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PROTECTIVE RF ATTENUATOR PLUG FOR WIRE-BRIDGE DETONATORS

Filed Aug. 29, 1968

2 Sheets-Sheet 1

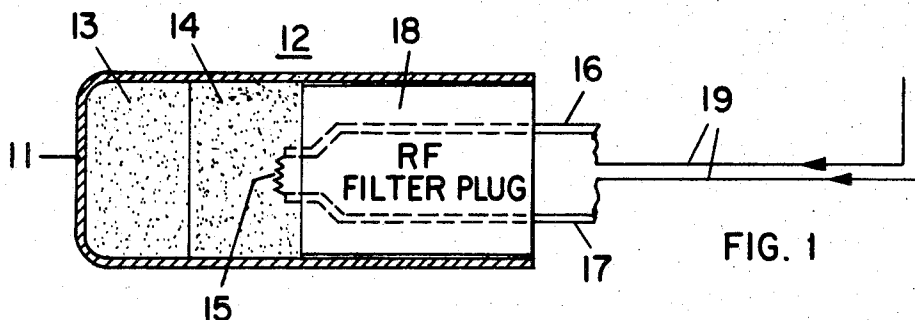


FIG. 1

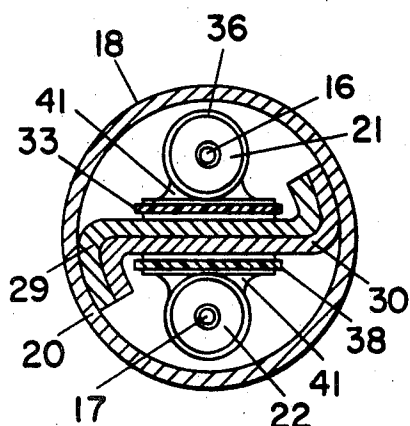


FIG. 3

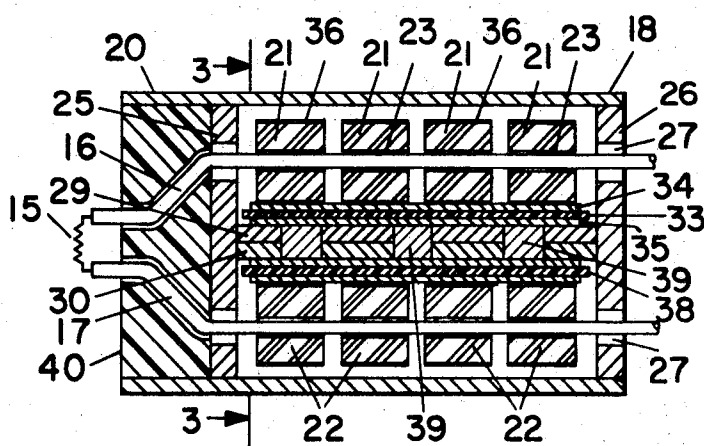


FIG. 2

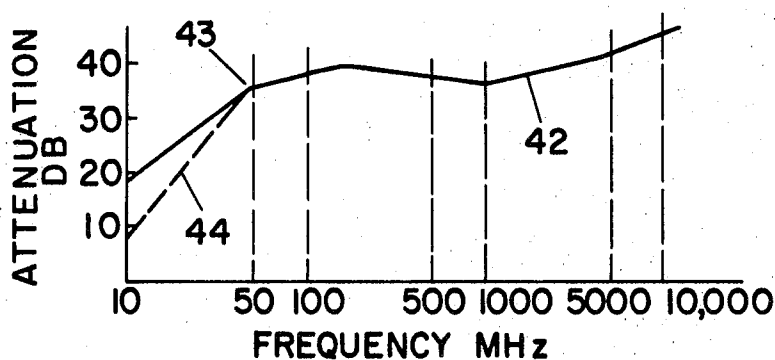


FIG. 4

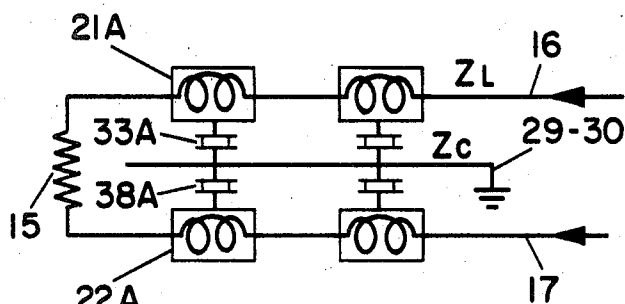


FIG. 5

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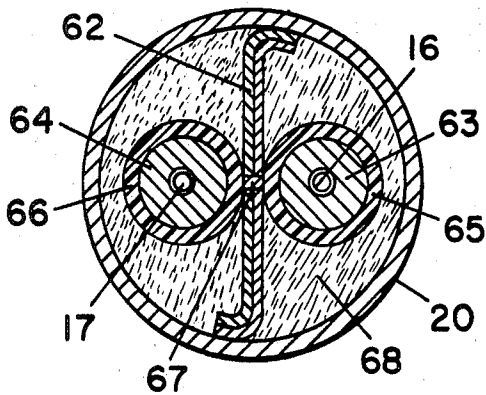
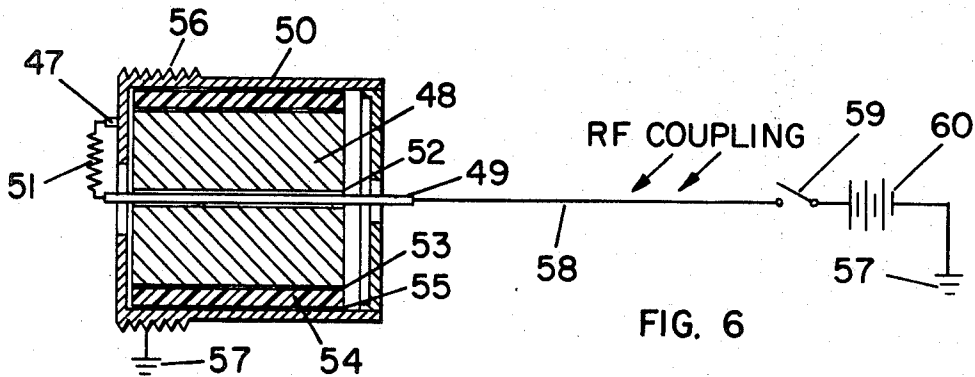


FIG. 7

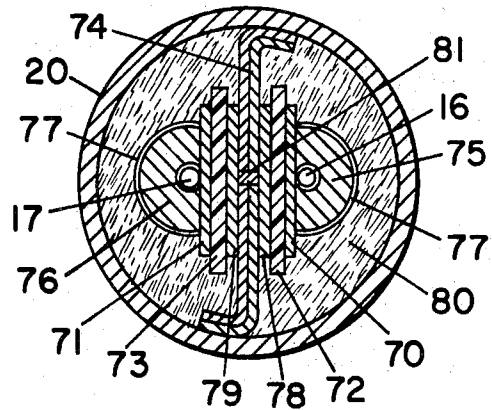


FIG. 8

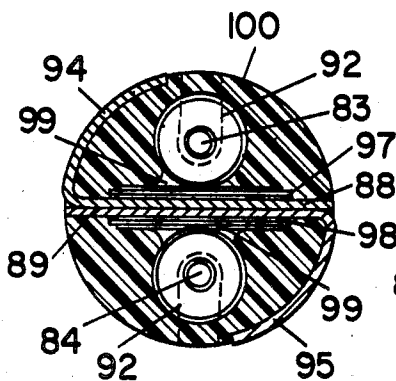
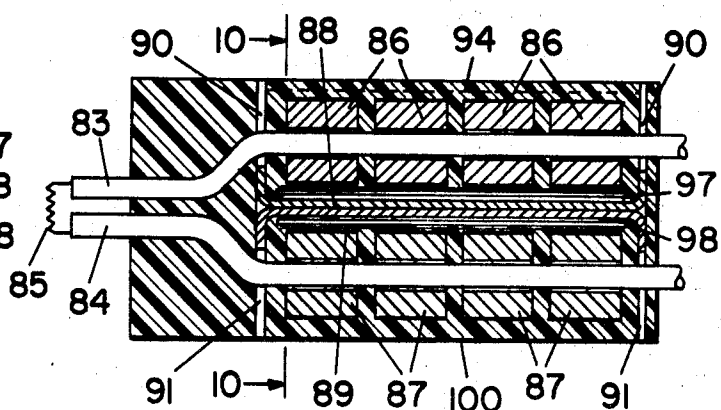


FIG. 10



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PROTECTIVE RF ATTENUATOR PLUG FOR
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U.S. Cl. 102—28

21 Claims

ABSTRACT OF THE DISCLOSURE

The plug portion of a wire-bridge detonator is replaced with a filter of the same physical shape and size. The input conductors for the bridge wire are each surrounded by a series of closely spaced ferrite beads. A conductive shield plate is provided between the conductors from which the ferrite beads are insulated by a strip of ceramic material on each side of the shield plate. The plug is provided with end shields of conducting material and an outer shield casing which may be of steel or other conducting material. The ferrite beads and the ceramic strips provide the inductive and capacitive elements of an RF filter or attenuator on the input conductors which operates to absorb stray radiated electromagnetic energy that might be picked up by these conductors, and prevents this energy from passing through to the bridge wire which might thus be prematurely fired thereby.

The invention may be manufactured, used, and licensed by or for the Government for governmental purposes without the payment to me of any royalty thereon.

The present invention relates to electroexplosive devices of the wire-bridge type, such as single or double wire-bridge detonators or detonator cartridges for explosive charges used in mine and demolition work, and for firing rockets.

The present invention relates more particularly to wire-bridge detonators of the type which include an insulating plug mount at one end for the input leads or conductors. In such detonators the plug is inserted into one end of a steel outer casing for the detonator in the opposite or inner end of which, and surrounding the bridge wire, is the explosion initiating or detonating element. This is generally in the form of a small body of explosive mixture. The plug which supports the conductors generally occupies a substantial portion of the entire length of the detonator cartridge.

Electrical energy is used to initiate electroexplosive devices of this type, and initiation occurs when this energy passes through the input conductors to the bridge wire, which is connected to the inner ends of the conductors through the plug, and causes the bridge wire to heat to the point of disintegration. The explosive mix of the detonator in proximity to the bridge wire is thus heated and ignited, and this operates to initiate the explosion of a larger charge or explosive body surrounding the cartridge or fuze. Since the bridge-wire element in such devices is susceptible to radio frequency or RF energy picked up by the supply conductors as well as the bridge wire conductors, it may be heated and fired thereby, thus creating a hazard. The old way of solving the problem of this hazard was to use an RF filter outside the electroexplosive device. This was unsatisfactory since such filters were relatively large and expensive, and could not be incorporated directly in the electroexplosive devices. However, with space becoming a premium, the filter element should best be incorporated in the electroexplosive device where protection is to be provided.

The problem of incorporating an RF filter is an electroexplosive device has existed for a long time without a

satisfactory solution. This is mainly because of the relatively small size of such devices, which in most cases may have an overall length and diameter measurable in small fractions of an inch.

It is an object of the present invention to provide an effective RF filter or attenuator that can be incorporated in an electroexplosive device of the small wire-bridge detonator type, thereby providing a safe condition and eliminating a hazard which has been present in such devices since their initial use.

In order to prevent such devices from igniting or initiating due to stray RF energy pick up, the original plastic plug as above referred to, as part of the electroexplosive device, is replaced with a filter or attenuator plug of the same physical size. Without any increase in overall size, the filter then absorbs stray or inadvertent energy such as that received from radio transmitters or radar transmitters in the vicinity of such devices when in use. Without the attenuator type plug, this radiated energy may often be sufficient, as noted above, to cause the bridge wire to disintegrate or melt and fire the fuze or detonator.

In accordance with the invention, the input conductors for the bridge wire or wires are each surrounded by ferrite bodies comprising small ferrite beads for a portion of their length at their input ends and with ceramic insulating material interposed between the ferrite beads and a conductive shield generally located between the conductors. The latter is generally in the form of a thin shield plate and, with the conductors and other elements, is surrounded by a similar conductive shield element which may be the outer steel casing of the electroexplosive device or detonator cartridge.

The elements of the attenuator are all included within the physical size of the original plastic plug. It is thus constructed in a manner which enables it to be incorporated into the detonator without change in the physical size or shape thereof. In this form it operates to prevent radiated electromagnetic and electrostatic energy, which passes into the input conductors, from reaching the bridge wire itself and firing the explosive charge. Thus, in accordance with the invention, an RF attenuator or filter is incorporated into the electroexplosive device and substituted in the place where a standard plastic plug would normally be located, to provide protection from stray radiation.

The invention will further be understood from the following description when considered with reference to the accompanying drawings, and its scope is pointed out in the appended claims.

In the drawing:

FIG. 1 is a cross-sectional view, in elevation, of an electroexplosive device of the detonator cartridge type provided with an RF filter or attenuator plug in accordance with the invention,

FIG. 2 is a cross-sectional view, in elevation, of the RF filter or attenuator plug of FIG. 1, showing the internal construction thereof in accordance with the invention,

FIG. 3 is a cross-sectional end view of the device of FIG. 2, taken on the section line 3—3 thereof, and showing further details of construction in accordance with the invention,

FIG. 4 is a graph showing a response curve illustrative of a frequency characteristic of a filter or attenuator plug embodying the invention,

FIG. 5 is a schematic circuit diagram illustrative of the electrical characteristics of a filter or attenuator plug embodying the invention,

FIG. 6 is a cross-sectional view, in elevation, showing a modification, in accordance with the invention, of the filter construction of FIG. 2 and a schematic circuit diagram therefor,

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FIGS. 7 and 8 are end views, in cross section and similar to that of FIG. 3, showing further modifications of the invention in the same general conformation as the filter or attenuator of FIGS. 2 and 3,

FIG. 9 is a cross-sectional view, in elevation, of an RF attenuator plug of the multi-element type similar to that of FIG. 2, showing a modification in the shielding and casing construction in accordance with the invention, and

FIG. 10 is a cross-sectional end view of the device of FIG. 9, taken on the section line 10—10, showing further details of construction in accordance with the invention.

Referring to the drawings, wherein like reference characters throughout the various figures refer to the like parts and elements, and referring particularly to FIG. 1, 11 is the elongated metallic outer casing of an electro-explosive device 12 of the single wire-bridge detonator or cartridge type, open at one end and containing, at the other end, a detonating charge or mixture 13 together with an initiating charge or mixture 14 therefor surrounding the filamentary bridge wire 15. The bridge wire is connected between the inner ends of two parallel input conductors 16 and 17 which extend through a plug 18 which fits into the outer or open end of the casing 11. In some cases a second bridge wire with another pair of input conductors is provided and arranged for simultaneous operation to insure detonation in case one bridge wire should fail. For simplicity and because single bridge wire detonators are more generally used, the single wire type is here shown and described. This plug is normally of rubber or other insulating material and normally merely holds the wires 16 and 17 in place. The outer ends of the input conductors 16 and 17, which are of relatively large size and rigid, are connected with a pair of current supply leads 19 from any suitable source of direct current (not shown) for firing the bridge wire 15 when it is desired to discharge the detonator. In such uses, as is well understood, the detonator or cartridge 12 is placed within the body of an explosive charge or mine (not shown) for firing the latter when energized through the leads 19.

The supply leads 19 and the conductors 16 and 17 are subject to stray or inadvertent energy pick up from nearby radiation sources, such as radio transmitters or radar transmitters, and may receive enough energy to fire or burn the bridge wire 15 prematurely. In accordance with the invention, to prevent this, the attenuator plug 18 is a replacement for the normal plastic plug and provides a filter of the same size. The filter surrounds the leads 16 and 17, as will be seen, and absorbs or attenuates the stray energy which is coupled through the leads 16 and 17 from outside sources, thereby preventing it from reaching the filamentary conductor 15 or bridge wire 15. The problem of incorporating an RF filter in such electro-explosive or wire-bridge detonator cartridges of such relatively-small size has been overcome by utilizing ferrite and barium titanate materials in predetermined relation to the conductors 16 and 17 within the filter plug, in accordance with the invention, as will be seen with reference to FIGS. 2 and 3.

Referring to FIGS. 2 and 3 along with FIG. 1, the internal elements of the plug 18 may be seen in operative relation to the two input conductors 16 and 17 and the wire bridge 15. Within a steel outer casing 20, for the detonator, which acts as a holder for the complete plug assembly, are four ferrite beads 21 in close spaced relation surrounding the conductor 16, and four like ferrite beads 22 in close spaced relation surrounding the conductor 17, as seen more clearly in FIG. 2. Four beads per conductor are shown only by way of example, as a greater or lesser number may be used, depending upon the size of the beads and the space available. As indicated at 23 in connection with the beads 21, each of the ferrite beads is provided with a silver conductive layer through each opening therein in contact with the wire which it surrounds. The wire is bonded to the silver conductive layer on assembly by heating, so that there is a good elec-

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trical connection between each ferrite bead and the wire it surrounds. The ferrite must be of high-permeability, high-conductivity and have a high-loss factor in order to be operative in the system of the filter or attenuator shown. A ferrite that has been found to be satisfactory for this use is manganese-zinc ferrite.

The ferrite beads act as high-frequency attenuator elements for the filter and the attenuation provided by the ferrite is a function of the length of each bead but, beyond a certain degree of attenuation, does not increase appreciably above a certain ratio to the diameter, such as 2:1, for example. In any case the inductance or inductive reactance of the ferrite beads is important. If the beads are infinitely small and many beads are used, the inductance will increase and, with increasing inductance around the conductors, the attenuation is found to increase. In the same filter or attenuators, the beads may be of different lengths and sizes to provide a desired inductive reactance characteristic and physical size overall.

The ferrite beads are electrically shielded at each end of the casing by a conductive shield wall 25 at the inner end and a conductive shield wall 26 at the outer end, through which the conductors 16 and 17 extend by the way of clearance openings 27. The end shields or walls 25 and 26 are of circular flat disk form and may be of any suitable conductive material such as silver coated ceramic, copper or steel, the same as the outer casing 20. They stand normal to the plane of the shield wall 29-30 and in contact and electrically connected therewith.

Extending diametrically across the casing 20 between the conductors 16 and 17 is a transverse conductive shield wall comprising two elements 29 and 30 in contacting nested relation, as shown in FIG. 3 more particularly, to maintain close contact with each other and the inner surface of the casing 20 as indicated in FIG. 3. The two conductors are effectively in separate compartments entirely shielded one from the other. For this purpose the shield elements 29 and 30 also contact the end shield walls 25 and 26 as indicated in FIG. 2. Preferably they may be of one piece or integral with the wall 29-30, which likewise may be of one piece. Thus this shield structure may be one unitary element.

The ferrite beads 21 on the conductor 16 are insulated and separated from the shield element 29-30 by means of a ceramic capacitor element or plate 33 which has silver coatings or electrodes 34 and 35 on either face thereof, the inner or lower coating or electrode 35 contacting the shield wall element 29 and the outer or upper coating or electrode 34 contacting the ferrite beads 21. The ferrite beads are likewise silver coated or plated, as indicated at 36, on their outer peripheral surfaces. These silver coatings are joined to the electrodes by heating during assembly to provide good bonded electrical connections between the ferrite beads and capacitor plate electrodes, and with the shield wall 29-30.

A similar ceramic capacitor plate or element 38 is provided between the beads 22 and the shield wall element 30 and is likewise silver coated to provide electrodes on its outer or upper and inner or lower surfaces in a manner similar to that of the plate 33, all as indicated in the drawing. In any case, the ceramic elements 33 and 38 are used to insulate the ferrite beads from the ground plane and to operate as a capacitance branch of the filter or attenuator, along with the inductive elements provided by the beads 21 and 22. The ceramic must be relatively thin or thin-walled, and have a high dielectric constant, a high capacity, and a high voltage breakdown. Furthermore it is preferable that the inductive reactance provided by the beads surrounding the conductors 16 and 17 be substantially matched to the capacitive reactance provided by the capacitor elements 33 and 38 between the ferrite beads and the shield wall 29-30. The whole structure is tightly bonded together electrically by heating.

At different points along the shield wall 29-30, perforations are provided through which the silver solder may

flow and join the two shield and capacitor elements together as indicated by the solder beads at 39, for example, in FIG. 2 and 41, for example, in FIG. 3. In the present structure, but not necessarily in all cases, a molded or preformed end wall or cap 40 is provided at the inner end of the plug to hold the leads 16 and 17 where they join the filamentary element 15 and to maintain the latter physically steady and unbroken before firing. This end cap or wall may be of insulating material, as indicated, or of metal with a glass-to-metal seal around each conductor. The entire casing may be filled with any suitable insulating binder (not shown) as may be desired, such as epoxy resin or a rubber compound, to act as a sealant against moisture and water in use.

This filter or attenuator plug measured in a matched attenuation measuring system has been found to provide a broad-band operating characteristic as illustrated by the attenuation curve 42 in FIG. 4 to which attention is now directed. This is taken for a filter of the type shown in FIG. 2, with only one bead and one capacitor element for each conductor, that is, one pair per conductor. The higher frequency portion of the curve to the right of the point 43 is found to be provided by the ferrite bead elements more particularly, while the portion to the left of the point 43 is found to be provided by the capacitor elements more particularly. In the absence of the capacitor elements, the curve 42 would tend to fall off generally along the dash line as indicated at 44. With the complete system consisting of more than one pair of elements on each side, as shown in FIGS. 2 and 3, the overall attenuation curve is substantially higher, in some cases over twice as high, thereby increasing the overall effective attenuation level from that shown.

It is desirable that the silver or conductive shield layer 36 around each ferrite bead be provided in order to prevent loss of attenuation and to provide good contact with the capacitor elements and their silver electrodes or contacts 34 and 35. The attenuator plug then operates to provide relatively broad-band attenuation in a wide frequency range as indicated.

The operation of this filter for attenuation may further be understood by reference to the circuit diagram of FIG. 5 along with the curve of FIG. 4. This shows the filter circuit with series inductance elements 21A and 22A as provided by the ferrite beads 21 and 22, along with the shunt capacitance elements 33A and 38A as provided by the capacitor plates or elements 33 and 38, in connection with the shield wall 29-30 or ground. It functions as an attenuator circuit to absorb the stray RF energy which is coupled into the leads or conductors 16 and 17 from outside sources with sufficient strength normally to apply current to the bridge wire 15 to melt it and thus fire the detonator. The circuit network thus provided operates to prevent this.

Generally, the more beads that are provided, in a specific plug size, the higher the overall attenuation level attained. The metal end shields 25 and 26 also aid in maintaining the upper frequency characteristics of the filter by preventing attenuation leakage through the ends of the ferrite beads. The length-to-diameter ratio of the ferrite beads is important. As pointed out hereinbefore, the attenuation provided by the ferrite bead is a function of the length and volume of the bead, but does not increase appreciably with length above a certain ratio to the diameter, consequently, the proper bead size must be chosen so that it matches the impedance of the capacitance element. That is, the inductive reactance Z_L should equal the capacitive reactance Z_C generally, in constructing a filter for maximum attenuation.

From the foregoing it will be seen that in an electro-explosive device or detonator cartridge of the wire-bridge type, the normal standard plastic plug may be replaced by a filter plug containing all of the elements indicated in FIGS. 2 and 3, or further modifications thereof as will be described, to absorb the stray or inadvertant energy

which otherwise might cause premature operation of the detonator by pick up from nearby energy source of radiation.

The present attenuator construction eliminates the necessity of using large, cumbersome and expensive filters outside of electroexplosive devices to protect them. The components to provide such improved attenuator or filter plugs are readily purchased or can be obtained in production at a cost which is relatively low. Furthermore, because of the small size and adaptability of the plug it may be used or incorporated as a protective means in any type of electroexplosive device where a bridge wire is provided, especially in miniaturized fuzes. This system, furthermore, provides greater RF safety across most of the RF band to stray or inadvertant electromagnetic energy and provides better protection than external filters, because of the shortness of the leads provided.

Any type of fuze may take advantage of this construction which provides space and shielding for the RF filter plug in the fuze housing, and thus may be protected from stray RF energy and inadvertant detonation. This system thus enables wired explosives to be transported into areas where radar transmitters are operating. Perhaps the greatest advantage of this system is provided by the fact that the plug, containing all of the filter elements, may be inserted in and become part of the electroexplosive device with no external elements or filter means. In the present example and in most instances it becomes a replacement for the former plug which occupied the same space without doing any more than holding the conductors for the bridge wires. Thus it provides protection without increasing the size of the detonator device.

While four ferrite beads have been shown in connection with each of the input conductors of the modifications of FIGS. 2 and 3, a larger or smaller number of beads may be employed depending upon the impedance or reactance desired and the amount of available space, and size of plug to be substituted. In some cases a single large ferrite bead may be used instead of a number of beads, as shown in FIG. 6 to which attention is now directed. In this modification, a single ferrite bead 48 is employed and surrounds a single input conductor or wire 49, with a ground return connection at 47 to the outer casing 50 through the filamentary bridge wire 51. The ferrite bead 48 is silver soldered to the conductor wire 49, as indicated at 52, for a good electrical connection therewith, and likewise is provided with an outer coating or conductive layer 53 of silver which acts as a shield around the ferrite.

Surrounding the coating 53 and in contact therewith is a relatively-thin ring 54 of ceramic material, such as barium titanate, the outer surface 55 of which is silver coated and in contact with the inner wall of the casing 50. The casing 50 is grounded as indicated at 57, through a screw thread connection 56, by which it is attached to any explosive device (not shown) with which it may be used. The firing circuit therefor is completed through a supply lead 58 from the conductor 49, and a switch 59, to a battery 60 and ground 57. When the switch 59 is closed, the current from the battery heats the filament or bridge wire 51 and fires the explosive charge which may be surrounding the bridge wire at that time. As described in connection with the operation of the preceding embodiment, any stray RF coupling, as indicated, which strikes the wire 58 is dissipated in the filter or attenuator provided by the ferrite body or bead 48 in connection with the capacitor element 54.

From the foregoing description it will be seen that the ceramic capacitor element and the ferrite inductive element may be arranged in concentric relation about an input conductor to provide an effective attenuator structure for protecting the bridge wire. In such arrangements, the ceramic and ferrite placement is reversible. In the present example the ceramic capacitor element may be circular and surround the ferrite bead which may be of any desired

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size for the required reactance and is insulated from ground thereby, as in the preceding example. This alternative method of construction, using one relatively large ferrite bead, instead of a number of smaller beads, makes the construction simpler and less expensive in the production of large quantities. The single conductor construction with grounded return also aids in size reduction and renders it better adapted for plug-in or screw-in elements in connection with other apparatus.

Both conductors of a two-wire detonator or explosive device may likewise be surrounded by a concentric ceramic and ferrite structure, such as a ferrite bead and a ring of ceramic material similar to that above described in FIG. 6. This type of construction is shown in FIG. 7 to which attention is now directed. In this case the conductors 16 and 17 of the previous embodiment are shown along with the outer conductive casing 20. A dual or two-element shield wall 62 is interposed between the conductors midway therebetween. This is grounded to the casing 20 by contact therewith as in the preceding embodiment, and the conductors 16 and 17 are surrounded by ferrite beads 63 and 64 respectively. These may be silver soldered to the conductors throughout their lengths as in the preceding example. Likewise the ferrite beads are provided with silver outer coatings which are in contact with relatively-thin outer concentric ceramic rings 65 and 66 respectively, the outer conductive coatings of which may be joined electrically through an opening in the shield 62 by a silver solder bead as indicated at 67. The interior of the casing 20 is then filled with a sealant comprising a matrix of powdered ferrite and epoxy cement as indicated at 68. Instead of the ferrite matrix, a silver filled epoxy cement may also be used. As noted above the relative positions of the ceramic and ferrite elements with respect to the conductors may be reversed, in which case the ceramic must be relatively thin with respect to the ferrite body.

In a further modification of the detonator device of FIG. 7, the ferrite elements may be of half-moon shape as shown in FIG. 8, for example, to which attention is now directed. In this modification, the conductors 16 and 17 are in contact with the metallic coatings or electrodes 70 and 71 of ceramic capacitor plates or elements 72 and 73, respectively, arranged on either side of the center conductive shield wall 74, similar to the construction shown and described with reference to FIGS. 2 and 3.

Surrounding the conductors 16 and 17, in part, are two half-moon ferrite beads 75 and 76, respectively, each of which has an outer silver shield coating 77. The ceramic elements may be of barium titanate as before. The electrode elements or electrodes therefor, including 70 and 71 along with inner electrode elements in or electrodes indicated at 78 and 79, may be provided by either silver or nickel plating as may be desired. The internal sealant around the elements within the casing 20 may, as before, be a matrix of ferrite powder, preferably of the sintered type, mixed with epoxy cement or of plastic or rubber or a resin. However, the ferrite matrix provides greater attenuation for high-frequency radiation received through the conductors and is therefore more desirable. As in the preceding embodiments, the two coatings or electrodes 78 and 79 are electrically connected to the shield wall 74 and by a solder bead 81 which is provided in an opening through the shield wall 74. More than one solder bead may be provided.

Referring again to FIGS. 1, 2 and 3, it will be seen that the RF filter or attenuator plug 18 is shielded within the outer metallic casing 11 and is in itself also shielded by the outer metallic casing 20 together with the end shields 25 and 26, so that the filter or attenuator elements comprising the ferrite beads and the capacitor strips are entirely inclosed within a conductive electrical shield. Thus such a device may, in itself, be used separately from the detonator in any circuit location where a filtering action is required. Thus, for example, the device may be

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utilized in radio, television or for that matter in any electrical network or system wherein filters are required. It is therefore to be understood that the invention as disclosed in the embodiment herein is merely illustrative of one of many applications therefor. It should also be understood that the device may be utilized in the disclosed embodiment but separately from the detonator, such as preceding a group of wire bridge detonator type devices. That is to say, the device of FIGS. 2 and 3 is in itself shielded and may be used within or without a shield casing such as that of the detonator device 12 which has its own outer metallic shield casing 11.

Therefore, where the shield wall 62 may be grounded to the outer metallic casing of the detonator cartridge, such as the casing 11 of FIG. 1 and the casing 20 and body of the plug may be entirely molded of plastic material as one unit, as will be seen with respect to a further modification of the invention.

An entirely plastic molded construction is easier and less costly to manufacture than that of FIGS. 2 and 3 because the outer conductive shield casing may be eliminated and the entire device may be cast in one mold complete with end shields and shield walls between the two conductors. Such a construction is shown in the modification of FIGS. 9 and 10 to which attention is now directed. In this construction, the input conductors 83 and 84 are arranged in spaced substantially parallel relation as in the preceding embodiments, and are connected at their inner ends by the bridge wire 85 which is melted or ignites when a firing current is applied to the conductors 83 and 84 as has been described.

Each conductor is surrounded by a series of spaced ferrite beads. These are shown at 86 and 87 on the conductors 83 and 84 respectively. A conductive shield wall is provided between the two conductors and extends therealong in parallel relation to the conductors. This wall is a composite structure comprising two shield plates or elements 88 and 89 of conducting material such as steel, in flat contacting relation to each other as indicated in both figures. Integral with the shield plate 88 at each end are upturned semicircular end plate sections or shield elements 90, and likewise at the ends of the shield plate 89 are two upturned end plate sections 91 of the same semicircular shape. As shown in FIG. 10 more particularly, each of the end plate sections are provided with clearance slots, indicated at 92, through which the conductors 83 and 84 pass without contact therewith. Together the semicircular end plate sections 90 and 91 provide a complete circular end plate or shield for each end of the filter or attenuator plug unit substantially integral with the shield plates 88-89 which extend along and between the two conductors as a common shield wall. The end shields are in planes normal to the plane of the shield plates and the composite shield wall which they provide.

Also integral with the plates 88 and 89 are peripheral contact elements for connecting or grounding the shield structure to the outer metallic casing of the detonator device with which the plug is to be used, such as that shown at 11 in FIG. 1, for example. The plug is cylindrical as indicated and when inserted into the metallic casing 11, or any similar shield element, it must provide contact with the casing for grounding the shield wall and end shields to the casing, thereby completing the enclosure of the device against absorption loss in operation. Thus, in the present example and as a preferred arrangement, the shield element 88 is provided along one edge with a curved upturned integral extension thereof to provide a peripheral contact element as indicated at 94. Thus this is curved to conform to the outer periphery of the cylindrical cartridge or plug as indicated more clearly in FIG. 10. Likewise the shield wall element 89 is provided along one edge with an upturned integral extension to provide a contact element 95 which is also curved along the peripheral surface of the cartridge or plug so that it may contact the shield wall of the casing in which

it is inserted, the same as for the contact element 94, which appears in dotted outline in FIG. 9.

Interposed between the inductive ferrite bead elements and the shield wall are the capacitive elements of the filter or attenuator. As in the preceding embodiments, the ferrite beads are insulated from the shield by ceramic capacitor elements as indicated at 97 and 98, respectively, for the ferrite beads 86 and 87. These capacitor elements are constructed as previously described, with electrode conductive surfaces on each face thereof, and likewise the ferrite beads are provided with surface coatings on the peripheral outer surfaces as well as the inner surfaces along the openings through which the conductors pass and the entire structure is electrically connected by heating and joining or bonding the various elements together through the silver solder means along the contacting surfaces and as previously described with the reference to the preceding embodiment. This bonding appears more clearly in FIG. 10 where the ferrite beads are attached to the conductive surfaces of the capacitor elements by solder or silver epoxy cement which is visible as at 99, for example.

The electrical elements of the plug are encapsulated or sealed into a cylindrical body 100 of plastic material, such as a resin or a rubber compound, or preferably a ferrite matrix comprising sintered ferrite powder mixed with epoxy cement into a sealant. It will be noted that the cylindrical body of the cartridge is extended toward the bridge wire 85 a considerable portion of the distance thereto to provide a rigid support for the conductors and the bridge wire at that point. It will also be noted that the contact elements 94 and 95 for the shield are clear of any sealant and are thoroughly exposed at the periphery for contact with the casing into which the cartridge is to be inserted in use, as indicated at 11 in FIG. 1 for example.

This construction has the advantage of lower production cost and better adaptability in that no additional shield is required. Good ground shield contact is made with the outer casing by the contact elements 94 and 95 which are exposed over a considerable area for the length of the cartridge between the end shield walls. The operation of the device in absorbing incoming undesirable pulses is the same as that described in connection with the embodiment of FIGS. 2 and 3. Any number of ferrite bead and capacitor element pairs may be provided in a device of this type, four being shown only by way of example as providing a relatively high level of absorption, as described in connection with FIG. 4 previously.

The protective RF filter or attenuator plug for wire bridge detonators as provided by the present invention operates, as has been described, to give broad-band attenuation and to absorb the stray incoming RF energy within the ferrite elements, aided by the capacitance elements to maintain the attenuation in the lower frequency end of the range. As noted, the ferrite beads are of high-permeability, high-conductivity and high-loss type, while the barium titanate or ceramic capacitor elements are of the high dielectric-constant and high-capacity type with a high voltage breakdown. As indicated, the impedance of the inductive elements are preferably equal to the impedance of the capacitive elements regardless of the form in which they are provided. In any case, a ferrite element or plurality of elements, are provided in good electrical contact with the input wires or conductors for the bridge wire, and are electrically insulated from ground or the shield by the ceramic elements which are complementary with respect thereto and combine therewith to provide the desired attenuation with either single or multiple units along the conductor or conductors.

I claim:

1. A radio-frequency attenuator plug for wire-bridge detonators and the like comprising in combination:
 - an extended rigid input conductor;
 - a bridge wire connected with one end of said input conductor for receiving firing current therefrom;

means providing a conductive ground plane along said input conductor and spaced therefrom;

at least one high-conductivity ferrite element having a predetermined length to diameter ratio for providing a predetermined inductive reactance as a function thereof, said element extending along said input conductor in bonded electrical connection therewith;

a shield conductor providing a silvered outer coating for said ferrite element;

ceramic capacitor means connected between and electrically bonded to said outer coating and the ground plane means, said capacitor means having a capacitive reactance equal in magnitude to the inductive reactance of said ferrite element at a frequency within the range of those frequencies designed to be attenuated; and

a body of plastic sealant surrounding and bonding said elements into a unitary plug structure with the input conductor and bridge wire extending therefrom.

2. A radio-frequency attenuator plug as defined in claim 1, wherein the ferrite element is of manganese-zinc and the ceramic capacitor means includes a barium titanate element of relatively-thin cross-section between said ferrite element and said ground plane means.

3. A radio-frequency attenuator plug as defined in claim 1, wherein the ferrite element and the capacitor means are cylindrical in form and arranged in concentric coaxial relation about the input conductor.

4. A radio-frequency attenuator plug as defined in claim 2, wherein the ferrite element is of a tubular shape having an inner surface and an outer surface, said bonded electrical connection with said input conductor is along said inner surface, and said shield conductor is on said outer surface.

5. A radio-frequency attenuator plug as defined in claim 4, wherein a silvered inner coating is provided on the inner surface of said ferrite element and said silvered inner coating is silver soldered to said input conductor to provide said bonded electrical connection.

6. A radio-frequency attenuator plug as defined in claim 5, wherein said predetermined length to diameter ratio of said ferrite element is 2:1.

7. A radio-frequency attenuator plug comprising in combination:

means providing a cylindrical casing for said plug;

a pair of conductors extending longitudinally through said casing in spaced relation to each other;

means providing a conductive shield wall as a ground plane extending along and between said conductors;

at least one high-conductivity ferrite element having a predetermined length to diameter ratio for providing a predetermined inductive reactance as a function thereof, said element extending along each of said conductors in bonded electrical connection therewith;

a relatively thin ceramic capacitor element having a capacitive reactance equal in magnitude to the inductive reactance of said ferrite element at a frequency within the range of those frequencies designed to be attenuated, said capacitor element being interposed between each ferrite element and said shield wall in bonded electrical connection therewith;

a pair of spaced conductive end shield elements in said casing connected to and in electrical contact with said shield wall and standing normal to the plane of said wall at opposite ends thereof; and

said casing comprising a body of plastic material surrounding and bonding said conductors and associated elements into a unitary structure with the conductors at opposite ends extending therefrom for terminal connection.

8. A radio-frequency attenuator plug as defined in claim 7, wherein said ferrite elements do not completely surround said conductors.

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9. A radio-frequency attenuator plug as defined in claim 7, wherein the ferrite elements are of manganese-zinc material and the ceramic capacitor plates are of barium titanate material, and wherein the plastic material of the casing body is a ferrite matrix of ferrite powder and epoxy cement.

10. A radio-frequency attenuator plug defined in claim 9, wherein said predetermined length to diameter ratio of said ferrite element is 2:1.

11. A radio-frequency attenuator plug for wire-bridge detonators and the like comprising in combination;

a cylindrical casing of conducting shield material for said plug;

a pair of rigid input conductors extending longitudinally through said casing in spaced parallel relation to each other;

a bridge wire connected between said conductors at one end for receiving firing current therefrom;

means providing a conductive shield wall extending along and between said conductors in contact with the inner wall of said casing to effect a grounding connection therewith;

at least one cylindrical high-conductivity ferrite bead element surrounding each of said conductors;

a peripheral silver coating on the outer surface of each bead element as an outer shield and electrical connecting element therefor;

an inner silver coating on the inner surface of each bead element as an inner shield and a bonded electrical connection with said conductors throughout the length of said bead element;

a relatively-thin ceramic capacitor plate of high dielectric constant interposed as an insulating element between each ferrite bead element and said shield wall with conductive surface coatings thereon in contact with and bonded to said wall and ferrite bead outer coatings to provide electrical connection therewith;

a pair of spaced conductive end shield plates in said casing connected to and in electrical contact with said shield wall and standing normal to the plane of said wall at opposite ends thereof; and

a plastic sealant surrounding and bonding said conductors and associated elements within said casing into a unitary structure with the conductors at one end extending therefrom with the bridge wire and at the opposite end extending therefrom for terminal connection with firing current supply means.

12. A radio-frequency attenuator plug as defined in claim 11, wherein the conductive shield wall means and the end shield plates are integrally connected, and wherein the said end shield plates are provided with clearance slots for the conductors.

13. A radio-frequency attenuator plug as defined in claim 12, wherein said ferrite bead elements are of manganese zinc material, said ceramic capacitor plates are of barium titanate material, said conductive surface coatings are silver and wherein said plastic sealant is a ferrite matrix of sintered ferrite powder and epoxy cement.

14. A radio-frequency attenuator plug for a wire-bridge detonator having an outer conductive cylindrical casing with one open end, comprising in combination:

a cylindrical body of plastic material for said plug adapted to fit into said casing at said open end as a closure therefor;

a pair of rigid input conductors extending in spaced parallel relation longitudinally through said plug body and extending therefrom at the inner and outer ends thereof;

a current-destructable bridge wire connected between said conductors at the inner end of the plug for firing said detonator in response to firing current there-through;

means providing a transverse conductive shield wall

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extending along and between said conductors in spaced relation thereto, as a ground plane;

at least one cylindrical high-conductivity ferrite element extending along each of said conductors as inductive reactance means thereon, having a silvered conductive layer on the inner surface of said element, and having bonded electrical connection with said conductor throughout the length of said element;

means providing a silvered conductive peripheral coating on the outer surface of each of said ferrite elements as an outer conductive shield thereon;

capacitive reactance means interposed between each ferrite element and the conductive shield wall and comprising a relatively-thin body of ceramic material with silvered conductive electrode surfaces in bonded electrical connection with the silvered coating of said ferrite elements and said shield wall, and means providing a pair of spaced circular end shield walls in electrical contact with and standing normal to the plane of said transverse shield wall at opposite ends thereof.

15. A radio-frequency attenuator plug as defined in claim 14, wherein the shield walls are joined effectively in one unitary shield structure with means for grounding to said detonator casing.

16. A radio-frequency attenuator plug as defined in claim 15, wherein the cylindrical plug body comprises a ferrite matrix of sintered powdered ferrite and epoxy cement.

17. A radio-frequency attenuator plug as defined in claim 16, wherein each ferrite element and the ceramic body bonded thereto are arranged in concentric coaxial relation.

18. A radio-frequency attenuator plug as defined in claim 14, wherein conductive contact means is provided in the outer peripheral surface of the plug body and connected with one of said shield walls for grounding said shield walls to the outer conductive casing of the detonator.

19. In an electro-explosive device of the wire-bridge detonator type having a conductive outer casing of elongated cylindrical shape with one open end, a protective radio-frequency attenuator plug seated in said open end of the casing and comprising:

a pair of rigid longitudinally-extending spaced input conductors having inner terminal ends;

a firing bridge wire connected between said conductors at said inner terminal ends for receiving firing current therefrom;

a conductive shield plate extending along and between said conductors in substantially equally spaced relation thereto;

a series of closely-spaced high-conductivity and high-permeability ferrite elements for establishing inductive reactance along said conductors, said ferrite elements each having a predetermined length to diameter ratio for providing a predetermined inductive reactance as a function thereof, and each extending along one of said conductors in bonded electrical contact therewith;

conductive end shields in planes normal to the plane of said shield plate at opposite ends thereof;

an insulating relatively-thin ceramic body of high dielectric constant and high capacity between said ferrite elements and the shield plate to establish capacitive reactance along said conductors in conjunction with said inductive reactance for attenuating stray induced energy radiation;

means providing conductive electrical surface coatings on each ceramic body in bonded electrical connection with said shield plate on one side and with the ferrite elements on the other; and

a cylindrical molded plastic body for said plug fitted to said casing and enclosing the elements thereof in a fixed matrix.

20. In an electro-explosive device of the wire-bridge detonator type having a conductive outer casing of elongated cylindrical shape with one open end, a protective radio-frequency attenuator plug as defined in claim 19, wherein said inductive reactance of each of said ferrite elements is equal in magnitude to said capacitive reactance at at least one frequency within the range of those frequencies designed to be attenuated.

21. The combination with an electro-explosive device of the wire-bridge detonator type having a conductive outer casing of elongated cylindrical shape with one open end, of a protective radio-frequency attenuator plug for seating in and closing said open end of the casing and comprising:

- a cylindrical molded plastic body fitted to said casing and enclosing the elements thereof in a fixed matrix of ferrite powder and a binder;
- a pair of rigid spaced input conductors extending longitudinally through said plug body and externally thereof at each end;
- a firing bridge wire connected between said conductors at the inner end of the plug body and closely adjacent thereto for receiving firing current therefrom;
- a transverse conductive shield plate within the plug body substantially on the diameter thereof extending along and between said conductors in substantially equally-spaced relation thereto;
- a series of closely-spaced intervalled cylindrical manganese zinc ferrite bead elements surrounding each conductor in bonded electrical contact therewith, said bead elements having a silver coating on the outer and inner surface thereof;
- conductive end shield plates for said bead elements in spaced relation thereto at opposite ends of the series in planes normal to the plane of said transverse shield plate and substantially integral with said plate;
- conductive contact means in the peripheral outer surface of said plug and integral with said transverse

shield plate at opposite edges for establishing an electrical grounding connection therefor with the outer casing;

an insulating relatively-thin ceramic plate of barium titanate interposed between each bead element and the transverse shield plate; and

silver surface coatings on each of said ceramic plates in bonded electrical connection with said transverse shield plate on one side and with the outer ferrite element coatings on the other,

thereby to establish inductive reactance through said ferrite bead elements and capacitive reactance through said ceramic plates with respect to said conductors for attenuating stray induced radio-frequency radiation.

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