MAGNETIC RADIO FREQUENCY SEAL FOR SHIELDED ENCLOSURES

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FIG. 1

FIG. 2

FIG. 3

FIG. 4

FIG. 5

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MAGNETIC RADIO FREQUENCY SEAL FOR SHIELDED ENCLOSURES

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This invention relates in general to RF shielded enclosures, and in particular to an improved seal for shielding openings in such enclosures against passage of radio-frequency waves.

Rapidly spreading interest in application of RF energy in recent years has developed a need for RF shielded enclosures which permit operation of equipment in an environment which is to a practical degree free of RF interference. An RF shielded enclosure consists ideally of a structure of metal whose electrical conductance exceeds a certain value at all points, and which is built as the closest possible approximation of an hermetically sealed box. Obviously, such a structure is of little practical value unless it be provided with means of access to its interior. This has previously been accomplished, in the case of relatively small openings and others which are opened infrequently, by providing a removable panel fitted with a continuous RF gasket, commonly metallic and of mesh or other yielding structure which is compressed between the overlapping parts by bolting or clamping.

A removable panel is practical for RF sealing large openings such as doors for entry of personnel but the use of gaskets with bolts or clamps at many points is not practical if they must be opened frequently. Commonly, any such opening has hitherto been made RF tight by the use of finger stock, which consists usually of one or two parallel strips of tin copper alloy each formed into a series of flexible fingers and attached along its uncut edge to one of the shielding elements to be sealed, with the fingers extending free of that element to make contact with the other element to be sealed in one or two essentially continuous lines around the entire periphery of the opening.

Such a system is satisfactory if sufficient pressure can be maintained on each finger, and if the elements of surface providing contact between parts are free of foreign substances or corrosion-formed films which may act as electrical insulators. However, when used on doors, as for entry of personnel, the requirement of adequate pressure on all parts of the finger stock results in the need for very stiff door leaves and means of developing massive closing forces. For high levels of performance, a correspondingly high degree of conductance in this vital albeit broken line of contact must be developed at the time of the original installation, and must be assured in use of the facility by continuing maintenance. This devolves to careful adjustment of the position of each finger to achieve the desired nice compromise between high pressure for assured contact and low pressure for ease of operation.

It is an object of this invention to provide an improved RF seal for the doors, or other removable closures, of openings in RF shielded enclosures. It is a further object to provide an improved RF seal between separable electrically-conducting shielding surfaces by means of which the surfaces are engageable in a substantial area of mutual contact without requiring manual action, beyond the mere closing of the door. It is another object to provide an improved RF seal in which separable conductive surfaces are held in mutual contact by pressure which results from the mutual attraction of magnetic elements. It is still a further object to secure electrical contact between separable conductive surfaces which may be warped or irregular, thereby to secure a more effective RF seal. Further objects and advantages of the invention will become apparent as the following description proceeds.

Briefly stated, a preferred embodiment of the improved RF seal incorporates a flexible electrically-conductive non-magnetic membrane for surface engagement with ferromagnetic electrically-conductive shielding. One of these members extends about the periphery of the opening to be sealed, and the other is affixed about the periphery of the door or other closure, for mutual area contact to complete a continuous circuit between the shielding of the enclosure and the door. To engage the surface of the membrane uniformly under pressure with the surface of the ferromagnetic shielding, the membrane is backed by a coextensive peripheral magnetic element, which is flexible or flexibly mounted, and acts on the ferromagnetic shielding to engage the membrane under pressure therewith. Because of the flexibility of the structure, the membrane is brought into uniform conductive engagement even though the surface of the shielding may be irregular or warped.

The structure utilized to bring about the flexible relationship of the membrane with the door may assume several forms. In one embodiment, the magnetic element is cemented at spaced intervals to a plastic foam backing strip, and at alternating intervals to the flexible membrane; flexing action of the foam permits the membrane to conform very closely to the surface of the ferromagnetic shielding, and also absorbs the impact of closure. In another form, the membrane is wrapped about the magnetic element, in the form of wrapping or tubing; and also may support the magnetic element in spaced relation to the door, thereby providing an increasingly flexible relationship. The wrapped shielding may have convolutions extending between the door and the magnetic element in this form.

It is also contemplated that one or more pairs of the essential elements may be made integral by utilizing materials having characteristics which meet the functions of both of these elements. Specifically, the magnetic element may be of a composition that exhibits sufficient conductivity, flexibility, and a sufficiently high insertion loss, to serve the function of the conductive membrane in the region of the seal, and thus form a direct connection between the shielding of the enclosure and the door. Plastic compositions of this nature are available. Also, if ferromagnetic shielding is used in the enclosures, a separate ferromagnetic member need not be employed for cooperation with the magnetic element.

While the specification concludes with claims particularly pointing out the subject matter which I regard as my invention, it is believed that a clearer understanding may be gained from the following detailed description of preferred embodiments thereof, referring to the accompanying drawings, in which:

FIG. 1 is a sectional plan view of a preferred embodiment of the invention;

FIG. 2 is a sectional view taken along line 2—2 in FIG. 1;

FIG. 3 is a sectional plan view of another embodiment;

FIG. 4 is a similar view of still another embodiment; and

FIG. 5 is a similar view showing a further form of the invention.

FIG. 1 illustrates an RF seal system by which the principles of this invention have been applied successively at openings in shielded enclosures. A conventionally hinged door 10 is shown installed in a wall of the enclosure 16 to permit ready passage of persons or equipment.
The construction illustrated is typical of the configuration in all portions of the periphery of the door and frame. Thus all elements of the seal are essentially continuous, in the configuration illustrated, over the entire periphery of the door and door frame. Elements associated with each edge are joined at the corners by methods which will be obvious to those skilled in the art.

The connection, at one or both of its interior and exterior faces, bears a shielding structure 12 which may, for example, be of commercial galvanized steel sheet, and possesses insertion loss characteristics equal in value to that of the shielding structure 18 of the enclosure 16.

One edge of a conductive non-magnetic membrane 14 is attached to and supported by the door 1 throughout its length, by means of a clamp 11 and a support bar 13, both of which may be made of steel bar. The membrane 14 may be of copper, and is continuously electrically connected to the shielding structure 12 through the support bar 13. A steel contact bar 15 is attached to the door frame 6 by suitable fasteners (not shown), and forms continuous electrical connection with the shielding structure 18, and thus becomes a portion of the shielding structure of the enclosure.

The separable electrical connection needed to accomplish a satisfactory RF seal is made in the act of closing the door, by superposition of the conductive membrane 14 in contact with the steel contact bar 15. The area of mutual contact coincides in extent with the face of the bar 15. Pressure needed to establish and maintain this contact is developed by mutual attraction of magnetic elements including a magnetic element 17. The magnet 17 is placed in close proximity to the conductive membrane 14 at its rear face, opposite that which provides contact with the contact bar 15, and is flexibly supported so that it is free to move as necessary to maintain that proximity.

The magnet 17 may be formed of a series of flexible plastic permanent magnets, such as are available from the Leyman Corporation, Cincinnati, Ohio, under the trade-name "Plastiform," cut to lengths as necessary, and fitted with negligible gaps between ends to provide an essentially continuous strip about the entire periphery of the door.

The magnet is supported in proximity to the membrane 14 by adhesive-bonding the magnet to a strip of flexible plastic foam 19, which in turn is adhesive-bonded to the door 10. The seal is protected by an edge band 21 secured about the edges of the door.

To give the freedom of movement of the magnet necessary to permit maintaining the membrane 14 in close conformity with the surface of the bar 15, the adhesive bonding is limited to small spaced-apart areas 20 within each plane of bonding, which are staggered as shown in FIG. 2 so that the areas of bonding one surface of the foam fall approximately midway between the areas of bonding the opposite surface. The flexible foam permits any portion of the magnet 17 to move away from the door 10 by flexing action in the foam, or to move closer to the door by compression of the foam, thus allowing the magnet 17 to force the membrane 14 to conform to irregularities in the surface of the bar 15.

In a modified form, the magnet 17 may be adhesive-bonded or otherwise secured directly to the membrane 14, in which case the bonding between the magnet and the foam 19 is omitted.

The magnet 17 thus constitutes the active member, and the steel contact bar 15 the passive member, of a pair of magnetic elements which are separated only by the thickness of the conductive membrane 14, and between which elements there exist substantial forces of mutual attraction which result in the application of adequate pressure on the area of mutual contact between the membrane and the bar 15 to insure a good electrical connection.

It will be apparent that as the door is moved from an open position in a direction to close it, and the conductive membrane 14 approaches the contact bar 15, the forces of mutual attraction between the magnet 17 and the contact bar will become increasingly strong as the distance separating them decreases; assuming no more than normal resistance to movement of the door on its hinges, the forces of mutual attraction can themselves furnish all the effort needed to completely close and RF seal the door.

The objects of this invention can be achieved through the use of arrangements of active and passive magnetic elements such as in the foregoing embodiment, or alternatively through the use of a combination of more than one active magnetic element. Active magnetic elements may be selected from many types, including metallic or ceramic permanent magnets, or electromagnets. Passive magnetic elements may be of any suitable ferro-magnetic material. The magnetic elements may be affixed to other seal elements as in the instant example, or they may be removable. Such alternate arrangements may be realized in many forms, as will be obvious to those skilled in the art. For example, the steel contact bar 15 of FIG. 1 may be omitted if the adjacent shielding element 18 is of ferro-magnetic material, so that it performs the function of a passive magnetic element, and also provides an electrically conductive surface. Galvanized sheet steel will serve this purpose, for example; the steel core of such sheet is ferro-magnetic, while an electrically conductive surface is provided in the zinc coating.

FIG. 3 illustrates another arrangement of magnetic and shielding elements wherein the shielding elements 12 and 18 are made of copper or other non-magnetic conductive metal, and the magnetic elements 15 and 17 are set into recesses in the door and the enclosure to give flush edges. The magnetic elements 17 is enveloped in a portion of the shielding 12, which thus integrally forms the membrane for connection with the shielding 18. Such a combination could be made, for example, by extruding conductive plastic in the complete form of shielding shown, either doing this in such manner that the magnetic element is enclosed in the membrane portion simultaneously with the extrusion operation, or alternatively in such manner that the magnetic element is inserted subsequently to the extrusion operation. The former alternative would readily permit achieving very small or zero clearance or integral bonding between magnetic element and membrane. This can also be accomplished by dispensing the membrane with internal fluid pressure and introducing the magnetic element while the membrane is thus distended.

FIG. 4 illustrates a form of the invention in which the flexible magnetic element 17, in addition to possessing magnetic properties, also has an electrically conductive surface which is electrically continuous with the shielding 12, and thus performs the function of the membrane of other embodiments. In this form, the magnetic element and adjacent shielding 12 can be made in a single unit, for example by simultaneous parallel extrusion of plastic materials of different composition which possess the required magnetic properties, and the other of which possesses the properties of insertion loss required in the conductive shielding. The extrusion is done in such a manner that a physical bond results between the two elements at their junction. Alternatively, this physical bonding could be accomplished, after separate extrusion of the elements, by adhesive bonding or by treatment of the joining surfaces to give them adhesion to one another.

The electrically conductive membrane which is required in the area of contact with the shielding 18 may also be provided by a layer of conductive material, e.g. metal foil (not shown), which is attached to the surface of the magnetic element 17. Such a layer must be made electrically continuous with the shielding 12 by bonding with electrically conductive substances, or alternatively by extending the area of the foil.

In FIG. 5 there is shown an embodiment in which the potential path of least insertion loss penetrates the con-
ductive membrane 14 through not one but two thicknesses, and which supports the magnetic element 17 with great flexibility. The membrane 14 is formed of conductive plastic tubing by extrusion or other means. An elongated plastic permanent magnet 17 is enclosed in the flexible plastic tube, and is supported in close proximity to the surface of the tube by means of convolutions 22 therein. This arrangement is especially useful in applications where the shielding structure 12 is located in a plane that is more remote from the plane of the shielding structure 18 than in the previously-described embodiments; or where it is desired to afford greater freedom for movement of the magnetic element and the membrane relative to the shielding structure 12, for the purpose of conforming to severe irregularities in the surface of the shielding 18.

It will be understood that the magnetic element may be of flexible material, or may comprise a series of separate magnetic elements which are either of flexible or rigid material; and that flexible mounting of the magnetic element may also be provided, as needed to accommodate relative displacement of the magnetic element to bring the conductive shielding surfaces into uniform surface engagement. Various changes and modifications will readily occur to those skilled in the art without departing from the true scope of the invention, which I therefore intend to define in the appended claims without limitation to the details of the embodiments which have been described by way of illustration.

What I claim is:

1. A radio-frequency seal for an RF shielded enclosure structure forming an opening, and a separable closure structure, said seal comprising two mutually magnetically attractive elements extending about the peripheries of the opening in the enclosure and of the closure, respectively; said seal having two separable electrically-conductive surfaces extending about the peripheries of the opening and of the closure, respectively, for mutual surface engagement in a closed position of the closure; each of said magnetically attractive elements backing a corresponding one of said conductive surfaces to compress said surfaces together therebetween in the closed position; at least one of said magnetically attractive elements and the corresponding one of said conductive surfaces being flexible with respect to the corresponding one of said structures, whereby the conductive surfaces are forced into substantially complete mutual surface contact although portions thereof may have an irregular conformation.

2. A radio-frequency seal as recited in claim 1, in which at least one of said electrically-conductive surfaces is formed by non-magnetic electrically-conductive shielding.

3. A radio-frequency seal as recited in claim 1, in which at least one of said magnetically-attractive elements is electrically conductive and in itself forms one of said electrically-conductive surfaces.

4. A radio-frequency seal for an enclosure having a structure defining an opening and a separable closure structure, and conductive RF shielding extending over a surface of each of said structures; said seal comprising two mutually magnetically attractive elements extending about the peripheries of the opening in the enclosure and of the closure, respectively, and supported by the corresponding structures; a flexible non-magnetic electrically-conductive membrane extending peripherally about one of said structures in electrical contact with the shielding thereof, for surface engagement with the shielding of the other of said structures in the closed position of the closure; one of said magnetically attractive elements backing said membrane and being flexible with respect to said one of said structures, whereby said membrane and said shielding are forced into substantially complete surface contact although portions thereof may have an irregular conformation.

5. A radio-frequency seal as recited in claim 4, together with a resilient strip interposed between said one of said magnetically-attractive elements and said one of said structures to afford flexible support therebetween.

6. A radio-frequency seal as recited in claim 5, in which said strip is secured to said one of said magnetically-attractive elements only at locations spaced apart along said strip, and is secured to said one of said structures only at further locations spaced apart along said strip and interspersed between the first-mentioned locations, whereby all portions of said one of said elements are flexibly supported with respect to said one of said structures.

7. A radio-frequency seal as recited in claim 4, in which said membrane envelopes said one of said magnetically-attractive elements and supports said one of said elements in spaced-apart flexible relation to said one of said structures.

8. A radio-frequency seal as recited in claim 7, in which said membrane comprises compressible tubing of larger cross-section than said one of said elements and having convolutions extending intermediate said one of said elements and said one of said structures to locate said one of said elements within said tubing.

No references cited.

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