July 4, 1961 F. DOVE 2,991,438

INDUCTIVE PICK-OFF DEVICES

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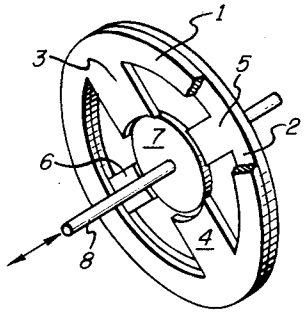


FIG.1.

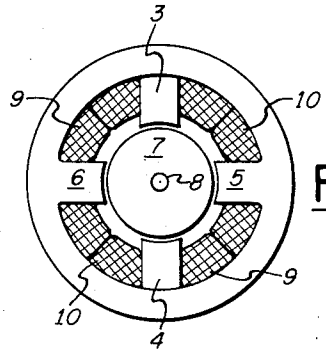


FIG.2.

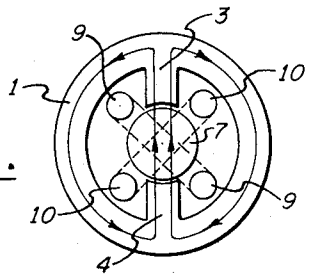


FIG.3.

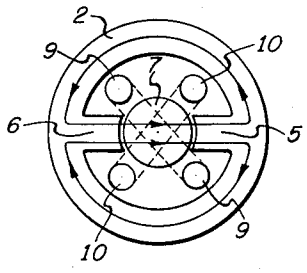


FIG.4.

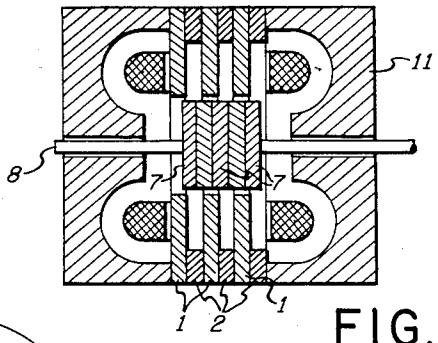


FIG.5.

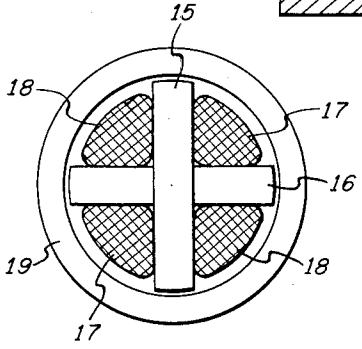


FIG.6.

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INDUCTIVE PICK-OFF DEVICES

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This invention relates to A.C. pick-off units and to pick-offs comprising a number of such units. For example, one use of a pick-off unit is to obtain an electrical signal which is a measure of the displacement of a movable member, for example displacement along an axis from a reference position. Thus a signal could be provided which is a measure of the displacement of a piston valve with respect to the valve's cylinder in a hydraulic control system, and the signal so obtained could be used as a feed-back signal.

According to one aspect of the present invention a pick-off unit includes two ferro-magnetic members, a ferro-magnetic armature completing by way of air gaps a magnetic circuit with each of the members, and mounted for movement from one position to another to decrease progressively the reluctance of one circuit and to increase progressively that of the other, means for exciting the circuits, and output coil means linking both circuits, the voltages generated in the output coil means due to the fluxes in the two circuits being in opposition.

It will be seen that movement of the armature changes the voltages generated in the coil means due to the two fluxes differentially so that the resultant voltage will show by its magnitude and sense the displacement of the armature from a reference position in which the two voltages are of equal magnitude.

By appropriate design of such a pick-off the output can be very nearly linearly related to the displacement of the armature, while the sensitivity can be high, the source impedance low, and the whole pick-off of quite small dimensions.

In a preferred form of the present invention a pick-off unit includes a pair of ferro-magnetic members displaced along an axis, each formed with two radial poles, the poles being angularly spaced around the axis with each pole on one member between two poles on the other, a ferromagnetic armature completing by way of the poles and air gaps a magnetic circuit with each of the members and mounted for axial movement to increase progressively the reluctance of one circuit and decrease progressively that of the other by movement in one direction, means for exciting the circuits, and output coil means linking both circuits, the voltages generated in the output coil means due to the fluxes in the two circuits being in opposition.

If, say, the armature is in line with the poles of one of the members, the reluctance of the circuit of the other member will be higher than if the armature is in line with the pole pieces on that member, since the air gap will be reduced in length as the armature is displaced from one position to the other. In general, of course, it will be arranged that in an intermediate position of the armature the voltages generated in the output coil means are of equal magnitude to give zero net output.

Preferably either or both of the output coil means and the exciting means comprises a single coil which may be of one or more turns linking both magnetic circuits. Thus where the members have circumferentially-spaced poles, the exciting coil may have one side extending parallel with the axis between two of the poles, and the opposite side extending parallel with the axis between the other two poles; conveniently then the output coil has

one side extending parallel with the axis between two poles of the same polarity, and the opposite side between the other two poles. This makes for a compact arrangement in which one of the four coil sides is in each of the four spaces between adjacent poles.

The invention includes a pick-off consisting of two or more units as defined stacked with their magnetic members held together and the armatures spaced apart by non-ferro-magnetic members, but arranged to be moved as one, but a single exciting coil and a single output coil being provided for all the units.

The invention can be carried into practice in various ways and three embodiments of the invention will now be described, by way of example, with reference to the accompanying drawing, in which:

FIGURE 1 is a perspective view of one embodiment of pick-off unit;

FIGURE 2 is an end view of the pick-off unit of FIGURE 1, the windings being shown in section;

FIGURE 3 shows the flow of flux at one instant of the exciting cycle when the armature is at one extremity of its movement;

FIGURE 4 shows the flow of flux at the same instant when the armature is at the other extremity;

FIGURE 5 is a sectional elevation of a pick-off comprising three units as shown in FIGURE 1 and one set of windings; and

FIGURE 6 is a transverse section of an alternative construction of a pick-off unit;

In FIGURE 1 is shown a stator comprising two laminations **1** and **2** of ferro-magnetic material of generally annular shape but each with two diagonally opposite inwardly directed salient poles. The laminations **1** and **2** are arranged coaxially with the salient poles **3**, **4** of lamination **1** disposed at 90° with respect to the salient poles **5**, **6** of lamination **2**. The ends of the poles provide a circular opening to accommodate an armature comprising a disc **7** of ferro-magnetic material and a rod **8** supported in a manner enabling it to move axially.

The slots in the stator between the salient poles contain a multi-turn exciting coil **9** and a similar output coil **10** as shown in FIGURE 2. The exciting coil **9** is in two halves, one half encircling poles **4** and **6**, and the other half encircling poles **3** and **5**. Similarly the output coil **10** is in two halves, one half encircling poles **5** and **4**, and the other half encircling poles **6** and **3**. However, for the purpose of understanding the invention the exciting coil **9** and the output coil **10** may each be considered as a single rectangular coil, the sides of the rectangle passing through diagonally opposite slots in the stator, and indeed they may be wound in this way.

If the armature disc **7** were displaced so that it lay substantially in the plane of lamination **1** and the flux was examined for a particular point in the cycle of an alternating voltage applied to the exciting coil **9** it would be seen (see the arrows in FIGURE 3) that the induced flux flows from pole **4** to pole **3** through disc **7** and in doing so links with the output coil **10** to produce an output voltage.

If now the armature disc were displaced to lie substantially in the plane of lamination **2** it would be seen (see the arrows in FIGURE 4) that, for the same point in the exciting voltage cycle, the flux now flows from pole **6** to pole **5** via disc **7** and in doing so links with output coil **10** but in the opposite sense, so that the output voltage is 180° out of phase with the output voltage produced when the armature disc was in the plane of lamination **1**. Thus the flux path via poles **3** and **4** and the flux path via poles **5** and **6** always link with the output coil **10** in opposite senses, the flux through each path being determined by the relative magnitudes of their re-

luctances, which reluctances are dependent upon the position of the armature disc **7**. Thus between the two extreme positions the net output voltage is zero when the armature disc **7** is in a central position and the flux paths have equal reluctances. Away from the central position the output voltage has a magnitude and phase depending upon the magnitude and direction of the displacement of the armature from the central position.

The pick-off may be used in conjunction with a phase-discriminating network to give a D.C. signal which is positive or negative according to the direction of displacement.

FIGURE 5 shows a pick-off comprising three pick-off units. Three pairs of laminations (one each of laminations **1** and **2** to each pair) are coaxially arranged and clamped together by duralumin end plates **11**, each end plate being drilled coaxially with the laminations to support the rod **8** so that it can move axially. The armature comprises three ferro-magnetic discs **7** which are spaced to the pitch of the pick-off units by spacers of non-magnetic material, e.g. copper. A single exciting coil and a single output coil are sufficient for this three-unit pick-off. The output voltage is three times greater than with the single unit described above.

In the pick-off shown in FIGURE 6, the stator comprises a pair of lamination strips **15** and **16** arranged in the form of a cross and windings **17** and **18** wound one above the other in diametrically opposite slots. The armature comprises a thin annular lamination **19** which is arranged coaxially with the stator and is supported for axial movement by means not shown. Movement of the lamination **19** varies the reluctances between the ends of the stator laminations to give a net output in the output coil as with the pick-off unit shown in FIGURES 1 to 4.

In the above described embodiments each lamination whether in the stator or the armature may in fact consist of several laminations secured together to provide the desired thickness. In a particular embodiment each stator lamination was formed by bending together four thinner laminations with an epoxy resin available under the registered Trade Mark "Araldite."

For the operation of a pick-off or pick-off unit as described, rotation of the armature is unnecessary and in some cases undesirable since any asymmetry in the construction may give errors during rotation. Therefore means such as a co-operating key and key-way may be provided on the rod **8** and its support to prevent such rotation. However, this is not necessary if the pick-off or pick-off unit is accurately constructed.

If friction is to be kept to a minimum, the rod **8** may be suspended by ligaments or concentrically corrugated diaphragms.

If the pitch of a cell, i.e. the thickness of the two laminations together is at least two and a half times the greatest displacement of the armature to be measured, the output voltage may be substantially linearly related to the displacement, except perhaps at the extreme positions.

The thickness of the magnetic armature laminations may be about one and a half times the thickness of the non-magnetic laminations.

In one pick-off a sensitivity of about 0–15 volts per thousandth of an inch displacement was achieved. The source impedance was about 110 ohms.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A pick-off unit, including two ferro-magnetic members displaced along an axis, each member having poles with each pole on one member between poles on the other member, a ferro-magnetic armature mounted in spaced relation with respect to said poles whereby to form equal air gaps between said armature and said poles when said armature is centrally disposed with respect to said poles, said armature completing by way of the poles and air gaps a magnetic circuit with each of the members, said armature being mounted for axial movement to increase progressively the reluctance of one circuit and decrease progressively that of the other by movement from a central position in one direction, means for exciting the circuits, and a single output coil linking both circuits, the voltages generated in the output coil means due to the fluxes in the two circuits being in opposition.

2. A pick-off unit, including a pair of ferro-magnetic members displaced along an axis, each formed with two radial poles, the poles being angularly spaced around the axis with each pole on one member between two poles on the other, a ferro-magnetic armature mounted in spaced relation with respect to said poles whereby to form equal air gaps between said armature and said poles when said armature is centrally disposed with respect to said poles, said armature completing by way of the poles and air gaps a magnetic circuit with each of the members, said armature being mounted for axial movement to increase progressively the reluctance of one circuit and decrease progressively that of the other by movement from a central position in one direction, means for exciting the circuits, and a single output coil linking both circuits, the voltages generated in the output coil means due to the fluxes in the two circuits being in opposition.

3. A pick-off unit as claimed in claim 2 in which in the central position of the armature the voltages generated in the output coil due to the fluxes in the two circuits are of equal magnitude.

4. A pick-off unit as claimed in claim 2 in which the exciting means comprises a single coil linking both circuits.

5. A pick-off unit as claimed in claim 2 in which the circuit constants of each circuit in one extreme position of the armature are the same as those of the other circuit in another extreme position.

6. A pick-off unit as claimed in claim 2 in which the exciting coil has one side extending parallel with the axis between two of the circumferentially spaced poles and the opposite side extending parallel with the axis between the other two of the poles.

7. A pick-off unit as claimed in claim 2 in which the output coil has one side extending parallel with the axis between two circumferentially spaced poles of the same polarity and the opposite side extending parallel with the axis between the other two of the poles.

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