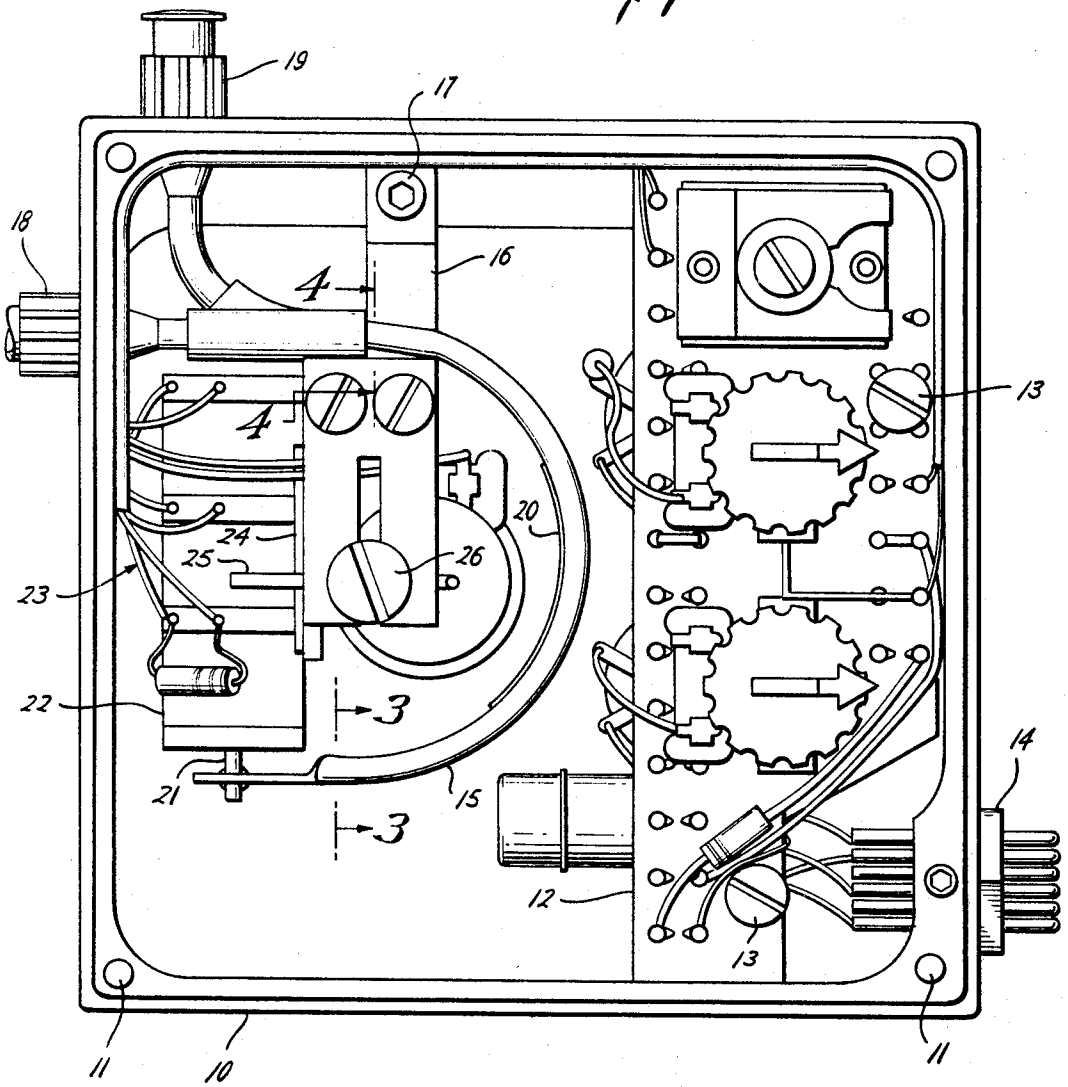
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MOTION RESPONSIVE DIFFERENTIAL TRANSFORMER TRANSDUCER SYSTEM

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Fig. 1



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Fig. 2

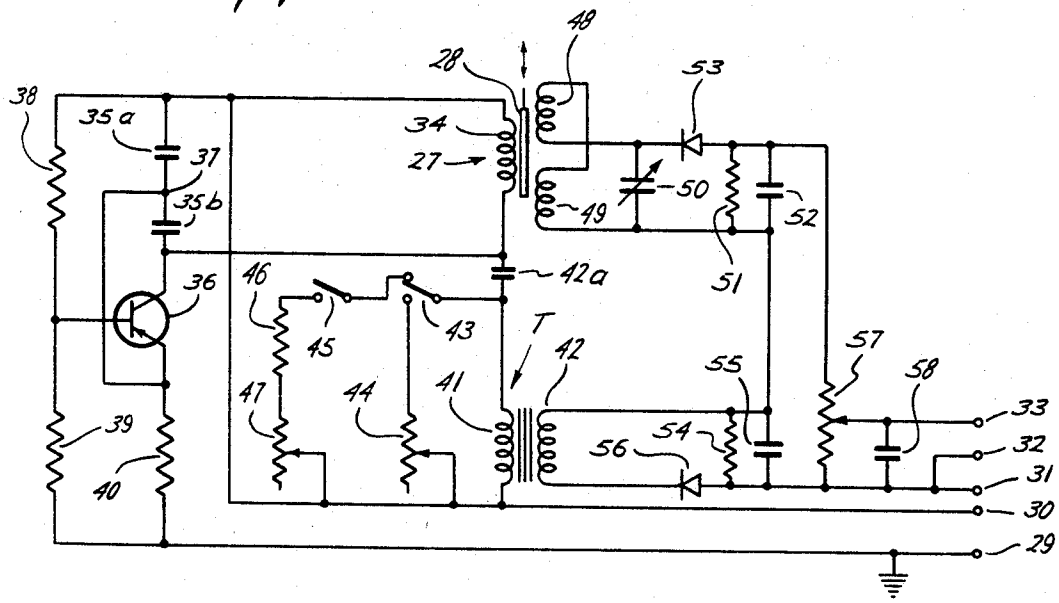
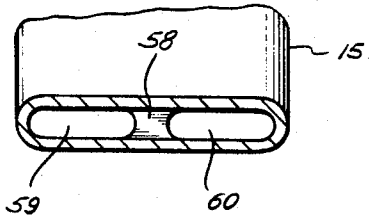


Fig. 3



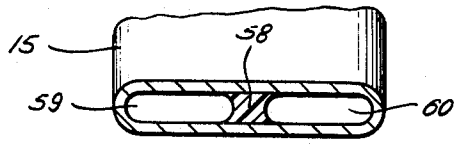


Fig. 4

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MOTION RESPONSIVE DIFFERENTIAL TRANSFORMER TRANSDUCER SYSTEM

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ABSTRACT OF THE DISCLOSURE

A transducer utilizing a differential transformer with a movable armature wherein the armature is displaced a sufficient distance to avoid entering its null or centered position, and includes a partitioned Bourdon tube which may be connected to the movable armature when a fluid pressure system is connected to the transducer.

The present invention relates generally to a transducer. More particularly, the present invention relates to a transducer for converting a movement into an electrical signal.

Many types of transducers have been used for converting motion to an electrical signal. In such devices, it is essential that the electrical output be proportional to the degree of movement from the initial position.

Differential transformers have been used to convert this motion into an electrical output. It has been noted, however, that such differential transformers have a null or central position for their armature and that when the armature passes through this central position, the relationship of the electrical output to the position of the armature is not maintained in the desired direction proportion.

Various devices have been used to translate a sensed value, such as pressure into a motion, which motion is used to move the armature in a differential transformer. Bourdon tubes have been used for this purpose; however, difficulty has been encountered with Bourdon tubes when used with liquid systems in that it is extremely difficut to completely eliminate all gas from a Bourdon tube.

Therefore, an object of the present invention is to provide a transducer converting a mechanical movement into an electrical output which is directly proportional to the position of a moving element throughout the whole range of movement of such element.

Another object of the present invention is to provide a pressure transducer including a differential transformer and a partitioned Bourdon tube connected to the armature of such transformer wherein the output of the transformer is direcly proportional to the positioning of the armature in such transformer by said Bourdon tube.

A further object of the present invention is to provide a differential transformer transducer in which the primary circuit of the transformer forms a part of the oscillation circuit to provide the energy for the differential transformer and also to provide the energy through a separate transformer for a direct current bucking voltage in the output circuit.

Another object of the present invention is to provide a differential transformer transducer in which the armature is offset from its central or null position and to provide a secondary bucking voltage from another transformer which is introduced in the output circuit of the differential transformer to balance the output resulting from the offset of the armature.

These and other objects of the present invention are hereinafter explained in relation to the drawings wherein:

FIGURE 1 is a view of the interior of a case containing a transducer constructed in accordance with the present invention.

FIGURE 2 is a schematic wiring diagram of the primary and secondary circuits of the differential transformer of the present invention.

FIGURE 3 is a sectional view of the Bourdon tube taken along lines 3—3 in FIGURE 1.

FIGURE 4 is another sectional view of the Bourdon tube taken along lines 4—4 in FIGURE 1.

Referring more in detail to the drawings, the device of the present invention illustrated in FIGURE 1 is shown to be contained within the case **10** which has the cover removed so that the individual components therein may readily be seen. The holes **11** are provided for fastening a cover (not shown) to the case. The circuit board **12** containing a substantial portion of circuitry necessary for the operation of the device of the present invention is secured to the case **10** by the screws **13**. The plug **14** provides the external connection for the electrical circuits and extends through the case connecting to the wiring from the circuit board **12**.

The device illustrated includes a Bourdon tube **15** which is mounted in a mounting member **16**. The mounting member is secured to the case **10** by the set screw **17**. Thus, the mounting member secures the one end of the Bourdon tube to which the lines **18** and **19** connect. The other end of the Bourdon tube **15** is free and substantially unrestricted in motion. A portion of the inner surface of the Bourdon tube is provided with the bimetallic member **20** secured thereto by cement or other suitable securing means to provide a temperature correction for the operation of the Bourdon tube **15**. The free end of the Bourdon tube **15** is suitably secured to an arm **21** which is connected to the armature (not shown) of the differential transformer **22**. Suitable leads **23** connect from the differential transformer **22** to the circuit board **12**. The rod **24** is positioned adjacent the exterior of the differential transformer **22** and is secured in place by cementing or other suitable means. The function of the rod **24** is to provide an external influence on the fields generated in the transformer. The rod **25** which is adjustably positioned by rotation of the slotted head of pin **26** provides a further adjustment to the fields created by the transformer **22**.

Referring to the wiring diagram of FIGURE 2, the differential transformer is designated generally with the number **27** and the movable armature with the number **28**. The secondary or output side of the transformer **27** includes two coils which are connected in series opposed circuit whereby when the armature **28** is positioned in its null or central position, the output of the secondary coils will be offset against each other.

The connections **29** through **33** into the circuit illustrated in FIGURE 2 include a ground connection **29**, the power connection **30** and the outlet connections **31**, **32** and **33**. The primary coil **34** of the transformer **27** forms a part of a simple transistor oscillator circuit which is used to excite the differential transformer **27**. The primary winding **34** has two series condensers **35***a* and **35***b* across it to form a tuned circuit in the collector circuit of the transistor **36**. The tap **37** between the condensers **35***a* and **35***b* is used to feed a signal to the emitter of the transistor **36**. The resistance **38** connects from one end of the primary **34** to the base of the transistor **36**. Resistance **39** connects from the base of the transistor **36** to the ground connection. Resistance **40** connects from the emitter of the transistor **36** to ground. Potential in relation to ground is provided across connection **30** and ground **29**. Connection **30** extends to the upper side of the primary coil **34**. The lower side of the primary coil **34** is connected to the collector of the transistor **36**. The transformer T is provided with a primary coil **41** which induces a bucking voltage in the secondary coil **42** which is connected to the secondaries of the differential transformer **27**, as here-

inafter set forth. The primary coil **41** and capacitor **42***a* are in series and they are connected in parallel with the primary coil **34**. Two test circuits are positioned in parallel across the primary **41**. The first test circuit includes a switch **43** and the variable resistor **44**. The second test circuit includes the switch **45**, the resistor **46** and the variable resistor **47**. As can be seen, actuation of the switch **43** will connect the circuit through the variable resistor **44** across the primary coil **41**. Switches **43** and **45** should be spring loaded to remain in the position shown until actuated. When the switch **45** is actuated, it will connect the circuit through the switch **43**, the switch **45**, the resistor **46** and the variable resistor **47** and across the primary coil **41**. These circuits are used for calibration and will function to reduce the bucking voltage by a predetermined amount which corresponds to a known input signal. A reduction in the bucking voltage produces the same effect as an increase in the output of the secondary coil.

As shown in FIGURE 2, the secondary coils **48** and **49** are connected in series opposed circuitry and have tuning condenser **50** connected across the lower leads from the coils **48** and **49**. The diode **53** is positioned in the lower lead from the coil **48** to provide for rectifying the alternating current produced to a direct current. The resistor **51** and the condenser **52** are connected across the rectified output of transformer **27**. Diode **56** is connected in the lower lead from the secondary coil **42**. The secondary coil **42** of the bucking voltage circuit is provided with a resistor **54** and a capacitor **55** connected in parallel across the rectified output from secondary coil **42**. The upper lead of secondary coil **42** is connected to the lower lead from the secondary **49**. The variable resistor **57** is connected to the upper lead of condenser **52** and the lower lead of condenser **55** across the opposed rectified outputs from the transformers **27** and T. Capacitor **58** is positioned across the leads extending to connections **33** and **31**.

From the foregoing it may be seen that the output circuitry is divided into two portions: the differential transformer output portion and the bucking voltage portion. The secondaries of the differential output transformer are connected in series opposed configuration so that when the movable armature **28** is symmetrically placed within the differential transformer **27**, the output across the resonating condenser should be exactly zero. It has been found desirable to displace the movable armature **28** a sufficient distance whereby during all normal operations of the device of the present invention, the movable armature **28** will not pass through its normal zero or null region. By avoiding the movement of the armature through the null region, the following problems generally encountered in the differential transformer are overcome. In practice, a perfect zero or balance is difficult to achieve because of resistive and capacitive unbalance in the transformer. The voltage output will be nonlinear with respect to the movement of the armature in the null region unless perfect electrical balance is achieved. The rectifying diode is a nonlinear device through its initial region of conduction. Single diode detection will provide an identical output whether the armature is displaced towards one secondary coil or towards the other; i.e., nondirectional detection.

Therefore, it is essential in this circuit configuration to initially displace the armature towards one of the secondary windings so that there is an initial direct current voltage across the output lead resistor. Provided the mechanical displacement of the armature is confined so that it does not traverse through the null region, the output voltage will increase or decrease in proportion to armature movement, with this increase or decrease being linear with respect to extent and direction of movement. It is preferable to have a zero voltage output which will fluctuate positively or negatively depending on armature movement. In this circuit an additional transformer has its primary **41** connected to the oscillator, and the rectified secondary voltage from the coil **42** is connected in series with reverse polarity to the secondaries of the differential transformer **27** so that the voltage across the load resistor **54** exactly balances the direct current voltage from the differential transformer circuit. The combined output circuitry provides a zero voltage output at the resting position of the armature and a positive or negative voltage directly proportional to the extent and direction of movement of the armature. The armature movement is restricted within the linear range of the differential transformer **27** on the one side and the null output position on the other.

The initial insertion of the armature is determined from the application. For instance, if the armature were linked to a Bourdon tube and the transducer were required to have a pressure range of 0–600 millimeters of mercury, the armature could be initially set close to the null point and would travel exclusively between that point and the outer limit of transducer linearity. If the transducer were required to operate between plus or minus 300 millimeters of mercury, the armature could be set initially in the mid position of linearity and travel for positive pressures towards the outer limit of linearity and for negative pressures towards the null position.

The bucking voltage is derived from the oscillator circuit and this makes the zero output of the combined output circuit relatively independent of the supply voltage to the transistor circuit.

With reference to the design of the Bourdon tube **15**, as illustrated in FIGURES 1, 3 and 4, it should be noted that the tube normally will be hollow. In order to partition the Bourdon tube **15** whereby inlet and outlet connections may be made thereto for connection to the lines **18** and **19**, both ends of the tube are left open while the partition **58** is inserted by any suitable method or as hereinafter more fully explained. The partition **58** then divides the tube **15** into two passages **59** and **60**. When the partition **58** is completely installed within the Bourdon tube **15**, a portion thereof is cut out to provide a communication between passage **59** and passage **60** near the closed end of the Bourdon tube **15**. Thus, when the lines **18** and **19** are connected to the Bourdon tube **15** and the other end of the Bourdon tube is closed, the liquid in the system may be conducted through line **18** into passage **60** of the Bourdon tube **15**. The liquid will flow to the end of the Bourdon tube and around the cut-out end of the partition **58** into passage **59** and out through line **19**. In this way any liquid which is to be measured by the device of the present invention will completely fill all of the Bourdon tube. Thus, any inaccuracies which might result from having gas trapped within the closed end of the Bourdon tube are eliminated from the system.

As pressure of the liquid in the system being measured increases, the increase in pressure will cause the Bourdon tube **15** to attempt to straighten and will cause the closed end of the Bourdon tube, as seen in FIGURE 1, to move downwardly thereby displacing the armature in the differential transformer **22** downwardly to provide an electric output of the secondary circuits directly proportional to the pressure of the liquid.

As hereinbefore mentioned, the partitioning of the Bourdon tube may be accomplished in any suitable manner; however, it is suggested that it may be done as hereinafter described. A standard Bourdon tube to be used in such applications should be open at both ends. Two plastic tubular members each taking up approximately the areas of the passages **59** and **60**, as illustrated in FIGURES 3 and 4, should be passed lengthwise through the tube until the ends of the members extend from each end of the Bourdon tube. With the inserted members spaced apart throughout their length, a suitable cement or plastic, which, when set, will adhere to the Bourdon tube but will not adhere to the inserted tubes, is pumped through the space between the inserted tubes in the Bourdon tube. This plastic material is allowed to set and when set,

the inserted members are removed. The excess material is trimmed from the one end, as hereinbefore described, to provide the cross passage between passage **59** and passage **60** at the closed end of the Bourdon tube. The Bourdon tube is then closed at such end and the other end is provided with suitable connections into the passages **59** and **60**.

Thus, with the Bourdon tube partitioned as hereinbefore defined, inaccuracies which would result in a liquid pressure measuring system from having a compressible gas in the system are completely eliminated. The fluid passage through the Bourdon tube is continuous allowing a complete filling of the tube with the fluid in the system being measured. The travel of the tube at its closed end will not be affected if the material used for the partition is a relatively flexible material. With the partition in the Bourdon tube it has been found that movement of the closed end of the tube will be linearly proportional to the pressure applied to the interior of the tube. As used in the present application, such a Bourdon tube will actually position the armature of a differential transformer in a position in which the amount of displacement of the armature will be directly related to the pressure within the Bourdon tube.

From the foregoing it can be seen that the present invention provides an improved transducer having an electrical output directly proportional to the input to the device. The present invention further provides a pressure tranducer including a differential transformer and a partitioned Bourdon tube for use in measuring fluid pressures, and the electric output of such transducer is directly proportional to the pressure in the system being measured.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made within the scope of the appended claims without departing from the spirit of the invention.

What is claimed is:

1. A differential transformer transducer comprising:
a primary winding,
secondary windings connected in series opposed circuit,
an armature,
means moving said armature with respect to said windings,
a transistor,
two series condensers connected across said primary winding to form a tuned circuit in the collector circuit of said transistor,
means connecting the emitter of said transistor to a point between said two condensers,
means connecting the base of said transistor to a biasing potential,
means providing potential to said primary winding, and
output means connected to said secondary winding.

2. A pressure transducer comprising:
a differential transformer having a primary winding, secondary windings connected in series opposed circuit and a movable armature,
a Bourdon tube having a closed end and an open end, said tube being partitioned lengthwise,
a passageway through said partition at the closed end of said tube,
means connecting the open end of said tube to a fluid pressure system,
means connecting the closed end of said tube to said movable armature whereby said tube wil move said armature responsive to the fluid pressure in said system,
a source of electric potential connected to said transformer, and
an outlet connected to said circuit of said secondary windings whereby the potential of said outlet is a measure of the fluid pressure in said system.

3. A transducer comprising,
a differential transformer having a primary winding, secondary windings connected in series opposed circuit and a movable armature,
a second transformer having a primary winding and a secondary winding, and
an oscillating circuit connected to excite said primary windings of said differential transformer and said second transformer,
said movable armature being at all times offset in one direction from its null position within said differential transformer,
said secondary winding of said second transformer being connected in series with said circuit of said secondary windings of said differential transformer whereby the rectified voltage outputs are in series opposition and will be directly proportional to the position of said movable armature within said differential transformer.

4. A transducer according to claim **3** including:
a test circuit incluling a switch and a resistor across the primary of said second transformer whereby closing of said switch will change the voltage output in said circuit by a predetermined amount.

5. A transducer according to claim **4** wherein:
said resistor is a variable resistor whereby said valtage output in said circuit is varied in accordance with the effective resistance of said variable resistor.

6. A transducer according to claim **3** including:
a pair of test circuits positioned in parallel across the primary of said second transformer,
each of said test circuits including a switch and a resistor,
connection of one of said test circuits by the closing of its switch changing the voltage output in said circuit of the secondary windings by a predetermined amount and connection of the other of said test circuits by the closing of its switch changing the voltage output in said circuit of the secondary windings by a different amount.

7. A transducer comprising:
a differential transformer having a primary winding, secondary windings connected in series opposed circuit and a movable armature,
a second transformer having a primary winding and a secondary winding,
means energizing the primary windings of said transformers from a common source, and
means for moving said movable armature within said differential transformer,
said means moving said armature having an at-rest position offsetting said armature from its null position within said differential transformer,
said secondary winding of said second transformer being connected in series and with reverse polarity with said secondary windings circuit whereby the output of said combined secondary is zero when said moving means for said armature is in its at-rest position.

8. As a subcombination in a transducer having a movable means, a pressure responsive device, comprising:
a Bourdon tube having a closed end and an open end, and
means partitioning said tube lengthwise,
said partition means defining a passageway between opposite sides of said partition means at the closed end of said tube,
the open end of said tube being adapted to be connected to a fluid pressure system,
the closed end of said tube being adapted to be connected to the movable means of the transducer whereby said movable means is moved by the closed end of said tube responsive to fluid pressure in said tube.

9. A transducer comprising:
a differential transformer having a primary winding,

secondary windings connected in series opposed circuit and a movable armature,

a second transformer having a primary winding and a secondary winding, and

circuit means connected to excite said primary windings of said differential transformer and said second transformer,

said movable armature being at all times offset in one direction from its null position within said differential transformer,

said secondary winding of said second transformer being connected in series with said circuit of said secondary winding of said differential transformer whereby rectified voltage outputs are in series opposition and will be directly proportional to the position of said movable armature within said differential transformer.

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