July 19, 1966 A. T. HUBBARD 3,262,080

ELECTRICAL TRANSDUCER

Original Filed Dec. 21, 1961

FIG. 1.

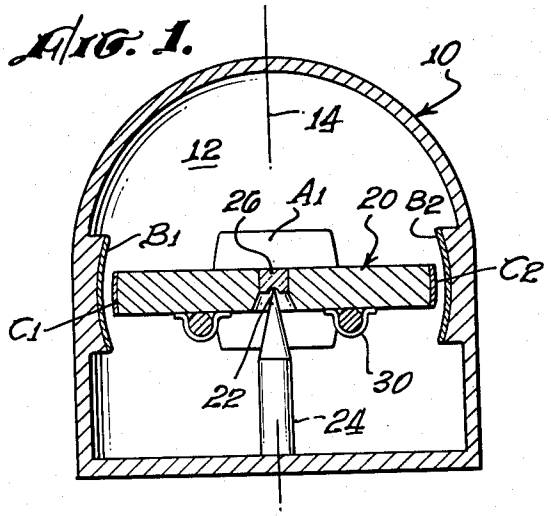
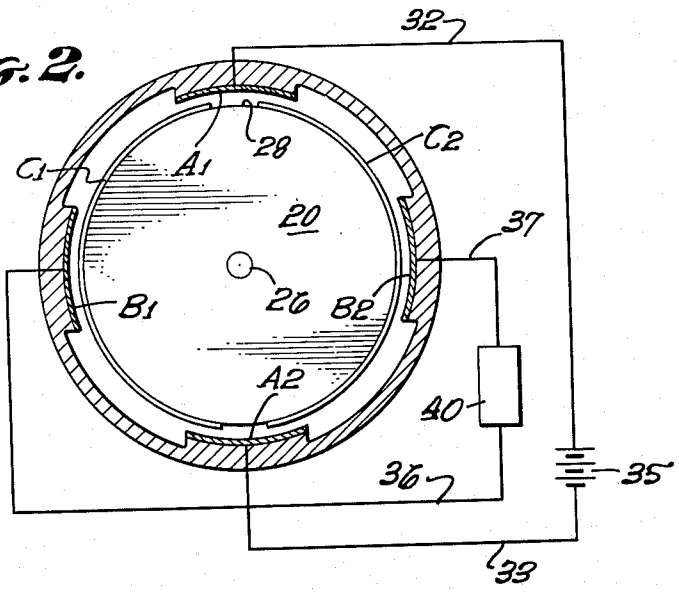


FIG. 2.



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ELECTRICAL TRANSDUCER

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Original application Dec. 21, 1961, Ser. No. 161,046, now Patent No. 3,162,832, dated Dec. 22, 1964. Divided and this application June 22, 1964, Ser. No. 377,026

4 Claims. (Cl. 338—13)

This is a division of application Serial No. 161,046, filed December 21, 1961, now Patent No. 3,162,832.

This invention has to do generally with electrical pickoff systems for instruments having a movable output element that is immersed in a liquid. The invention concerns more particularly such pickoff systems that develop the output signal from variations in electrical resistance through such a liquid between relatively movable electrodes.

Many pickoff systems of that general type have been proposed, but considerable difficulty has been experienced in making them fully reliable and stable in operation.

A primary object of the present invention is to provide more satisfactory specific liquids of limited electric conductivity for use in such pickoff systems together with improved electrode materials for use with such liquids.

A more particular object of the invention is to provide liquids and electrode materials which can withstand large voltages and conduct appreciable currents without developing gaseous products of electrolysis or otherwise changing irreversibly.

A further object of the invention is to provide such materials which are substantially free from polarization effect and therefore can be relied upon to give an accurate signal dependent only upon the relative positions of the electrodes.

In accordance with one aspect of the invention, those and other objectives are attained by utilizing as liquid a mixture comprising an alcohol and a homologous aldehyde. An organic acid or a salt of an organic acid is preferably added in relatively small quantity to stabilize the mixture and increase its conductivity. Such liquids are preferably used with electrodes formed or coated with a suitable material capable of catalyzing the oxidation of the alcohol and the reduction of the aldehyde. Platinum and palladium black are effective catalysts.

In accordance with a further aspect of the invention, to which the present application is more particularly directed, the electrodes are formed of metallic zinc and the surrounding liquid is a solution of a suitable zinc salt in a nonaqueous solvent. Zinc chloride and zinc acetate are particularly satisfactory salts for that purpose.

A full understanding of the invention, and of its further objects and advantages will be had from the following description of illustrative manners in which it may be carried out. The particulars of that description, and of the accompanying drawings which form a part of it, are intended only as illustration, and not as a limitation upon the scope of the invention, which is defined in the appended claims.

In the drawings:

FIG. 1 is an axial section representing an illustrative instrument in accordance with the invention; and

FIG. 2 is a transverse section.

FIGS. 1 and 2 represent schematically an illustrative instrument of the general type to which the invention pertains. That instrument comprises a magnetic compass, with a housing **10** of plastic or other non-conducting material enclosing a compass chamber **12** having a normally vertical axis **14**. A compass card of similar material is indicated schematically at **20**, pivotally mounted by the pivot pin **22** for limited universal rotation about

a point on axis **14**. As shown, pivot **22** is mounted on a post **24**, fixedly supported coaxially of chamber **12**, and engages a pivot bearing **26**, fixed at the center of the card. Compass card **20** typically comprises a structure of disk form, with circular periphery **28**. Two permanent magnets **30** are typically mounted in any suitable manner on the lower side of card **20**. Those magnets both maintain the card axis normally vertical and orient the compass card about that axis in accordance with the earth's magnetic field.

Compass chamber **12** is filled with a suitable liquid, to be more fully described, which typically damps the movement of the compass card, and may buoyantly support a major portion of its weight. That liquid also plays an important role in the pickoff system. That system is adapted to develop an electrical signal representing the rotary position of card **20** about chamber axis **14**, the signal being substantially independent of swinging movement of the card about a transverse axis.

The present illustrative electrode structure comprises two input electrodes A1 and A2, and two output electrodes B1 and B2, fixedly mounted in chamber **12** in angular spaced relation, with the output electrodes intermediate the input electrodes; and two mutually insulated arcuate card electrodes C1 and C2, mounted on the periphery of the compass card with working faces radially spaced from the working faces of the fixed electrodes. The upper adjacent ends of card electrodes C1 and C2 are angularly spaced from each other and overlap input electrode A1 by equal angles in zero position of the card, as illustrated. The lower adjacent ends of C1 and C2 similarly overlap input electrode A2. Output electrodes B1 and B2 directly oppose intermediate portions of the respective card electrodes. The two input electrodes are connected, as by the wires **32** and **33**, to opposite terminals of a suitable source of electrical excitation power, which may in general be either alternating or direct current. A direct current battery is illustratively shown at **35**. The two output electrodes are connected, as by the wires **36** and **37**, to a utilization device of any desired type, represented schematically at **40**. The output signal on lines **36** and **37** is of push-pull form. It is zero in zero position of the compass card, and increases substantially proportionally to the card deflection through an appreciable angle, the polarity or phase of the signal corresponding to the direction of deflection.

Utilization device **40** may, for example, comprise a repeater compass, or may comprise an autopilot system for a boat or the like, which utilizes the output signal from compass **10** to maintain a predetermined heading. Such devices may be of conventional type, and do not require further description for the present purpose. Many other usual structural features of a practical compass are omitted from the present drawings for clarity of illustration, such as an air chamber, for example, for accommodating temperature expansion of the liquid in compass chamber **12**. Certain aspects of the present illustrative pickoff system are more fully described and are claimed in the copending patent application, Serial No. 160,016, filed December 18, 1961, by William B. Hatch under the title "Electrical Pickoff System for Magnetic Compasses" and assigned to the same assignee as the present invention.

One particularly satisfactory conductive liquid in accordance with the present invention, for use in an instrument chamber such as **12**, comprises primarily a mixture of methanol (CH_3OH) and formaldehyde (HCHO), together with sufficient water to maintain the formaldehyde in solution. Such a mixture can be prepared conveniently by combining suitable quantities of methanol and formalin, which is a 40% aqueous solution of formaldehyde containing a small quantity of methanol as a pre-

servative. The proportions are not highly critical, but a satisfactory mixture is obtained with from about 10 to about 45 percent formalin by volume in methanol. The range of formalin concentrations between about 20 and about 30 percent gives a particularly good combination of conductivity and stability. It is usually desirable to include also a relatively small quantity of acetic acid, which may be added in the form of glacial acetic acid, for example. From about one to about four percent of acetic acid is normally satisfactory, depending primarily upon the degree to which it is desired to increase the electrical conductivity of the methanol-formalin solution. The acetic acid has the further advantage of preventing polymerization of the formaldehyde and is believed to aid the desired chemical reactions at the electrode surfaces. Further reduction of the resistivity of the solution may be obtained, if desired, by addition of up to about one percent of saturated aqueous solution of sodium acetate ($NaC_2H_3O_2$). That particular salt has the great advantage that electrolysis does not introduce any foreign anion.

With the described illustrative electrolyte, electrons entering the solution from the cathode are believed to be taken up by aldehyde molecules, enabling them to combine with hydrogen ions in the solution to form methanol. Thus the hydrogen ions are consumed in reduction of the aldehyde, and do not appear as hydrogen gas. At the anode methanol and hydroxide ions combine to form formaldehyde and water, with release of electrons to the anode. Hence oxygen does not appear as gas, but is consumed in oxidation of the methanol.

Both of the described reactions that are believed to take place at the electrode surfaces ordinarily proceed at an inadequate rate unless accelerated by a suitable catalyst. Presence of acetic acid in the solution appears to catalyze the cathode reaction and to aid in the elimination of any polarization that may develop at the cathode. A more complete and satisfactory type of catalyst can be provided directly at the electrode surface. A particularly satisfactory solid catalyst for that purpose is platinum black, which can be produced on the surface of a metallic platinum electrode in known manner. For example, a platinum electrode can be coated with platinum black by cathodic electrolysis in an aqueous solution containing about 3% platinic chloride and about 0.03% lead acetate, using a platinum anode. Electrodes of conductive materials other than platinum, such as graphite, for example, can also be coated with platinum black in the same manner. In preferred form of the present aspect of the invention, the working surfaces of all electrodes are coated with platinum black. Since this material catalyzes both anodic and cathodic reactions, the system can be used with either direct or alternating current excitation without special precautions; and when direct current is used the polarity may be selected arbitrarily, or changed frequently as desired.

It is sometimes advantageous for the conductive liquid to be substantially free of water. In particular, that makes possible the use of higher voltages and currents without development of gas at the electrodes. I have found that a mixture of ethanol and acetaldehyde in proportions from about 10 to about 50% acetaldehyde by volume is satisfactory for that purpose. It is usually helpful to add a smaller proportion of acetic acid which increases the conductivity and which may be added in the form of acetic anhydride. Formic acid is also effective for increasing the conductivity of this and the previously described composition. The electrode reactions are homologous to those already described. Palladium black is a satisfactory catalyst for both cathodic and anodic reactions in that liquid, and may be formed on a conductive surface by electrolysis of palladium in a manner generally analogous to the described formation of platinum black.

In accordance with a further aspect of the invention, the electrodes are all formed of metallic zinc and the surrounding fluid is a substantially non-aqueous solution of zinc chloride or zinc acetate. As in the previously described solution, a moderate proportion, typically from about 2% to 10%, of acetic anhydride can be added as desired to reduce the resistance of the solution. A lower alcohol, such as methanol or ethanol, for example, is a suitable solvent for such mixtures. A wide range of concentrations may be used, preferably exceeding about one percent to provide adequate conductivity, and well below saturation to avoid precipitation at low temperatures. As an example, 100 grams of zinc acetate in the form of $Zn(C_2H_3O_2)_2 \cdot 2H_2O$ per liter of methanol gives a satisfactory solution, having a resistivity of approximately 800 ohm cm. A solution of 100 grams $ZnCl_2$ in methanol is also satisfactory and has a considerably lower resistivity of approximately 250 ohm cm. Especially if these solutions are used with direct current excitation, the chamber should be sealed tightly against water vapor, since the zinc salts are quite hygroscopic. A particular advantage of employing zinc electrodes is that most structural metals are lower in the electromotive series and can be used in the chamber without danger of deterioration from electrolysis. Moreover, zinc is relatively inexpensive and can be worked and machined conveniently to any forms that may be required.

I claim:

1. Pickoff means for an instrument having an output element movable in a fluid tight chamber,

said pickoff means comprising a substantially nonaqueous solution of a lower alcohol and a salt selected from the group consisting of zinc chloride and zinc acetate,

mutually spaced cooperating electrode means mounted respectively on the element and in fixed relation to the chamber and exposed to the liquid and having working surfaces of metallic zinc,

and circuit means connected to said electrode means for deriving an electrical signal responsive to movement of said element.

2. Pickoff means as defined in claim 1, and wherein said solution includes also from about 2% to about 10% by volume of acetic anhydride.

3. Pickoff means as defined in claim 1, and wherein said solution comprises zinc acetate dissolved in methanol in a concentration of the order of 100 grams of

$$Zn(C_2H_3O_2)_2 \cdot 2H_2O$$

per liter of methanol.

4. Pickoff means as defined in claim 1, and wherein said solution comprises zinc chloride dissolved in methanol in a concentration of the order of 100 grams of $ZnCl_2$ per liter of methanol.

No references cited.

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