

United States Patent

[11] 3,586,964

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[21]	Appl. No.	820,409
[22]	Filed	Apr. 30, 1969
[45]	Patented	June 22, 1971
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[32]	Priority	May 8, 1968
[33]		Great Britain
[31]		21873/68

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[54] INDUCTIVE TRANSDUCERS
12 Claims, 5 Drawing Figs.

[52] **U.S. Cl.**..... 324/34,
336/83, 336/84, 336/96, 336/234

[51] **Int. Cl.**..... G01r 33/00,
H01f 15/02, H01f 27/24

[50] **Field of Search**..... 336/84, 83,
96, 233, 234, 96, 212; 323/34

ABSTRACT: The present invention relates to inductive transducers and discloses constructions of such transducers having two concentrically arranged coil and core assemblies wherein the cores are formed of ferromagnetic material and have their ends terminating at the working face of the transducer. In operation, the coils of the transducer may be connected in the opposed arms of a bridge circuit, thereby producing a substantially linear output from the bridge circuit.

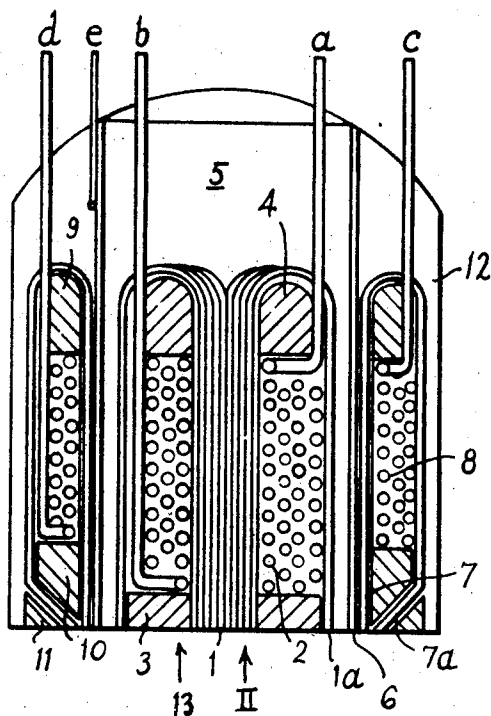


Fig.1

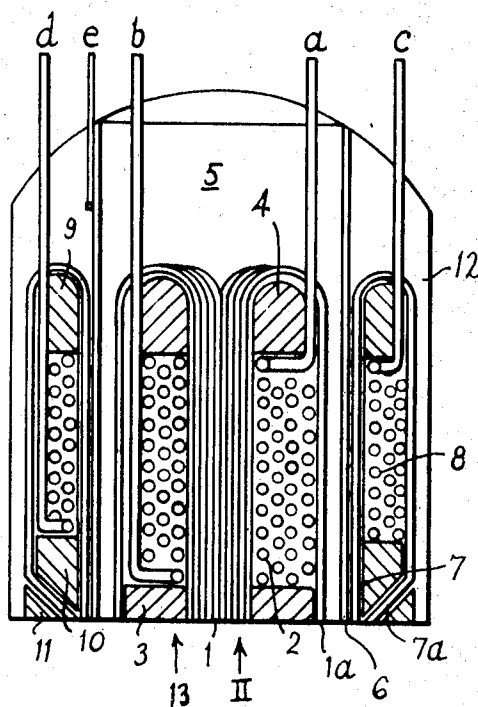


Fig.2

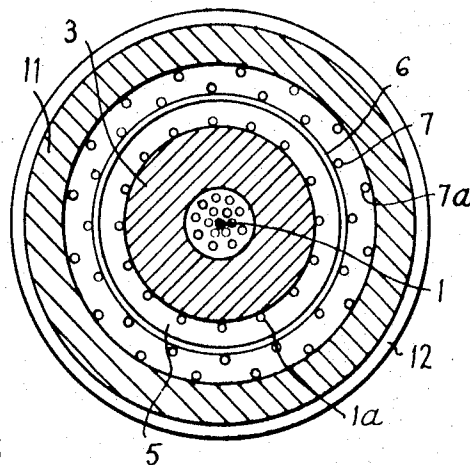
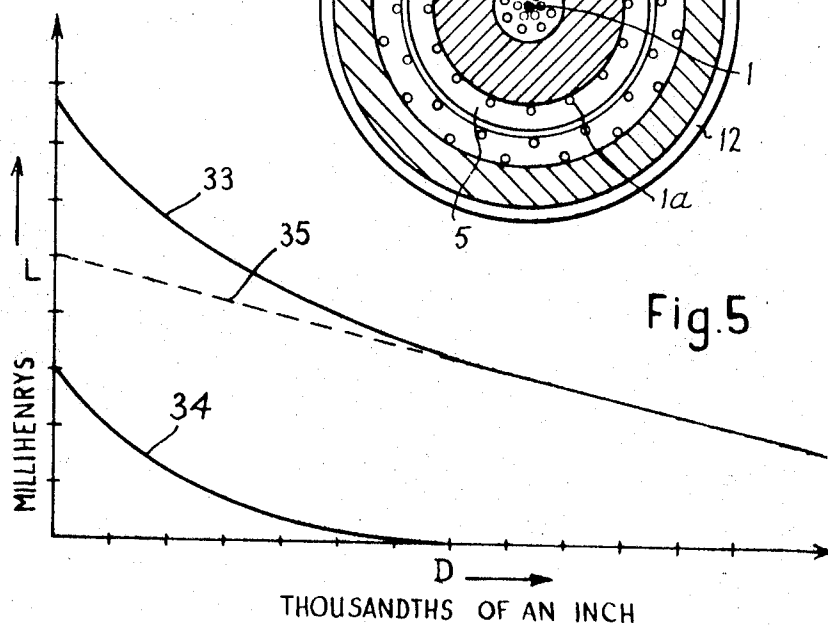
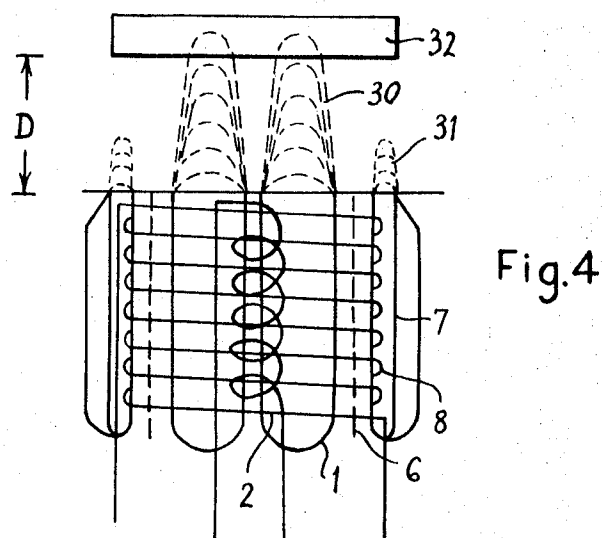
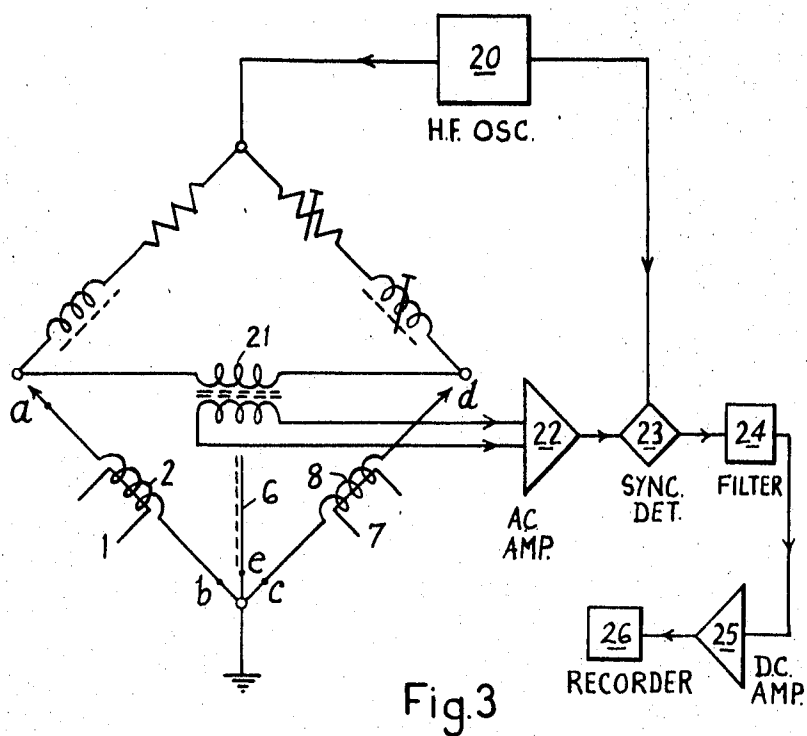


Fig.5





INDUCTIVE TRANSDUCERS

This invention relates to inductive transducers.

According to this invention an inductive transducer comprises a first ferromagnetic core, a first coil extending around said first core, part of said first core being turned back round the outside of said first coil, both ends of said first core terminating in a plane forming the working face of the transducer; a second ferromagnetic core disposed around the periphery of said first coil, a second coil extending around said second core, part of said second core being turned back round the outside of said second coil, both ends of said second core terminating at said working face; the spacing between the two ends of one of said cores being substantially greater than the spacing between the two ends of the other said core.

The first and second cores may each include a plurality of ferromagnetic wires having part of their length turned back round the outside of the first and second coils respectively.

A screen of ferromagnetic material is preferably arranged between the two coil and core assemblies.

Preferably said first and second coils are connected in opposed arms of a bridge circuit, so that the effect of a change of inductance occurring in one said coil is at least partially compensated by the effect of a change of inductance in the same sense occurring in the other said coil, thereby producing a substantially linear output from the bridge.

In the preferred arrangement, said first and second coils are connected in first and second arms respectively of an AC bridge, the output of the bridge being connected across one end of said first and said second arms, the other end of said first and second arms being connected together and to earth, and the AC input being connected across the common point of the third and fourth arms and earth.

One embodiment of the invention will now be described by way of example with reference to the accompanying drawings, in which:

FIG. 1 is a diagrammatic longitudinal section of an inductive transducer in accordance with the invention,

FIG. 2 is an elevation of the transducer, in the direction of arrow II IN FIG. 1,

FIG. 3 is a circuit diagram showing the measuring circuit of the transducer,

FIG. 4 is a diagram illustrating an aspect of the operation of the transducer, the view being similar to that of FIG. 1 and

FIG. 5 is a graph showing inductance plotted against armature displacement.

Referring to FIGS. 1 and 2, the transducer includes a core 1 consisting of 16 iron wires, which is surrounded by an inner coil 2 wound between two insulating rings 3, 4. The coil 2 is of copper wire and has its ends led out to terminals *a*, *b* of the transducer. The wires of the core 1 are folded back, at the end furthest from the working face 13 of the transducer, around the outside of the coil 2, and are substantially equally spaced around the periphery (as seen at 1A). The assembly is then encapsulated in an epoxy resin 5, which in turn is surrounded by a screen 6 of ferromagnetic material which is connected to terminal *e*. This terminal is connected to earth potential.

The screen 6 is surrounded by an outer core 7 consisting of 16 iron wires equally spaced round the circumference, and the outer core is in turn surrounded by an outer coil 8. The latter has approximately the same axial extent as the inner coil 2, and in order to have the same number of turns and the same total resistance as the inner coil, as is preferred, may be wound of a copper wire having a lower specific resistance. The outer coil 8 is wound between two insulating rings 9, 10, of which the ring 10 nearer the working face of the transducer is of substantially triangular or trapezium section, and the ends of the coil are led out to terminals *c*, *d*. The wires of the outer core 7 are folded back, at the end furthest from the working face, around the outside of the outer coil 8 (as seen at 7A), and are surrounded adjacent the working face by an insulating collar 11. The assembly is then encapsulated in epoxy resin 12, which fills the interstices between parts 7-11.

The radial spacing between the two ends of the wires of the inner core 1 is preferably 15 to 20 times the radial spacing between the ends of the wires of the outer core 7.

As seen in FIG. 3, the inner and outer coils 2, 8, are connected to form two arms of a bridge circuit; and since one end (*b*, *c*) of each coil is earthed in this arrangement, these ends may be connected to the earthing connection *e* to the screen 6, so that the transducer need only have three terminals *a*, *d*, *e*, one of which is the earth terminal. The other two arms of the bridge circuit each comprise an inductance and a resistor, and the components of one of these arms may be adjustable for setting-UP purposes.

In operation, a carrier wave of a frequency of, for example, 100 kHz. is supplied across the bridge from a HF oscillator 20, and the output of the bridge is taken, through a transformer 21, by way of an AC amplifier 22 to a synchronous detector 23 and a filter 24, from which the output, after further amplification in a DC amplifier 25, is fed to a recorder of an oscilloscope 26.

Referring to FIG. 4, it can be seen that the magnetic field lines 31 from the outer iron core 7 do not extend so far across the air gap as the magnetic field lines 30 from the inner iron core 1. This is due to the difference in the radial spacing between the ends of the wires of the iron core 7 and those of the iron core 1. Therefore any material 32, forming an armature, coming towards the active face of the transducer will first penetrate the magnetic field lines 30 and, at a smaller distance from the active face, it will penetrate the field lines 31.

FIG. 5 shows the corresponding inductance *L* of coil 2 and coil 8, plotted against the distance *D*, of the armature 32 from the active face of the transducer. Line 33 represents the inductance of coil 2 and line 34 that of coil 8.

If the transducers are connected as in the bridge circuit of FIG. 3 then the inductance of coil 8 (line 34) will be subtracted from the inductance of coil 2 (line 33), resulting in line 35; this represents a linear, or substantially linear, output from the bridge. Moreover, the gap *D* may be decreased to zero, i.e. with the armature 32 in contact with the ends of the wires of the cores 1, 7, and, as will be seen from FIG. 5, this gives the maximum output and therefore enables the transducer to have the maximum sensitivity.

The transducer in accordance with the invention may be applied to the measurement of gap or displacement, for example, where the transducer casing is secured in a housing and the armature is a part movable relative to the housing; or to the measurement of vibration (i.e. fluctuating displacement). The transducer may be applied to the measurement of pressure by provision of an armature in the form of a diaphragm which deflects with pressure and cooperates with the working face; and also to the measurement of temperature, where the armature is in a fixed position relative to the working face but has a magnetic permeability which varies with temperature, and thus varies the inductance of the transducer.

It will be appreciated that, in the case for example of a displacement transducer, the inner and outer elements will tend to be subjected to the same temperature, and thus any changes in inductance or resistance are compensated by arranging the transducers in two arms of a bridge circuit as shown in FIG. 3.

Moreover, any changes in the magnetic permeability of the armature as a result of changing temperature will be compensated, since the change in one arm of the bridge will be offset by that in the other.

The working face 13 need not necessarily be a flat plane; for example, where the transducer is mounted in a bearing and the armature is formed by a rotating shaft carried in the bearing, the working face may lie in a curved plan corresponding to the curvature of the bearing surface.

Furthermore, instead of making the cores from ferromagnetic wires, solid cores of a ferromagnetic material may be used.

I claim:

1. An inductive transducer comprising a first ferromagnetic core, a first coil extending around said core, part of said first core being turned back round the outside of said first coil,

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both ends of said first core terminating in a plane forming the working face of the transducer, a second ferromagnetic core disposed around the periphery of said first coil, a second coil extending around said second core, part of said second core being turned back round the outside of said second coil, both ends of said second core terminating at said working face, the spacing between the two ends of one of said cores being substantially greater than the spacing between the two ends of the wires of the other said core.

2. A transducer as claimed in claim 1, wherein said first and second cores each include a plurality of ferromagnetic wires having part of their length turned back round the outside of the first and second coils respectively.

3. A transducer as claimed in claim 1, including a screen of ferromagnetic material arranged between the two coil and core assemblies.

4. A transducer as claimed in claim 1, wherein the first coil is wound between two portions of insulating material surrounding the first core, and the second coil is wound between two portions of insulating material surrounding the second core.

5. A transducer as claimed in claim 2, wherein the first and second cores are formed from iron wires and the first and second coils are wound from copper wires.

6. A transducer as claimed in claim 1, wherein the second coil has approximately the same axial extent as the first coil and also has approximately the same number of turns as the first coil and wherein, in order to have the same total resistance as the first coil, said second coil is wound of a wire having a lower specific resistance than the wire forming the first coil.

7. A transducer as claimed in claim 1, having a substantially circular cross section to the axial direction of said cores and

wherein the radial spacing between the two ends of the first core is substantially greater than the radial spacing between the two ends of the second core.

8. A transducer as claimed in claim 7, wherein the first and second cores each include a plurality of ferromagnetic wires, and the folded back portion of the wires of said first and second cores are substantially equally spaced in a circumferential direction around the transducer.

9. A transducer as claimed in claim 1, wherein the coil and core assemblies are encapsulated in an insulating material, such as an epoxy resin.

10. A circuit arrangement including an inductive transducer as claimed in claim 1, wherein said first and second coils are connected to form the opposed arms of a bridge circuit, so that the effect of a change of inductance occurring in one of said coils is at least partially compensated by the effect of a change of inductance in the same sense occurring in the other of said coils, thereby producing a substantially linear output from the bridge.

11. An arrangement as claimed in claim 10, wherein said first and second coils are connected respectively in first and second arms of an AC bridge circuit, means for deriving an output from across one end of said first and second arms, means connecting the other end of said first and second arms together and to earth potential, and an AC input connected across the common point of the third and fourth arms of the bridge circuit and earth.

12. An arrangement as claimed in claim 11, in which the AC input is a high frequency carrier wave and the output of the bridge is fed through a synchronous detector and a filter to a recorder or an oscilloscope.

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