils are secured in place with the armature initially in only a substantially centered symmetrical position, a micrometric adjustment of the core relative to its actuator, or of the coils relative to the armature is indicated or necessary. Owing to the minute measurements involved, this is a very delicate operation, and is usually ineffective for the purpose. This invention contemplates the provision of a small magnetic mass centered in the end of the cylinder and axially adjustable to effectively change the center of the armature to the center of the primary. To this end the rough mechanical relative adjustments are so made as to cause the stator to be to the left of center (in Fig. 7). Then a ceramic or other insulating disc 25 is pushed or screwed into the end of the cylinder 10, provided with a fine-threaded axial bore 26, in which an elongated threaded shank 27, preferably in the form of a screw having a slotted or like head 28, is mounted. When an approximation of the symmetrical disposition of the armature 15 in the exciting coil 12 is attained, but, as noted, to the right of such actual center (as the stator is to the left thereof and there is, therefore, a predominant excess of flux in coil 14 because of the presence of the armature) the plug is inserted, or if previously inserted, the screw is adjusted inwardly as indicated in dotted lines. The final setting and a vernier adjustment is secured by small adjustments of the screw, moving the mass relative to the armature 15. In the illustrative initial unbalance recited, this effectively places iron in coil 13 and balances the excess armature iron in coil 14. As indicated, a minute adjustment of the screw to the right, as indicated in dotted lines in Fig. 7, effectively shifts the armature 15 to the left, to vary its effective center of null output, without actually moving the armature. Of course, if the initial adjustment is made with the screw all the way in, and the adjustment is with the stator to right of center, withdrawal of the screw effects the balance in output of the secondaries without moving the armature. Thus, extremely minute but accurate adjustments of the armature and coils, without disturbing the relation of the armature and the actuating source are accomplished.

Having thus described my invention, I claim:

A differential transformer comprising an exciting primary coil and a pair of secondaries coupled in bucking series relation, a relatively movable armature movable relative to the primary coil and arranged to unbalance the outputs of the secondaries to secure a potential, electro-

magnetic means spaced from the primary and arranged to form a supplemental flux path juxtaposed to the movable armature to reduce the linear deviation of the ratio of the change of voltage to the change of armature positions, and a second electro-magnetic means spaced from the primary on the opposite side thereof from the first mentioned electro-magnetic means and arranged to form a supplemental flux path juxtaposed to the movable armature to still further reduce the linear deviation of the ratio of the change of voltage to the change of armature position.

WILLIAM D. MACGEORGE.

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