May 3, 1966 TAKESHI SASAMOTO ETAL 3,249,728

REED SWITCH HAVING MULTI-LAYER DIFFUSED CONTACTS

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Fig. 1.

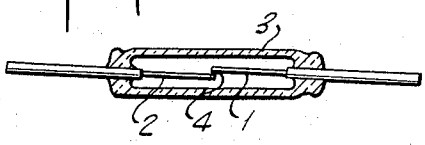


Fig. 2.

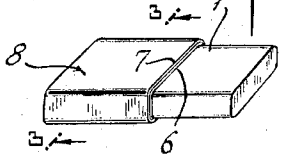


Fig. 3.

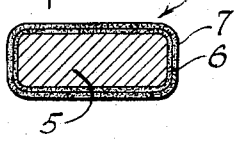
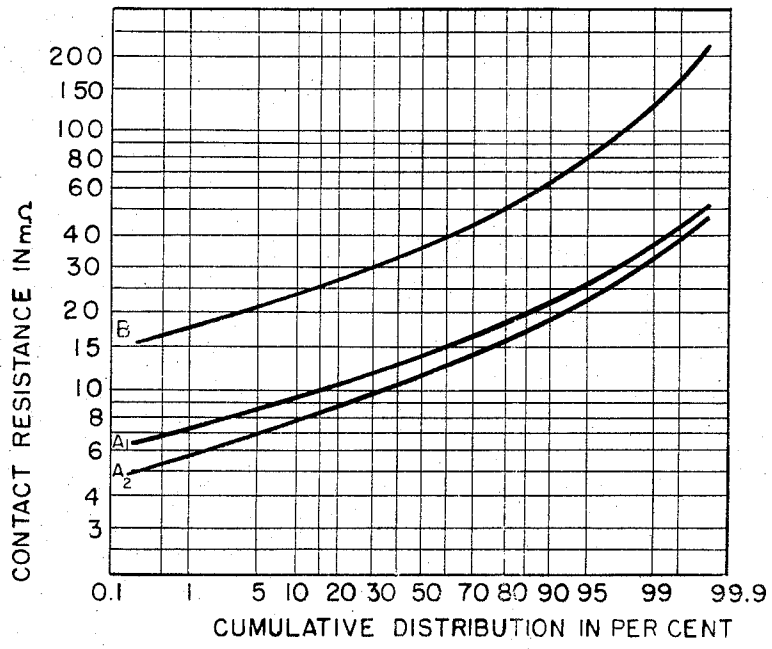


Fig. 4.



A_1 MULTI LAYER DIFFUSED CONTACTS (NICKEL-GOLD)
A_2 MULTI LAYER DIFFUSED CONTACTS (COPPER-GOLD)
B GOLD DIFFUSED CONTACTS
(MEASURED AT 0.9mV 1000 C/S)

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Fig. 5.

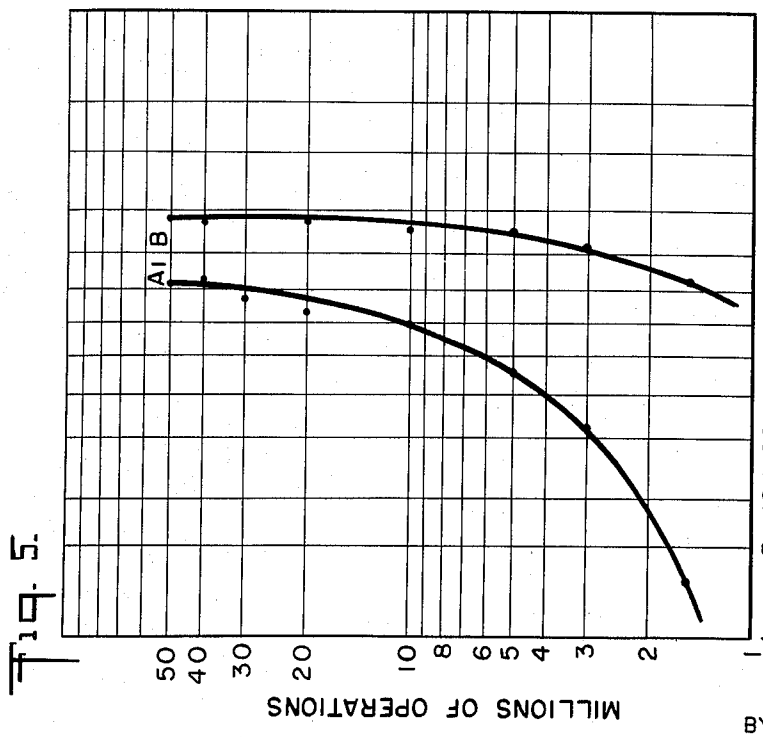
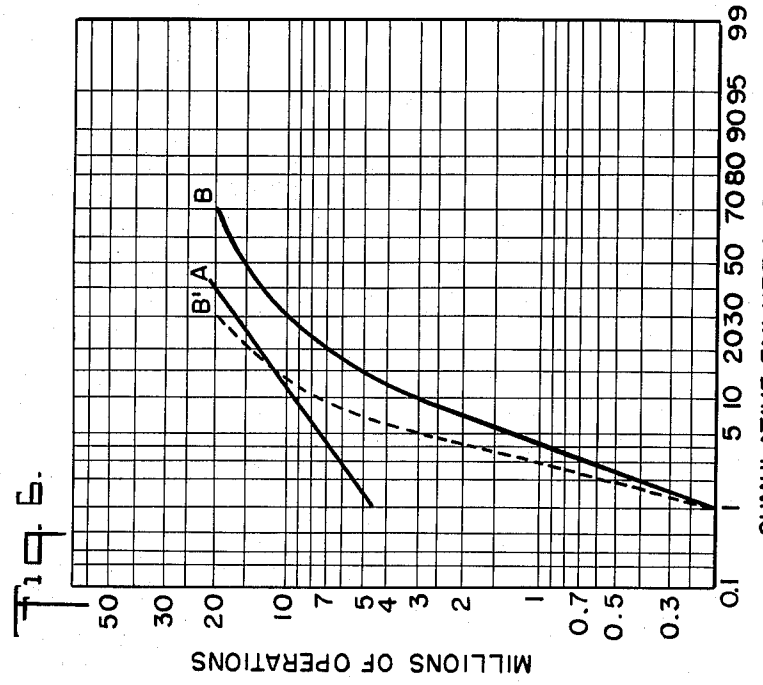


Fig. 6.



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REED SWITCH HAVING MULTI-LAYER DIFFUSED CONTACTS

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This invention relates to improvements in the construction of the contacts of sealed metallic contact devices and is particularly useful with reed switches of the type in which reeds of ferromagnetic material are caused to operate by means of an externally applied magnetic field so that an electrical circuit may be opened and closed as desired.

Reed switches are generally hermetically sealed in an envelope so as to be unaffected by detrimental atmospheric influences such as gases, small dirt particles, etc. Nevertheless, problems are presented in providing proper switch operation since the reeds serve dual functions as a magnetic path and as switching contacts.

One of these problems is to provide reed members having a sufficient magnetic attraction despite their small size, which requires that they be made of an alloy with high saturation flux density.

Another problem is that when the envelope is made of glass, the thermal expansion coefficients of the reeds and glass must be approximately the same. For the above reasons, an alloy composed of nickel and iron as the principal constituents has generally been used. This alloy, however, has the drawbacks of making the contact resistance of reed switches rather high because the specific resistance of the alloy itself is inherently high and further, the alloy oxidizes rather quickly.

In order to obviate these disadvantages, a method has for some time been known by which the contacts of the reeds are plated with a noble metal such as gold and then subjected to a diffusion process in a reducing atmosphere such as for example, hydrogen, so that the iron and nickel of which the reed core is composed may diffuse into the gold layer. However the iron which diffuses into the newly created layer composed of gold, nickel, and iron is easily oxidized in a brief time period prior to the sealing process to form an oxide film with high contact resistance over the layer. Even after the reeds have been sealed in an envelope, iron combines with residual oxygen within the envelope on account of local heating accompanied by mechanical collision occurring in the operation of the reed switch, with the result that both the contact surfaces of the reeds and the powders produced by mechanical wear are oxidized to bring about an increase in the contact resistance.

Another difficulty with the use of iron is its inherent quality of easily establishing fine bridging in switching a current from "on" to "off." This tendency holds true for iron present in proximity to the surface of the above-mentioned newly created layer of gold, nickel, and iron. As a result, with reed switches using gold diffusion contacts, fine bridging may occur in a comparatively early state of operation, and will culminate in the inability of the contacts to separate.

A still further problem with reed switches using gold-diffusion contacts as described above results from the formation of metallic oxide powders due to chemical combination of the powder with residual oxygen within the envelope when current is switched from "on" to "off" and vice versa. These powders tend to accumulate and adhere to the contact surface, resulting in imperfect contact, under circuit conditions in which the possibility of occurrence of glow discharge is small.

Accordingly, it is an object of this invention to provide a sealed metallic contact device having a longer useful switching life than similar prior art devices.

It is another object of the invention to provide a reed switch having a lower contact resistance during its life span than such switches of known construction.

All of the objects, features and advantages of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawing, in which

FIG. 1 shows a longitudinal cross sectional view of a reed switch in accordance with an embodiment of the invention;

FIG. 2 shows an enlarged view of the free end portion of the reed in the embodiment of FIG. 1;

FIG. 3 illustrates a lateral cross sectional view of the free end portion of the reed before it is subjected to the diffusion process; and

FIGS. 4, 5 and 6 are graphs illustrating the superior advantages realized by reason of the invention.

In accordance with the invention a switch of improved characteristics is achieved by providing contacts made by means of the gold diffusion type process referred to above but in which the amount of iron in the gold outer layer is substantially reduced. This is accomplished by providing an intermediate layer of suitable metal between the reed core material and the gold layer.

Referring now to FIG. 1 there is shown a longitudinal cross section of a make-type reed switch, wherein the numerals **1** and **2** denote reeds made of nickel-iron alloy, and numeral **3** denotes an envelope of suitable material such as glass or ceramic. The reeds **1** and **2** are separated at their free ends by a small gap **4**, with the result that they attract each other to make contact to close an electrical circuit when a magnetic field is applied in the axial direction of the reeds. Upon removal of the magnetic field, the reeds **1** and **2** are released to the normal position by the spring restoring force to interrupt the electrical circuit.

FIG. 2 shows an enlarged view of the free end of the reed **1**, the end portion **8** being the part to be gold plated and serving as one of the reed contacts. FIG. 3 shows a cross section of the portion **8**, taken along the line **3—3** of FIG. 2, and illustrates the construction of this portion prior to the diffusion process. In FIG. 3, the numeral **5** denotes the inner core preferably of nickel-iron alloy. In accordance with the invention, an intermediate layer **6** is provided over the core **5**; this layer **6** is composed of a metal or metals other than iron and gold such as, for example, nickel, cobalt, manganese, or copper, etc., that can diffuse with gold. The numeral **7** denotes a gold layer.

After the end portion of each reed which forms the contact portion such as shown in FIG. 3 has been plated, the reeds **1** and **2** are subjected to the diffusion process at a suitable high temperature.

As one example, we have achieved good results when the intermediate layer **6** is made of nickel or copper and has a thickness of approximately 0.002 mm., which may be nearly equal that of the outer gold layer **7**, however, this ratio is not critical and various thicknesses and ratios may be employed. Diffusion is achieved by heating to a temperature of 850° C. for 15 minutes in a non-inert atmosphere such as hydrogen. However, it should be observed that the temperature and heating times are not critical; the temperature may be in the range of 650° to 950° C. and the time may vary from 1 minute to 120 minutes, depending upon the temperature. The temperature, however, must not exceed the melting point of

any of the materials forming the core 5 and layers 6 and 7. This heating process causes gold to diffuse into the intermediate layer 6 and reed core 5, further causing the intermediate layer metal to diffuse into the gold layer 7, and resulting in a reduction of the proportion of iron on the contact surfaces compared with the prior art process. This results in considerable reduction of the mechanical wear and electrical erosion experienced with prior reeds during contact opening and closure, and also prevents contact sticking due to the adhesion that would otherwise occur between the gold layers on each reed 1 and 2.

As evidence of the advantages of the invention, we shall compare conventional reed switches in which the contact surfaces are plated only with gold, with make-type reed switches constructed in accordance with the invention and having the contact portion of each reed made of a nickel-iron alloy plated with nickel or cooper and then with gold. The switches under consideration might have typical operating characteristics as follows: a contact pressure of 5 grams, a restoring force of 5 grams, a normally open gap of 0.1 mm., and a natural reed frequency of 2.4 kc./s.

Curves A_1 and A_2 in FIG. 4 show cumulative distribution curves for the contact resistances of such reed switches made in accordance with the invention, while curve B shows the contact resistances for conventional reed switches of the same size using gold-diffusion contact surfaces. The improved contact resistance shown by the curves A_1 and A_2 and measured in milli-ohms is apparent from the graph. The contact resistance was measured at a voltage of 0.9 mv. at 1000 c.p.s. in each case.

FIG. 5 shows the life characteristics of the contact resistances for both the conventional and the improved reed switches when purely mechanical switching operations are performed, i.e. without current flowing. In FIG. 5, curve A_1 represents the embodiment of this invention and curve B represents the conventional reed switch using gold diffusion contacts. The standard of failure is based upon the contact resistance exceeding the value of 200 milli-ohms. It will be noted that the results of the embodiment utilizing copper as the intermediate layer 6 were so excellent that no failure occurred and the curve A_2 is therefore not shown.

FIG. 6 shows a comparison of life characteristics of the above-mentioned reed switches when an inductive load is switched on and off repeatedly without using a spark quenching circuit. In conducting this experiment, failure of contact separation due to contact bridging was regarded as a fault. Curve A shows a case in which an inductive load capable of storing energy of 20 millijoules is switched on and off by a reed switch constructed according to the invention. Curve B shows a case in which the same circuit is switched on and off by a conventional reed switch with the well known gold diffusion contacts. Curve B' shows a case in which an inductive load capable of storing energy of 2 millijoules is switched on and off by a conventional reed switch. Where an inductive load capable of storing energy of 2 millijoules is switched on and off repeatedly by a reed switch constructed in accordance with the invention, it was found that no faults occurred until approximately 20 million operations.

The multi-layer diffused contact copper-gold construction is superior for very low current working conditions, while the multi-layer diffused contact nickel-gold construction shows superiority when used under rated current working conditions.

From the foregoing it will be appreciated that the teaching of the invention makes possible switches of greatly

superior characteristics such as lower contact resistance, lower failure rate, less contact sticking and greater reliability.

Although this invention has been described above in connection with the make-type reed switch as a specific embodiment of the invention, it will be understood that the invention is also applicable to the transfer type sealed metallic contact device which is commonly referred to as the transfer type reed switch, and other switches as well.

While the foregoing description sets forth the principles of the invention in connection with specific apparatus, it is to be understood that the description is made only by way of example and not as a limitation of the scope of the invention as set forth in the objects thereof and in the accompanying claims.

What is claimed is:

1. A reed type switch having at least one reed actuable in response to a magnetic field, and having a contact formed thereon, comprising
an elongated member made of an iron-nickel alloy,
an intermediate layer of nickel on one end of said member,
and a layer of gold on said intermediate layer,
a portion of metal from said intermediate layer being diffused into said gold layer, and a portion of metal from said gold layer being diffused into said intermediate layer and into said member, whereby said contact is provided on said one end of said member, said contact having the improved characteristics of improved reliability, longer life and lower contact resistance.

2. A reed type switch having at least one reed actuable in response to a magnetic field, and having a contact formed thereon, comprising
an elongated member made of an iron-nickel alloy,
an intermediate layer of copper on one end of said member,
and a layer of gold on said intermediate layer,
a portion of metal from said intermediate layer being diffused into said gold layer, and a portion of metal from said gold layer being diffused into said intermediate layer and into said member, whereby said contact is provided on said one end of said member, said contact having the improved characteristics of improved reliability, longer life and lower contact resistance.

3. A reed type switch having at least one reed actuable in response to a magnetic field, and having a contact formed thereon, comprising
an elongated member made of an iron-nickel alloy,
an intermediate layer on one end of said member, said layer being of a metal selected from the group consisting of nickel, copper, cobalt and manganese,
and a layer of gold on said intermediate layer,
a portion of the metal from said intermediate layer being diffused into said gold layer, and a portion of the metal from said gold layer being diffused into said intermediate layer and into said member, whereby said contact is provided on said one end of said member.

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