

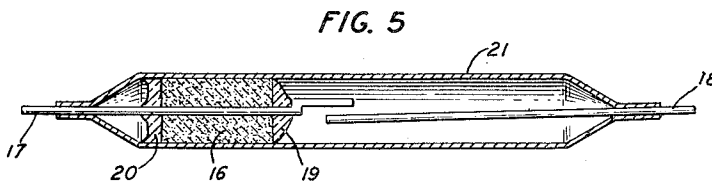
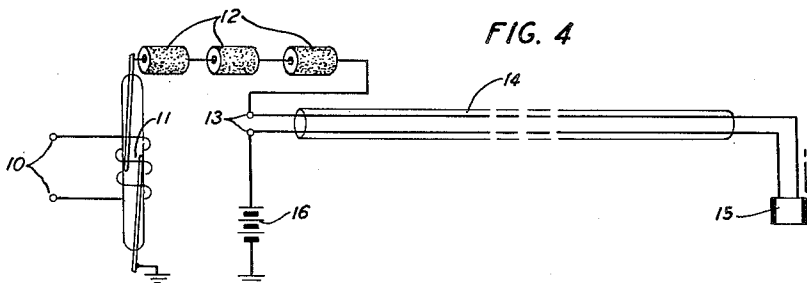
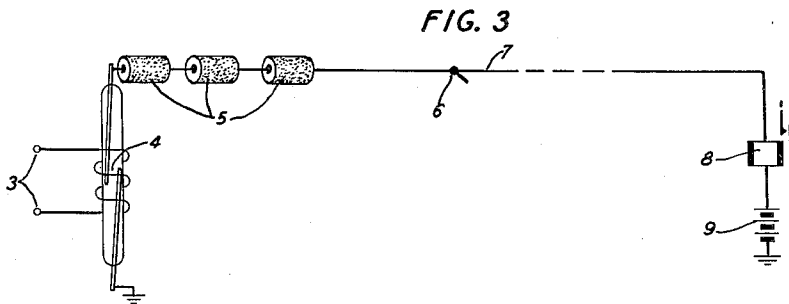
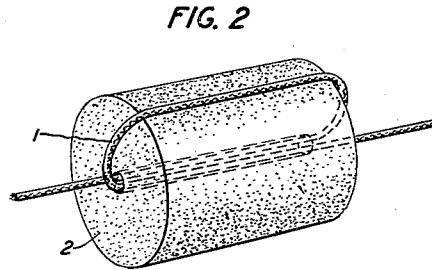
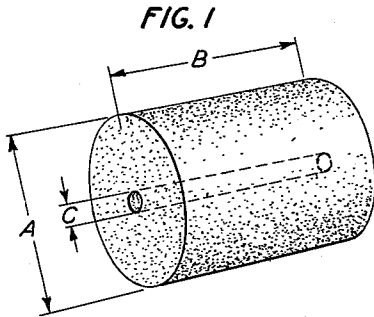
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CONTACT PROTECTION ARRANGEMENT

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CONTACT PROTECTION ARRANGEMENT

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This invention relates to electrical make-and-break contacts, and more particularly to circuit arrangements for protecting said contacts from deleterious erosion caused by electrical arcing and/or energy dissipation during contact operations.

Contacts of the type which make and break energized electrical circuits develop a number of faults in service. For example, the repeated making and breaking of a circuit with current flowing therethrough often results in irregular arcing attended with transfer of contact metal from one cooperating contact to the other, with consequent pitting of one contact surface and building up of projections on the other. Also, the continued transfer of material from one contact to another often brings about a localization of the contact area with a resultant increase in current density at such restricted area of contact. This localization condition renders more pronounced the deteriorating action of the contact arcing. The transfer of material under these circumstances sometimes becomes so great that a sufficient amount thereof is built up on one of the make-and-break contacts to prevent the breaking of the circuit by separation of the contacts.

In addition, arcing often forms thin films of oxides or other compounds on contact faces thereby increasing the contact resistance which in turn tends to aggravate the arc creating conditions until finally the contacts burn away or will otherwise no longer pass current.

In order to alleviate the effects of arcing there exist in the prior art several circuit arrangements for minimizing contact erosion. Various resistor-capacitor networks have been used; however, in addition to being space consuming and difficult to install in existing plant, such arrangements have usually proved to be ineffective on both the make-and-break contact operations. One such arrangement, which has been widely used, wherein a series resistor-capacitor subcombination shunted a contact to be protected proved to be very effective on the break contact operation but tended to be harmful on the make contact operation. For complete contact protection this circuit arrangement was preferably employed with additional components which were to minimize contact arcing on the make contact operation.

As the amplitude of the transients occurring at contacts opening and closing circuits are influenced to a great extent by both the inductance and the distributed capacitance to ground of the conductors connected to the contacts, and as a large part of the energy in these transients

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is at frequencies about 500,000 cycles per second, it is obvious that modification of the high frequency or characteristic impedance of the conductors connecting a contact to its associated circuit will affect the arcing created and the energy dissipated at the contacts during make-and-break operations.

It has long been known in the art that arcing occurring during contact operations can be minimized or eliminated by connecting an inductor which has a high impedance at contact arc transient frequencies in series with the contact energizing circuit at a point close to said contact. In early experiments high frequency choke coils were used to eliminate arcing. For example, in 1918 it was found that the radio frequency interference radiated by a make-and-break spark ignition system on a submarine chaser could be greatly reduced by inserting an iron core single layer choke coil between the spark points and the wiring connected thereto. In 1935 the usefulness of such choke coils was demonstrated in reducing erosion of telephone relay contacts.

In 1938 a choke coil was suggested which comprised a permalloy plated wire wound on a permalloy shell of a relay structure and in the discussions of this device, the usefulness of permalloy plated or iron wire as conductors in lieu of the usual copper was debated. It was believed that the self-conductance of permalloy plated wire or solid iron wire was sufficient to prevent arcing without the inclusion of a lumped inductor close to the contacts. Oscillographic observations showed little difference between the voltage transients of contacts connected to their load by iron or permalloy plated wire as compared to copper wire but revealed that the current surges were much weaker than in the case of contacts connected by copper wire. Life tests indicated that differences in surge characteristics gave corresponding differences in erosion and it was conclusively shown that the erosion was distinctly less on the contacts connected by iron and permalloy plated wire than on those connected by copper. During these tests it was noticed that the contacts connected by copper wire could easily be distinguished from those connected by iron or permalloy plated wire as the arc was distinctly brighter with the former.

Attempts were made to eliminate the difficulties and expense encountered in using the aforementioned iron and/or permalloy plated wire in contact circuit arrangements. Iron wire introduced an objectionably high direct-current resistance in many of the relay circuits connected

therewith and also produced small iron particles due to filing at the time of making connection therewith which lodged in contact air-gaps. Whereas, although permalloy coated copper had a satisfactory resistance value, the plating of copper with permalloy was expensive and also the permalloy coating was difficult to make soldered connections to. Furthermore, a length of several feet of iron or permalloy plated wire was required to effectively limit contact arcing. To overcome these difficulties the usual connecting copper conductors were passed through permalloy beads or pieces of permalloy tubing adjacent the make-and-break contacts so that they provided a lumped series inductance near said contacts. However, it was found that the eddy currents generated at the high contact arcing transient frequencies created a magnetic skin effect on the surface of the beads or tubing. As a consequence, the magnetic lines of flux in the beads created by the transients tended to concentrate on the surface of the bead or the tubing and the inner portion of the bead or tubing was ineffectual for the purpose of adding to the series inductive effect necessary to minimize arcing or energy dissipation at the contacts. Therefore, beads or tubing of ordinary magnetic materials of a practical or convenient size are not effective as contact protection due to their small value of inductance.

Accordingly, it is an object and feature of this invention to minimize contact erosion by employing one or more bead type inductors having sufficient inductance at the transient frequencies present in contact arcs to minimize or eliminate contact arcing.

Another object and feature of this invention is a bead-type inductor which is small in size, economical in cost, and which presents sufficient inductance and effective alternating-current resistance in a transient make-and-break contact circuit to minimize or eliminate arcing on both the make-and-break contact operations without increasing the direct-current resistance of said circuit.

To fulfill the objects of this invention a recently discovered magnetic material called ferrite in the form of a bead or the like surrounds a conductor connecting to a contact of a relay or switch at or near the point where the conductor connects to the contact. This arrangement performs the function of imparting to the surrounded portion of conductor a high impedance at high frequencies so as to slow down and dissipate the discharge of the distributed conductor capacitance on a make contact operation, and during a break contact operation the bead inserts a dissipative resistance component to the contact connecting conductor so that a large part of the stored energy of the conductor which causes arcing is dissipated in the loading bead instead of the contact.

The use of ferrite beads for contact protection is advantageous because this material possesses the properties of high permeability and high electrical resistivity which provides a high effective inductance without lamination at frequencies in excess of a megacycle. A solid slug of the usual magnetic materials has little effective inductance at these frequencies because of the shielding or skin effect caused by induced eddy currents; however, the electrical resistivity of ferrites, ferrites being ceramic in nature, prevents the generation of high amplitude eddy currents at high frequencies by presenting a high resistance path to the flow of these currents and at the same time main-

taining a permeability of about 50 to 2500 depending upon the ferrite used at a flux density of 10 gaussess.

A ferrite has the general formula MF_2O_4 where M represents a bivalent metal. When this bivalent metal is iron, nickel, manganese, magnesium, cadmium or zinc, a cubic lattice structure is formed. With the exception of cadmium and zinc ferrites, ferrites of these metals are ferromagnetic. The resistivity values range from 10^{-2} ohm-centimeter to 10^6 ohm-centimeter compared to a value of 55×10^{-6} ohm-centimeter for 4-79 molybdenum permalloy, for example. Only one of them, ferrous ferrite ($FeFe_2O_4$), or magnetite, has had any appreciable use as a magnetic core material in the prior art. This is a well-known ferrite which occurs in nature. In its natural and synthetic form, it has been applied commercially in radio frequency cores for a number of years.

It is characteristic of the cubic ferrites discussed above that they can be made to form solid solutions with each other in all proportions. In the recent developments in this field, certain of these solid solutions have been found to exhibit strong ferromagnetic properties, with permeabilities many times higher and hysteresis losses much lower than those of the constituent ferrites. This is brought about through proper choice and proportions of components and control of heat treatment to produce the conditions necessary for high permeability and low hysteresis loss; namely, low crystal anisotropy and low magnetostriction. These characteristics are obtained in part through the use of a non-magnetic zinc ferrite component to reduce the Curie point; i. e., the temperature at which the material loses its ferromagnetism. In this way the elevated portion of the initial permeability temperature curve which occurs just below the Curie point can be brought within a useful temperature range.

Although the conditions for highest permeability and lower hysteresis loss do not correspond to conditions for highest resistivity, the resistivity of the high permeability ferrite is still of the order of 100 ohm-centimeters or higher than that of metals by a factor of 10^8 .

The process most used for producing ferrites consists of mixing the various finely powdered oxides in proper proportions, pressing them into the desired shape and heat treating at approximately 1200° C. in an appropriate atmosphere. Since a linear shrinkage of around 15 per cent occurs during heat treatment, uniform density throughout the unfired parts is necessary in order to prevent the development of mechanical imperfections during firing. This tends to restrict the forming of parts from dry or semidry powders to simple shapes, such as rings, discs, bars, cylinders and shallow cups. It is possible that other pressing or extruding processes can be developed for these in more complicated form. However, for the purpose of making lumped inductors for contact protection simple geometrical shapes are quite adequate.

Because of the high resistivity of ferrites, conventional eddy current losses are usually low so that hysteresis losses and high frequency residual losses become controlling. Residual loss is not fully understood but in one recent explanation it is attributed to an electronic resonance. It is a function of frequency, the loss increasing much more rapidly above a certain critical frequency. This rapid increase in loss is accompanied also by a decrease in permeability. For

purposes of analysis the critical frequency has been taken as that at which the permeability drops to 80 per cent of the direct-current or low frequency permeability. The low frequency permeability and critical frequency bear an inverse relationship. Therefore, for an application over a given frequency range, a ferrite material having an appropriate low frequency permeability should be chosen. For example, manganese-zinc ferrite with a permeability of 1200 is useful up to about 3 megacycles while nickel-zinc ferrite with a permeability of 50 has usable properties up to 40 megacycles. The ferrite compounds which have been found to be best suited for contact protection are the manganese-zinc series, the nickel-zinc series, copper-zinc series and magnesium-zinc series. For further information concerning ferrites, reference is herein made to publications by J. L. Snoek, *Non-metallic Materials for High Frequencies*, Philips Technical Review, December 1946, volume 8, No. 12, pages 353 to 384; *New Developments in Magnetic Materials*, 1947, Elsevier Publishing Company.

In order that the invention may be clearly understood and readily carried into effect it will now be fully described with reference to the accompanying drawing, in which:

Fig. 1 shows a ferrite bead having a cylindrical shape with a hole therethrough for passing a single straight wire through said bead;

Fig. 2 shows an alternate arrangement in which a ferrite bead is used in conjunction with a single turn coil of wire so that a greater inductance value may be obtained for improved contact protection;

Fig. 3 shows an embodiment wherein ferrite beads protect switch contacts from arcs generated by the distributed capacitance of the connecting conductors during operation of said switch;

Fig. 4 shows how ferrite beads are applied to switch contacts whose circuit connection includes a twisted or cable pair of conductors; and

Fig. 5 shows ferrite bead protection directly incorporated into a switch.

The drawing of Fig. 1 shows a cylindrical-shaped ferrite bead with a hole therethrough which can be used for contact protection by stringing said bead on a conductor connected to the contact to be protected at a position preferably as close as possible to the contact. As the air surrounding a particular conductor has a permeability less than that of the ferrite material, it is obvious that the center hole should have the smallest diameter C which will allow the connecting conductor to pass therethrough. As ferrite is essentially a ceramic this hole may be made during the method steps preceding the firing of the ceramic constituents. The bead can be made into many other geometrical shapes; however, simple geometrical shapes are easier to form than complex shapes. It is believed that the cylindrical bead shape represents the best form of ferrite for contact protection. The material is black, hard and brittle, resembling a ceramic in physical properties.

The inductance in henries of a single conductor provided with a cylindrical bead is expressed by the equation

$$\frac{4\mu B(A-B)}{10^9 \times (A+C)}$$

where A represents the diameter of the cylinder in centimeters, B represents the length of the

cylinder in centimeters, C the diameter of the hole passing therethrough in centimeters, and μ the permeability of the particular ferrite used.

In Fig. 2 a single turn of wire 1, which is preferably insulated, is passed through the hole of a ferrite bead 2. Such an arrangement increases the inductance imparted to a conductor passed therethrough by an amount which varies directly as the square of the number of loops used, provided that the bead is not otherwise magnetically saturated. In certain contact applications where space is at a premium it is desirable to increase the series inductance by having a plurality of turns on the bead in lieu of using more than a fixed number of beads. In many applications the cost of additional turns may exceed the cost of an equivalent number of simple beads on one straight conductor.

The property of these beads which is of particular importance in the make contact operation is the combination of high magnetic permeability and high electrical resistivity which permits a high effective inductance to be obtained without lamination at frequencies in excess of 500,000 cycles. Whereas, other types of lump inductance arrangements used in the prior art were unsatisfactory in that the amplitude of the eddy currents generated at arc transient frequencies produced a magnetic skin effect which prevented the center portion of the lumped inductor material from adding to the inductance necessary to minimize arcing. Ordinary laminations are still much too thick while dust cores have sufficient permeability to be effective.

On the break contact operation these beads are effective because they impart to the contact connecting conductor an effective alternating-current resistance component which varies from approximately 0 to 50 ohms per bead for a frequency range of 0 to 3 megacycles with a bead having a diameter A of approximately 0.3 inch, and a length B of approximately 0.5 inch. The resistance component is reflected into the conductor connected to the contact and effectively dissipates a portion of the electrical energy stored in the distributed capacitance and inductance of the conductors connected thereto. This reflected resistance component also minimizes contact arcing on the make contact operation but to a lesser extent as the inductive component predominates the resistive component in value.

In Fig. 3 three ferrite beads are shown in a circuit arrangement for protecting a set of switch contacts, which, for the purpose of illustration, are enclosed in a dry reed switch vessel, said contacts controlling a relay winding energizing circuit. Ferrite beads 5 are strung on a conductor 7 which is preferably insulated. The beads should be placed as close as possible to contacts 4 so a minimum of unprotected wiring will be attached to the contacts. When a potential is applied to terminals 3 the magnetic electrodes of the switch approach one another until the contacts 4 are made. During the make contact operation the electrical energy stored in the distributed components of the circuit will attempt to discharge through the switch thereby creating an arc at contacts 4 if sufficient series impedance does not prevent such an occurrence. The resistive and inductive components of the ferrite beads 5 delay and dissipate the transient energy thereby preventing arcing at the contacts during the make contact operation. When the steady state condition is reached, battery 9 supplies energizing current to relay winding 8. During

the steady state current conditions the ferrite beads do not increase the direct-current resistance of conductor 7. Consequently, the circuit is not affected at these times by the beads.

On the break contact operation the ferrite beads introduce a high frequency resistance component into conductor 7 of sufficient value to delay and dissipate part of the electrical energy which was stored in the magnetic and electrical fields associated with conductor 7 and which would otherwise be dissipated in the contact with corresponding contact arcing.

Experimental tests wherein make-and-break contacts of a particular type were connected to a battery supply over a 12-foot cable revealed a lengthening of the life of said contacts of 100 to 350 per cent when four small ferrite beads were employed adjacent each of said contacts.

The use of ferrite beads as contact protection is especially advantageous whenever a plurality of conductors are multipled to a particular set of contacts as the value of the distributed circuit components which cause troublesome arcing increases. For example, if a plurality of conductors were connected to multiple strap 6 the increased capacitance to ground would aggravate the arcing at contacts 4 as the number of conductors connected thereto is increased.

In Fig. 4 ferrite bead protection is incorporated in a circuit arrangement for energizing a relay winding wherein part of the circuit connection includes a cable 14 connected to terminals 13 and relay winding 15 so that battery 16 will energize said relay winding when contacts 11 are closed by the application of a potential to terminals 10. Ferrite beads 12 function in the same manner as do the beads 5 of Fig. 3. However, with a cable arrangement or twisted pair arrangement it is necessary that only a single conductor pass through the ferrite beads as is shown in Fig. 4. If both conductors of cable 14 passed through each of the beads the inductance of the beads would be very small due to the canceling magnetic fields of the conductors.

In Fig. 5 a single ferrite bead is shown cooperating with an enclosed contact of a dry reed-type switch. Bead 16 forms a collar for stationary electrode 17 within glass switch envelope 21. Seals 19 and 20 fix the position of the bead with respect to electrode 17 as well as provide support for said electrode. Bead 16 functions in the same manner as the leads 5 and 12 of Figs. 3 and 4, respectively.

Such an arrangement wherein the ferrite bead is positioned closely to the make-and-break contact electrodes 17 and 18 improves the efficiency of the contact protection in that the impedance reflected into the contact circuit is much closer to the arcing contact faces than is possible in the usual case.

It is to be understood that the above-described arrangements are illustrative of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the scope of the invention.

What is claimed is:

1. In an electrical circuit including a pair of contacts movable with respect to one another for opening and closing said circuit to the flow of electrical current therethrough, a contact arc minimizing arrangement comprising a conductor connected to said contacts, a mass of magnetic ferrite closely surrounding said conductor at a point immediately adjacent said pair of contacts

whereby said ferrite mass imparts a reflected impedance into said conductor at the contact arc transient frequencies so as to dissipate and otherwise slow down the flow of electrical energy to said contact during said contact make-and-break operations.

2. A make-and-break contact protection arrangement, as defined in claim 1, wherein said mass is a manganese-zinc ferrite.

10 3. A make-and-break contact protection arrangement, as defined in claim 1, wherein said mass is a nickel-zinc ferrite.

4. A make-and-break contact protection arrangement, as defined in claim 1, wherein said 15 mass is a copper-zinc ferrite.

5. A make-and-break contact protection arrangement, as defined in claim 1, wherein said mass is a magnesium-zinc ferrite.

6. In an electrical circuit including a pair of 20 contacts movable with respect to one another for opening and closing said circuit to the flow of electrical current therethrough, a contact arc minimizing arrangement comprising an electrical conductor for carrying current to and from said pair of contacts, a mass of magnetic ferrite material having an electrical resistivity in the range 25 of 10^{-2} ohm-centimeters to 10^6 ohm-centimeters at room temperature and a magnetic permeability in the range of 50 to 2500 at a magnetic flux density of 10 gauss at a magnetizing current 30 frequency within the range of 0.5 to 3.0 megacycles, and said ferrite mass being magnetically coupled to said conductor by a close physical positioning of said mass to the conductor portion 35 immediately adjacent said contacts.

7. In an electrical circuit including a pair of make-and-break contacts for controlling the flow of current in said circuit, a contact arc minimizing arrangement comprising a conductor connected to said contacts and a bead of magnetic ferrite with a hole therein through which said 40 conductor is passed and said bead physically positioned adjacent said contacts whereby a change of magnetic flux density in said bead induces an electromotive force in said conductor during make-contact operations.

8. In an electrical circuit including a sealed switch having a pair of conducting electrodes with make-and-break contacts thereon, a contact 50 arc minimizing arrangement comprising a mass of magnetic ferrite magnetically coupled to one of said conducting electrodes by physically positioning said mass closely to an enclosed conducting electrode of said switch whereby said mass imparts a reflected impedance into said conducting 55 electrode during contact operations so as to minimize contact arcing.

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