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FRICTIONLESS CONTACT CONSTRUCTION FOR ELECTRICAL DEVICES

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2 Sheets-Sheet 1

FIG. 1

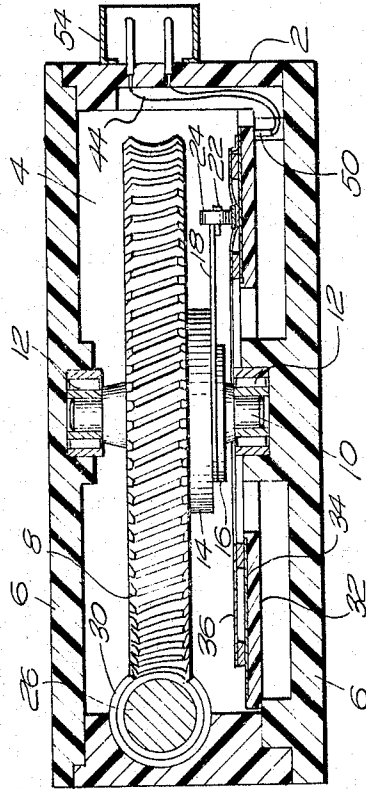
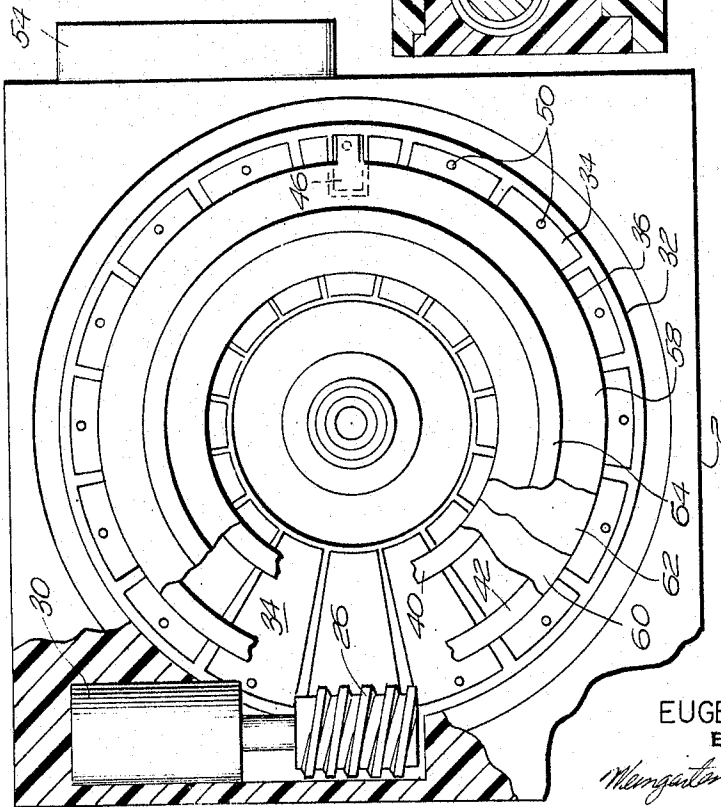


FIG. 2

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FRictionless CONTACT CONSTRUCTION FOR ELECTRICAL DEVICES

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This invention relates to electrical devices embodying low-noise contacts and more particularly to frictionless contacts for electrical components such as commutators and potentiometers.

The advent of telemetry and precision navigation systems for research space vehicles, satellites, missiles and aircraft has made critical the need for lower threshold noise levels in order to achieve reliable and unambiguous signal recognition and processing. For this reason considerable effort has been expended in eliminating contact noise in electronic components such as commutators and potentiometers, wherein signals are coupled or developed by way of movable contact members. Various inventions have been conceived for reducing contact noise, including new contact designs as well as new contact materials and shapes. The present invention is an improvement on the unique frictionless contact construction shown and described in U.S. Patent No. 2,862,089, issued Nov. 25, 1958 to William J. Mairs for Variable Resistor or Potentiometer, and in the copending application of James L. King, Ser. No. 131,573, now Patent No. 3,146,323, filed Aug. 15, 1961 for Commutator Switch. The patented constructions essentially involve a flexible laminated contact diaphragm made up of an outer insulating layer and an inner conductive layer. The flexible diaphragm is positioned over a conductive element of selected electrical resistance and a movable depressor member moves along its outer surface to successively depress successive portions of its inner conductive layer into contact with successive portions of the conductive element. Because no sliding or wearing action on the conductive element occurs as a result of the flexural motion of the laminated diaphragm, the patented construction provides smooth contacting action with exceptionally low contact noise. However, prior to the present invention it was quite difficult to fabricate contact diaphragms capable of yielding top performance over an extended life, e.g. 5-10 million operating cycles, under the conditions of use normally encountered in airborne systems. While occasionally laminated diaphragms could be constructed which would exhibit good life and exceptional reliability, it was not possible to repeat such success on a production basis with any kind of satisfactory yield. This inability to repeatedly produce contact diaphragms with any moderate degree of assurance that they would function satisfactorily over an extended life was due to a variety of factors, including cracking of the inner conductive layer due to the pressure required to flex the diaphragm or due to poor bonding or air pockets between the several layers. This latter difficulty occurred chiefly where the outer insulating layer was made of flexible sheet plastic such as Mylar (a polyethylene terephthalate product of E. I. du Pont de Nemours & Co., Inc., Wilmington, Delaware). Substitution of a glass fiber fabric impregnated with Teflon (du Pont trademark for tetrafluoroethylene resin) for the sheet plastic was not satisfactory because a greater bearing pressure was required to be exerted by the movable depressor member in order to achieve the same degree of flexure. This greater bearing pressure not only caused wear and cracking of the flexible contact member but also increased the force required to move the depressor. Other materials which were unsuccessful included beryllium copper. However, while these different

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diaphragm materials did not provide good life under the conditions encountered by airborne systems, they did demonstrate that this approach would yield little or no contact noise because of the fact that the mode of operation did not involve wiping one conductive element with another.

Accordingly the primary object of the present invention is to provide a new flexible laminated contact diaphragm which overcomes the deficiencies of the contact diaphragms previously employed in frictionless contact devices.

A more specific object of the present invention is to provide improved electrical devices such as commutators and potentiometers which embody flexible laminated contact diaphragms capable of a useful life of 25-50 million cycles before deteriorating to any material degree.

Laminated contact diaphragms according to the present invention utilize a cobalt-base metal alloy as a high strength fatigue-resistant resilient backing for a firmly bonded conductive metal layer. Specific details of the laminate construction are provided by the following specification which is to be considered together with the accompanying drawings wherein:

FIG. 1 is a cross-sectional view of one form of commutator embodying the present invention;

FIG. 2 is a fragmentary plan sectional view of the same commutator with certain parts broken away;

FIG. 3 is a greatly enlarged view of a section of the switch assembly and the depressor member of the commutator of FIG. 1;

FIG. 4 is an exploded perspective view of an encapsulated resistor assembly embodying the present invention; and

FIG. 5 is a sectional view of a potentiometer embodying the resistor unit of FIG. 4.

Turning now to FIGS. 1 and 2, there is shown one form of commutator embodying an encapsulated switch assembly with a flexible contact diaphragm constructed according to the present invention. The illustrated commutator comprises a rectangular housing 2 formed from a single block and having a large chamber 4 formed by a through bore and closed off by top and bottom cover plates 6. The chamber 4 accommodates an encapsulated switch assembly and a depressor assembly.

The depressor assembly comprises a worm gear 8 which is mounted on a stub shaft 10 whose ends are supported by bearings 12 mounted in the cover plates. Worm gear 8 has hub section 14 on one side to which an annular plate 16 is removably secured by means of screws (not shown). Captivated between hub section 14 and plate 16 is a flat leaf spring member 18. The captivated portion of the leaf spring is bifurcated or has a hole (not shown) to receive shaft 10. Attached to the free end of the leaf spring is a small diameter shaft 22 that carries a rotatable depressor at its free end in the form of a miniature precision ball bearing 24. The latter presses against the diaphragm of the encapsulated switch assembly.

The worm gear 8 is driven by a worm 26 that is mounted in a bore in the housing which is substantially tangent to and intersects with the bore defining chamber 4. The worm is mounted on the end of the output shaft of a miniature electric motor 30 disposed in the same bore. While not shown, it is to be understood that the motor is sealed off from the atmosphere by a cover plate and power is coupled to it by way of a suitable connector mounted in the housing wall.

The switch assembly comprises (a) a rigid annular non-conductive switch disc 32 having a plurality of spaced conductive switch segments 34 on its upper face, (b) a flexural annular diaphragm contact identified generally at 36 overlying the switch disc, (c) a pair of concentric

stand-off rings 40 and 42 disposed between the switch disc and the contact diaphragm and functioning to support the latter in spaced relation to the switch segments, and (d) a plurality of leads 44. The switch disc additionally includes a conductive segment 46 located between two adjacent segments 34. A tab 48 formed on the outer edge of the contact diaphragm is soldered to segment 46. The switch disc also carries a plurality of terminal pins 50 for the segments 34 and 46. These terminal pins are connected by leads 44 to separate terminals of a multi-pin connector 54 mounted in a cavity in the side-wall of the housing. In practice the diaphragm functions as a common output pole for the switch segments, with exterior connections for input and output made by the multi-pin connector 54.

The contact diaphragm comprises an outer layer 58 formed of a selected cobalt-base alloy having predetermined physical characteristics and an inner layer 60 of gold film. These two layers are secured together by an intermediate layer 62 of metal which can bond readily to both the alloy and gold. Gold is used as the contact surface because it has very low noise characteristics compared to such other materials as silver and rhodium. In the preferred embodiment the intermediate layer is nickel. Also forming part of the contact diaphragm is a concentric depressor tracking ring 64 for electrical insulation and reduction of mechanical wear. This ring is adhesively secured to the upper side of the alloy layer.

The cobalt-based alloy should be hard, have spring properties which are retained to a satisfactory degree over a wide temperature range, e.g. from sub-zero temperatures up to at least about 500° F., and high fatigue endurance limit. Preferably the alloy is "Havar," a non-magnetic age hardening cobalt-base alloy which is a product of Hamilton Watch Co., Precision Metals Division, Lancaster, Pennsylvania. Havar has the following nominal composition by weight:

	Percent
Cobalt	42.5
Nickel	13.0
Chromium	20.0
Molybdenum	2.0
Carbon	0.20
Beryllium	0.04
Manganese	1.60
Tungsten	2.80
Iron	Balance

Its physical properties are as follows:

	As rolled	Aged
Tensile Strength, p.s.i.	260,000-290,000	330,000-360,000
Yield Strength, p.s.i. (0.20% set)	200,000-220,000	260,000-280,000
Rockwell Hardness (C)	48-50	56-60

Its physical constants are as follows:

Specific gravity, 9/cc.	8.3
Coefficient linear expansion, ° C. (0°-50° C.)	0.0000125
Electrical resistance (ohms/cir. mil. ft.) ..	550
Thermoelasticity, ° C. (0°-65° C.)	51×10 ⁻⁵
Modulus of Elasticity, p.s.i. (×10 ⁶)	29.5-30.2

Of course, the alloy need not have precisely the foregoing composition; other cobalt-based alloys having similar compositions and properties also may be used. Thus, for example, it is possible to use the cobalt-based alloy "Elgiloy" sold by the Elgin National Watch Co. This alloy has characteristics quite similar to "Havar" and comprises the following nominal composition by weight:

	Percent
Cobalt	40
Nickel	15
Chromium	20
Molybdenum	7
Magnesium	2
Beryllium	1.04
Carbon	A trace
Iron	Balance
10 1 Optional.	

Elgiloy is not quite as satisfactory as Havar, but will yield a life of at least 25 million cycles when employed as herein described. The essential thing is that the alloy be a cobalt-based alloy essentially comprising cobalt, nickel, chromium and iron so that it will have substantially the same physical characteristics as the alloy compositions set forth above.

In practice it is preferred that the alloy layer have a thickness in the order of .008" while the nickel and gold layers each have a thickness in the order of .000050". However, the alloy layer may have a thickness of .005"-.010". The contact laminate is formed by plating the nickel onto the alloy and then electroplating the gold onto the nickel. It is essential that the nickel and gold layers be applied free of stress. It is also essential that the layers of the contact laminate be free of depressions, wrinkles and scratches.

The depressor tracking ring 64 is formed of a flexible insulating material attached to the upper surface of the alloy layer by means of a suitable cement. The depressor tracking ring may be in the form of a narrow band or may be wider. In fact it may even fully cover the alloy layer. Preferably it is made of Mylar and has a thickness in the order of .005". The composition of the tracking ring is not critical and other kinds of insulating material of acceptable physical properties also are useable. The thickness of the tracking ring is critical and should be kept within .003"-.008". The kind of cement used to secure the tracking ring to the alloy layer is not critical except that it must be strong and not deteriorate under the conditions of use. In practice Pliobond cement (made by Goodyear Tire & Rubber Co. of Akron, Ohio) is used for this purpose. Preferably the same cement or kind of cement is used to secure the standoff rings 40 and 42 to the rigid switch disc and also to the contact diaphragm. While in the illustrated embodiment the contact diaphragm is cemented directly to the standoff rings, it is also appreciated that it may have a much larger outside diameter and such smaller inside diameter than the outer and inner standoff rings respectively so as to permit it to be cemented directly to the switch disc. The standoff rings may be formed of a variety of material, such as kraft paper or a plastic material such as Mylar. The thickness of standoff rings 40 and 42 should be sufficient to keep the diaphragm out of engagement with the switch segments on the switch disc, except where it is depressed by the depressor member without exceptional pressure. In practice the standoff rings are made with a thickness of approximately .002 inch.

The switch disc may be made of a suitable insulating material such as fiberglass-filled epoxy resin or fiber-filled phenolic resin. The switch segments may vary in number and their shape or size is not critical to the present invention. Preferably the switch segments comprise a bottom layer of copper, an intermediate layer of nickel, and a top layer of gold. This yields a low noise gold-to-gold contact. Preferably the segments are inlaid so as not to project above the surface of the switch disc by more than about .00005 inch.

A commutator designed as just described is characterized by great reliability with uniformly low contact resistance and virtually noiseless operation as well as small weight and size. Its long life is believed due in great measure to its hardness as rolled, since materials

with greater or less hardness have proven unsatisfactory. Moreover, the switch contacts are encapsulated so as to be completely sealed off against foreign matter and humidity. The contact diaphragm is sufficiently resilient to make contact with the switch segments under relatively light depressor pressure, yet its flexural motion is conservatively within the elastic limit of the cobalt-base alloy to assure a useful life averaging 25 to 50 million cycles. An important feature is that the construction of the mechanical elements of the commutator can vary considerably without departing from the principles of construction of the contact diaphragm. Thus, for example, it is not necessary for the commutator to include an internal drive. Instead the commutator could be designed so that the worm is driven by an external drive. It is also appreciated that the commutator need not have a worm gear drive. Instead, for example, the depressor member could be mounted on a rotatable shaft which is coaxial with the switch segment and which is driven by an internal or external drive. The commutator also may be adapted for ganging with other commutators or with other electromechanical units such as potentiometers.

FIGS. 4 and 5 show how the present invention is applicable to potentiometers as well as commutators. In FIG. 5 the potentiometer comprises a cylindrical housing 70 having a cover 72 at one end and an integral end wall 74 at the other end. A shaft 78 is rotatably mounted in the end wall and is provided with a flange 80 to which is affixed a depressor assembly. The latter comprises a spring metal arm 82 and a small shaft 86 attached at one end to arm 82 and provided on its free end with a miniature roller bearing 88. The latter engages the contact diaphragm of an encapsulated resistor unit constructed in accordance with the teachings of the aforementioned Patent 2,862,089 issued to William J. Mairs but modified to embody the present invention. Described briefly, the resistor unit comprises a contact diaphragm 90 and a rigid insulating base 92 upon which there has been deposited an annular strip of selected metal film 94 to serve as a resistance element. Suitable contacts or terminations 96 and 98 are provided for making electrical connections to the ends of the resistance element. Another contact 100 is provided on the peripheral portion of the base for cooperation with a projecting tab 102 formed on the outer edge of the contact diaphragm 90. These contacts are connected by suitable flexible leads (not shown) to the terminals of a three-pin connector 104 mounted on the casing. The connector facilitates use of the unit as a potentiometer or as a variable resistor. Two annular insulating standoff rings 105 and 106 are mounted on the base and function to support the contact diaphragm in spaced relation to the base. The contact diaphragm 90 has the same construction as the one illustrated in FIGS. 1 to 3, comprising an alloy top layer 108, a nickel intermediate layer 110, and a gold inner layer 112, with a concentric Mylar tracking ring 114 mounted on the alloy layer. Its tab 102 is secured to the contact element 100 provided on the peripheral portion of the base. It is believed to be obvious that as the shaft 78 is rotated, the depressor rolls along the Mylar strip and presses successive portions of the gold layer into contact with successive portions of the resistance element. The actual area of the gold layer which engages the resistance element at any one time is relatively small and substantially infinite resolution is attainable with the illustrated construction.

As in the commutator construction, the potentiometer of FIGS. 4 and 5 is characterized by exceptionally long diaphragm life. Due to the absence of an abrasive wiping contact with the resistance element, the device is free of the deleterious effects of wear heretofore encountered in conventional variable resistor and potentiometer designs. Additionally the resistive film is sealed off so as not to be effected by humidity, fumes, dust or other foreign matter.

While in the two illustrated embodiments the depressor member moves in a circular path, it is to be appreciated that the invention is applicable equally well to devices where the depressor member moves in a non-circular path, e.g., a rectilinear path. Thus, for example, it could be embodied in the translatable potentiometer with frictionless contact shown in FIGS. 1 and 2 of Mairs Patent 2,862,089. It is believed equally obvious that the resistive element of the same translatable potentiometer could be replaced by a series of conductive switch segments, each provided with its own terminal connection.

Obviously, many modifications and variations of the present invention are possible in the light of the foregoing teaching. It is to be understood, therefore, that the invention is not limited in its application to the details of construction and arrangement of parts specifically described or illustrated, and that within the scope of the appended claims it may be practiced otherwise than as specifically described or illustrated.

What is claimed is:

1. An electrical device comprising a housing and an encapsulated contact assembly mounted within said housing, said contact assembly comprising (1) a rigid disc having at least one conductive element on one face thereof and (2) a flexural contact diaphragm overlying and secured to said disc in parallel spaced relation to said conductive element, said contact diaphragm comprising an outer layer of a resilient hard cobalt-base alloy, an intermediate layer of nickel, and an inner layer of gold, with a tracking band of flexible insulating material overlying the outer surface of said alloy, said alloy essentially comprising cobalt, nickel, chromium, molybdenum and iron with cobalt present in the greatest relative amount, a first terminal connected to said contact diaphragm, an additional terminal connected to said conductive element, and depressor means mounted within said housing in engagement with said tracking band, said depressor means pressing a portion of said diaphragm into contact with said at least one conductive element, and means for moving said depressor means along said tracking band whereby to cause successive portions of said gold layer to engage successive portions of said at least one conductive element.

2. A device as defined by claim 1 wherein said conductive element comprises an electrical resistance with a terminal at each end.

3. A device as defined by claim 1 wherein said disc has a plurality of spaced conductive elements disposed in a circular array.

4. An electrical device comprising a stiff sheet of insulating material having on one surface thereof an electrically conductive element and a contact diaphragm positioned parallel to and spaced from said conductive element, said contact diaphragm comprising a gold-surfaced flexible hard cobalt-base alloy, said alloy having a tensile strength of approximately 330,000 p.s.i., a yield strength of approximately 260,000 p.s.i., and a modulus of elasticity equal to approximately 29.5×10^6 p.s.i., said contact diaphragm secured to said sheet of insulating material with the gold surface thereof facing but spaced from said conductive element.

5. A device as defined by claim 4 wherein said alloy essentially comprises cobalt, chromium, nickel and iron.

6. A device as defined by claim 4 further including a flexible layer of non-conductive material on the surface of said diaphragm facing away from said conductive element.

7. A device as defined by claim 4 wherein said alloy comprises approximately 40-42.5% cobalt, approximately 13-15% nickel, approximately 20% chromium, approximately 2-7% molybdenum, and approximately 7.86-15.96% iron.

8. An electrical device comprising a stiff sheet of insulating material having on one surface thereof a conductive element, and a resilient diaphragm of laminated construction positioned parallel to and overlying said conduc-

tive element, said diaphragm comprising an inner layer of gold facing said conductive element and an outer layer of a flexible hard cobalt-base alloy to which said gold layer is securely bonded, said cobalt-base alloy comprising approximately 40% cobalt together with smaller amounts of chromium, nickel and iron, said alloy having a substantially greater thickness than said gold layer, the edges of said sheet and said diaphragm secured together with said gold layer supported in spaced relation to said conductive element, said diaphragm being sufficiently resilient to be flexed into and out of contact with said conductive element within the elastic limit of said alloy.

9. A switch comprising a stiff sheet of insulating material having on one surface thereof a conductive element, a diaphragm of laminated construction positioned parallel to and spaced from said conductive element, said sheet and the edges of said diaphragm sealed together, said diaphragm comprising an inner layer of gold and an outer layer of a hard high fatigue resistant spring alloy essentially comprising cobalt, nickel, chromium and iron, and a band of a flexible insulating material cemented to the outer surface of said alloy layer.

10. A switch as defined by claim 9 wherein said band is made of Mylar.

11. An electrical device as defined by claim 1 wherein said gold and nickel layers each have a thickness in the

order of .000050 inch and said layer of alloy has a thickness in the order of .008 inch.

12. A switch as defined by claim 9 wherein said layer of gold has a thickness in the order of .000050 inch and said alloy has a thickness of about .005 inch to about .010 inch.

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