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TITLE OF INVENTION

SEALING GROMMET

FIELD OF THE INVENTION

[0002] The invention relates to grommets and similar devices used for sealing openings in pressurized enclosures such as those provided for supplying conditioned air to electronic equipment in data centers and the like while allowing cables, hoses, conduits and the like to pass through the openings.

BACKGROUND OF THE INVENTION

[0003] In data centers in particular, and in a variety of other circumstances as well, there is a need and desire to provide for the passage of cables, conduits, hoses and other pass-through elements, through openings in floors, walls, ceilings, cabinet panels, etc., while providing for effective sealing of the opening and at the same time accommodating the efficient addition and/or removal and/or rearrangement of the pass-through elements as may be required from time to time. A typical data center, for example, will house a large number of computer servers, arranged in racks, which are connected by cables to other servers, networks, etc. These data centers typically are highly dynamic in the sense

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that equipment is continually being added and removed, rearranged and reconnected, as networks are expanded, and restructured.

[0004] Because of significant heat generated by servers in a data center, and the detrimental effect of such heat on computer performance, it is customary to provide for cooling the servers, usually by supplying conditioned air to the equipment racks. To this end a typical data center is constructed with a raised floor, providing a space for cables, hoses, conduits and other service elements, and also functioning as a plenum for the supply of conditioned air. The elements of the raised floor, typically metal "tiles", are provided with specially placed outlet openings for the discharge of conditioned air, for example at the front of a rack of servers. The conditioned air, under relatively higher pressure than the ambient air in the data center, is discharged upwardly along the front of the rack and is drawn into the individual servers by internal blowers provided therein.

[0005] Also associated with the server racks are one or more floor openings which allow cables and other service elements to be passed through the floor tiles from the under-floor space, for connecting to the servers. These openings, sometimes referred to herein as service openings, are separate from the before mentioned outlet openings for conditioned air. It is important to minimize the escape of conditioned air through these service openings because air released through these openings simply mixes with ambient air in the data center and does not provide efficient or effective cooling of the servers. At the same time, it is desired to provide for the easy and efficient installation, removal and other rearrangement of service elements in these service openings. Accordingly, any sealing means associated with such openings needs to accommodate such rearrangement while at the same time providing for an effective seal

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against the undesired loss of conditioned air under pressure from the plenum space below the raised floor.

[0006] One particularly advantageous form of seal for achieving the objectives stated above is described in the Sempliner et al US Patent No. 6,632,999, the disclosure of which is incorporated by reference in its entirety. The '999 patent discloses a form of grommet which includes a frame, positioned in or over a service opening and provided with one or more brush-like elements which extend across the opening of the frame and serve to resist any flow of conditioned air from a pressurized enclosure or plenum space into the ambient air on the opposite side of the grommet. The brush-like elements accommodate the presence of pass-through elements, such as cables, conduits, etc. while substantially minimizing air flow through the opening. The arrangement also accommodates and facilitates the installation, removal and rearrangement of the pass-through elements as is necessary in the dynamic environment of a data center.

SUMMARY OF THE INVENTION

[0007] The present invention relates to an improved form of sealing grommet of the general type disclosed in the above-mentioned '999 patent, which incorporates a novel form of impermeable, flexible elastomeric sealing member providing highly efficient sealing under all operating conditions. An almost perfect seal is provided when no pass-through elements are present, and a highly efficient seal is provided when one or more pass-through elements extend through the grommet because the character and configuration of the elastomeric sealing member enable it to closely envelop and form a seal around the pass-through elements and reduce to a practical minimum any open space around them.

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[0008] In one advantageous form, the grommet of the invention has opposed, impermeable, resiliently deformable, elastomeric sealing members, formed with deep corrugations. The corrugated sealing members provide a highly efficient seal with and without cables passing through the grommet. The impermeable material of the corrugated sealing members allows substantially no air to pass through the interior portion of the sealing members. When the corrugated sealing members are undisturbed (that is, not displaced by a cable or other pass-through element) the corrugations of opposed sealing members preferably are aligned substantially "in-phase" such that the free ends of the opposed sealing members abut one another and form a seal therebetween. When a cable or other pass-through element extends through the grommet, the free ends of the corrugations are displaced away from their "at rest" positions. However, the configuration of the sealing members, derived from the deep corrugations therein in relation to the width of the opening, enables and causes the flexible elastomeric sealing members to closely envelop the cable (including very large cables or bundles of cables) and maintain substantial closure of a sealing line between sealing members, even when the cable is displaced from the center of the grommet.

[0009] The corrugations of the sealing members preferably are arranged in a repeating wave shape, with semicircular apex and trough portions interconnected by generally vertical side portions. Other repeating and non-repeating (e.g., variable) wave forms may also be suitable, such as a sine wave, square wave, triangle or saw tooth waves and the like.

[0010] In certain forms of grommet seals, it may be advantageous to form cross corrugations, particularly near the free ends of the sealing members. The cross corrugations, which can be provided in one or more rows, provide for a softer action at the free ends of the sealing members and can further enhance the ability of the sealing members to

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closely envelop, and form a seal around, any pass-through elements. The cross corrugations preferably are relatively shallow in comparison to the deep primary corrugations of the sealing member.

[00011] The grommet of the invention typically includes a relatively rigid peripheral frame, preferably of a hard plastic material, such as ABS. The frame may be formed from two generally U-shaped half sections, with a resiliently deformable, corrugated sealing member mounted in each half section to form two half-grommets. The two half-grommets, constituting a grommet kit, are joined together when installed to form a complete grommet. A single half-grommet may be utilized in certain circumstances, as where a floor or panel opening abuts a wall or other confronting surface that serves as a boundary against which the open side of the half-grommet is positioned.

[00012] Although the sealing members may be fixed to the frame members in various ways, a preferred and advantageous way is to co-mold the elastomeric sealing members with the frames such that the sealing members form a strong bond with the frame sections. To particular advantage, the elastomeric material of the sealing members is electrically conductive, and the co-molding procedure is carried out in such a manner that a portion of the conductive material is caused to flow from inside the frame to one or more locations on the outside of the frame to provide electrical contact with the surface on which the grommet is mounted. (usually a metal tile).

[00013] For a more complete understanding of the above and other features and advantages of the invention, reference should be made to the following detailed description and to the accompany drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

[00014] FIG. 1 and 2 are perspective views from above of "male" and "female" type half sections respectively of one preferred form of sealing grommet according to the invention.

[00015] FIG. 3 is a top plan view of one form of sealing grommet incorporating features of the invention.

[00016] FIG. 4 is a cross sectional view as taken generally on line 4-4 of Fig. 3.

[00017] FIG. 5 is a cross sectional view as taken generally on line 5-5 of Fig. 3.

[00018] FIG. 6 is an enlarged, fragmentary cross sectional view of an encircled portion "FIG. 5" of Fig. 5 showing structural details.

[00019] FIG. 7 is a cross section view as taken generally on line 7-7 of Fig. 3.

[00020] FIG. 8 is an enlarged, fragmentary cross sectional view of an encircled portion "FIG. 8" of Fig. 7.

[00021] FIG. 9 is a bottom plan view of the sealing grommet of Fig. 3.

[00022] FIGS. 10 and 11 are side and end elevational views respectively of the sealing grommet of Fig. 3.

[00023] FIG. 12 is a cross sectional view as taken generally on line 12-12 of Fig. 10.

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[00024] FIG. 13 is an enlarged, fragmentary cross sectional view of an encircled portion K of Fig. 12.

[00025] FIG. 14 is an enlarged, fragmentary perspective view of an encircled portion "FIG. 14" of Fig. 1.

[00026] FIG. 15 is an enlarged, fragmentary cross sectional view as taken generally on line 7-7 of Fig. 3, illustrating further details of grommet construction.

[00027] FIG. 16 is a simplified schematic view illustrating the use of a half grommet according to the invention used for sealing an opening in a floor, panel or the like, where one side of the opening is defined by a wall or other surface disposed at right angles thereto.

[00028] FIG. 17 is a simplified schematic view illustrating the use of a sealing grommet according to the invention in connection with a plenum providing a space for service elements and supplying conditioned air under pressure for controlled discharge through selected openings

[00029] FIG. 18 is a top view of an alternate form of the new grommet showing a pass-through element enveloped by the grommet seal.

[00030] Fig 19A is a side elevational view of an alternative embodiment of a grommet according invention having a round configuration for use in connection with a circular service opening.

[00031] Fig. 19B is a top plan view of the grommet of Fig. 19A.

[00032] Figs. 19C and 19D are cross sectional views taken generally along lines 19C-19C and 19D-19D respectively of Fig. 19B.

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[00033] Fig. 19E is an end elevational view of the grommet of Fig. 19A.

[00034] Fig. 19F is a bottom plan view of the grommet of Fig. 19A.

[00035] Fig. 19G is a cross sectional view as taken generally along line 19G-19G of Fig. 19B.

[00036] Fig. 19H is an enlarged fragmentary view of a portion of the grommet shown in the encircled portion of Fig. 19F.

[00037] Figs. 20A and 20B are bottom and top perspective views respectively of the grommet shown in Figs. 19A-19G.

[00038] Fig. 21 is a collective view of the embodiment of Fig. 19, comprising top and front perspective views of male and female grommet parts and enlarged, fragmentary views showing details of circled portions of the perspective views.

[00039] Figs. 22A and 22B are an exploded view and a top perspective view respectively of another embodiment of the invention, in which the individual corrugated elements of the elastomeric seal are arrayed in a circular configuration, sealing against a floor tile or the like.

[00040] Fig. 23 is a collective view comprising a bottom view and a side view of the sealing element incorporated in the embodiment of Fig. 22.

[00041] Fig. 24 is a bottom perspective view of the sealing element of Fig. 23.

DETAILED DESCRIPTION OF THE INVENTION

[00042] Referring now to the drawings, and initially to Figs. 1-4 thereof, the numeral 10 designates generally a sealing grommet according to a preferred embodiment of the invention. The grommet comprises an external frame formed of two half-sections 11, 12 of generally U-shaped configuration. Each frame section 11, 12 has a back portion 60 and two opposed side portions 62, 64 extending from opposite ends of the back portion 60. Each of the back and side portions 60, 62, 64 preferably has an inverted L-shaped cross section defined by a vertical wall 13, 14, 15 (see Fig. 7), dividing the frame into inner and outer portions, and an outwardly extending horizontal flange 16, 17, 18. The illustrated grommet is intended to be seated in or over a generally rectangular service opening (not shown) of about 6 by 8 inches in size, although it will be understood that the grommet of the invention may take a variety of shapes and sizes depending upon requirements.

[00043] Figs. 1 and 2 illustrate individual half-grommet sections that are configured to be securely but releasably joined together to form a frame of closed, rectangular configuration. To this end, one half section 11 is a "male" section and is provided at free ends 66, 68 of the side portions 62, 64 with vertically extending, tapered tongue elements 19 arranged to be received in complimentary shaped vertical grooves or slots 20 located at corresponding positions in the opposite or "female" half section 12. The slots 20 are open at the bottom and closed at the top, and are tapered to correspond to the taper of the tongue elements 19 to provide a releasable, friction fitting joint when the two frame sections 11, 12 are joined. See Figs. 12, 13. Desirably, the two frame sections 11, 12 of the grommet are not symmetrical, in that both of the tongue elements 19 are provided on the male frame section 11 and both slots 20 are formed in the female section 12. The free ends 66, 68 of the side portions 62, 64 of the U-shaped

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female frame section 12 are thus flat and capable of being butted flush to or closely against an external confronting boundary surface, enabling half-sections of the grommet to be utilized in appropriate circumstances.

[00044] Pursuant to aspects of the invention, each of the U-shaped frame sections mounts a resiliently deformable sealing member 21 forming an air barrier of unique and advantageous configuration. The sealing member has a corrugated portion formed of a relatively soft and flexible web-like elastomeric material which is impervious to air, and which is shaped in a repeating wave form propagating over at least a portion of the width and/or depth of the sealing member, but more typically from one side portion 62 to the other side portion 64 of the frame and for the full depth of the frame. The corrugated portion has a corrugated free end portion and a base portion opposite to the free edge. The corrugated free end portion is resiliently deformable toward the base portion. Where the corrugated portion extends for the full depth of the sealing member, the base portion will be located at the back portion of the frame.

[00045] In the illustrated form of the invention, the repeating wave form is in the nature of a set of deep corrugations 22 defined by apex portions 23 and trough portions 24 of generally semi-circular cross-section and generally vertical wall portions 25 connecting the apex and trough portions. In an illustrative but non-limiting example of the invention, a suitable form of sealing member may have a corrugated wave form in which the corrugations propagate parallel to a horizontal propagation axis (X) (Fig. 1) and oscillate parallel to a vertical oscillation axis (Y) orthogonal to the propagation axis. For a common grommet size having a 8 inch by 6 inch frame opening, an advantageous configuration of the sealing member can be a deeply corrugated form, as shown in the drawings, with a wave length (parallel to the propagation axis X) of about one inch and an amplitude (parallel to the oscillation axis Y) of about 1.5 inches (the term

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"amplitude", as used throughout, refers to peak-to-trough amplitude of a wave form). The apex and trough portions of the wave may have a radius of about one-fourth inch, with adjacent peaks and troughs being connected by the generally vertical walls 25. The sealing member 21 is resiliently deformable at least in toward the back portion 60 of the frame 11, 12, for example in a deformation direction (Z) orthogonal to both the propagation (X) and oscillation (Y) axes. While the described wave form is particularly desirable, it is contemplated that many other wave forms may also be suitable, as heretofore mentioned.

[00046] For practical reasons it is preferable to utilize wave forms of constant wave length and amplitude over the full width of the corrugated portion of the sealing member 21. However, where desired, the wave shape, frequency or amplitude may be varied along the width (propagation axis) or depth (along axis Z) of the sealing member. In general, it is desired that the flat pattern length or arc length (L) of the corrugated portion of the sealing member 21 be from about 2 to about 6 times the width (W) of the corrugated portion, where the arc length (L) is the length of the arc created by the wave form and the width (W) is measured generally parallel to the propagation axis (X). Thus, where the corrugated portion spans from one side portion 62 of the frame to the other side portion 64, the width (W) will be the distance between such side portions. Also, in general, a ratio of amplitude of the wave form to its wave length desirably is a number greater than one. Thus, in the typical and non-limiting example above, a sealing member for a grommet frame having an eight inch opening might advantageously be formed with 8 full corrugations, each having an amplitude of about 1.5 inches, a wave length of about 1 inch, and an arc length of about 3.5 inches. The overall arc length (L) for the eight inch sealing member as described would be approximately 28 inches and the ratio of arc length(L) to width (W) would be approximately 3.5. A preferable ratio of arc length to width is somewhat variable, depending on the nature

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of the sealing member material, shape and size of sealing member 21, the shape and size of the pass-through element, etc. However, inasmuch as the ability of the sealing member to envelop and seal around a pass-through element positioned in the grommet is a substantial function of the amount of "excess" material surrounding the pass-through element, the ratio of arc length to width should be such as to provide a desired degree of such "excess" material. Typically, a ratio of 2 would be considered to be a practical minimum. Ratios higher than 3.5 may be appropriate where the length of the corrugations (from fixed ends to free ends) is longer than in the example described herein, for example, or where the material of the sealing members is less flexible.

[00047] To provide for mounting of the sealing member 21 in the frames 11, 12, the sealing members advantageously are formed with side flanges 26, 27, extending vertically from the end-most corrugations, and a vertical back flange 28 which extends along the full width of the sealing member and which is integral with the back ends of the corrugations 22. Preferably, the side flanges 26 and 27 join with the back flange 28 at the corners (see Fig. 12) and form a three-sided, U-shaped support for the sealing member. The sealing members can be mounted to the frame elements 11, 12 by securing the side and back flanges 26, 27, 28 to the respective side and back walls 13, 14, 15 of the frame sections. This can be done by fasteners, adhesives, etc., but preferably and in accordance with a feature of the invention the sealing member is co-molded to the frame such that the flanges 26, 27, 28 are mold-bonded to the frame walls 13, 14, 15. This provides a far superior joining of the components and provides manufacturing economies as well. The co-molding procedures require certain compatibilities between the frame material and the material of the sealing members, to be described hereinafter.

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[00048] As shown in Figs. 1 and 2, the corrugations 22 are integral with and fixed at their back ends to the back flange 28 and extend in cantilever fashion from the back flange to a point slightly beyond (for example, about 0.010 inch beyond) a sealing plane 32 connecting the outer ends of the side portions 62, 64 of the frame 11, 12 (ignoring the tongues 19 in the case of the frame 11). The arrangement is such that, when two frame sections 11, 12 are joined in the manner heretofore described, the corrugated portions of the sealing members will interfere slightly and thus be slightly compressed to assure an effective seal along the sealing plane on which the two sealing members abut. Additionally, the corrugations 22 of the respective grommet sections 10 are aligned in phase, such that the outer end edges of the corrugations of one sealing member follow and directly abut the outer end edges of corrugations of the other sealing member.

[00049] In a particularly advantageous embodiment of the invention, the corrugated free end portion of the sealing member 21 is formed with an end flange 29 which broadens the end surface of the corrugations. The end flanges of opposed sealing members can thus remain in sealing contact even though the opposed corrugations become slightly out of phase during use, as when portions of the sealing members are displaced by pass-through elements, or by temporary displacements resulting from repositioning or removing pass-through elements. In the illustrated embodiment, the end flange 29 preferably is in the form of an arcuate portion which terminates in a flat outer end portion 29a. The flange 29 turns downwardly and the outer end portion 29a is disposed substantially at right angles to the web material of the sealing member, substantially parallel to the sealing plane 32 containing the ends of the primary corrugations. To advantage, the thickness of the material forming the corrugations 22 is tapered slightly from the fixed ends thereof to the corrugated free end portion. As an illustrative and non-limiting example,

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the material may have a thickness of about 0.075 inch at the fixed end thereof and taper gradually or in steps toward the corrugated free end portion thereof to a final thickness of about 0.045 at the end flange portion 29.

[00050] As illustrated particularly in Figs. 1 and 2, and in Fig. 15, and in accordance with certain aspects of the invention, the outer end portions of the corrugations 22 may advantageously be formed with a set of one or more relatively shallow secondary (or "cross") corrugations 30, 31 which facilitate displacement of the primary corrugations 22 caused by the presence of a pass-through element and also improve the ability of the sealing member to envelop and seal around a pass-through element while elsewhere maintaining closure along the sealing plane 32 between opposed sealing members. In the form of the invention illustrated in Figs. 1, 2 and 15, the sealing member 21 includes a first (outer) secondary corrugation 30 and a second (inner) secondary corrugation 31. The amplitude of the secondary corrugations may decrease from the inner to the outer secondary corrugation. For example, the outer secondary corrugation 30 may have an amplitude of about 0.050 inch, while the inner secondary corrugation 31 may have a lesser amplitude of about 0.025 inch. The wave length of the secondary corrugations may be constant at about 0.67 inch. In practical embodiments of the invention, a ratio of amplitude to wave length of the secondary corrugations may be in a range of from about 1:13.5 to about 1:27. The amplitude of the secondary corrugations is significantly less than a typical 1.5 inch amplitude of the primary corrugations 22.

[00051] The secondary corrugations 30, 31 preferably propagate parallel to a secondary propagation axis (Z) which is orthogonal to both the propagation (X) and oscillation (Y) axes of the primary corrugations. The

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secondary propagations oscillate normal (i.e., perpendicular) to the surface of the primary set of corrugations.

[00052] In a preferred embodiment of the invention, the corrugated sealing members 21 are formed by co-molding of the sealing members with the frame sections 11, 12. The co-molding operation involves placement of pre-formed frame sections into a mold and thereafter injecting the material of the sealing member into the mold. The co-molding operation simultaneously forms the sealing member and bonds its side and back flanges 26, 27, 28 to side and back walls 13, 14, 15 of the frame section. To this end, the respective materials of the frame sections and the sealing members must be compatible in order to achieve a desired molecular bond between the frames and sealing members. Desirably, the frame sections may be formed of a blend of polycarbonate and a styrene based material such as ABS. Such a material has the strength and rigidity desired for the frame and also the necessary fire rating for the intended service. A suitably compatible material for the sealing members 21 is a thermoplastic elastomer commercially available from the RTP Company of Winona MN. A particularly desirable thermoplastic elastomer is offered by the RTP Company as of the filing date hereof under its designation RTP 2099 E x 123155A. The indicated material is flexible and soft, with a Shore durometer of approximately 47A, has the necessary fire rating (UL94-40) and, importantly is electrostatically dissipative (ESD) so as to be able to dissipate electrostatic charges that may develop in normal operations of a data center.

[00053] Although a thermoplastic elastomer material is particularly desirable for use in the grommet of the invention, other materials can be used to advantage with an acceptable level of performance. For example, non-thermoplastic elastomers or incompatible elastomers may be utilized where a molecular bond between the frames

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and the sealing members is not a requirement. In such cases, the sealing members may be secured to the frames by suitable adhesives and/or mechanical fasteners.

[00054] In order to take full advantage of the ESD characteristics of the thermoplastic elastomer, provisions are made for causing a portion of the elastomer to flow during the molding process to positions in which contact areas 36 formed thereby will be in electrical contact with a floor tile or other grommet-supporting structure when the grommet is mounted in a service opening. For example, the elastomer may flow underneath the outwardly extending horizontal frame flanges 16, 17 such that, when the grommet is installed on an electrically conductive floor tile (typically used in data centers) or other conductive surface, the material of the sealing member 21 will be in electrical communication with the floor tile to provide one or more conductive paths from the sealing members for electrostatic discharge. To advantage, the contact areas 36 positioned under the flanges 16, 17 fully or partially encircle, or are otherwise closely associated with, fastener openings, such as screw holes 33, formed in the flanges for securing the grommet in place. When the grommet frame is installed and secured with screws or other fasteners (not shown) the underlying elastomer contact areas 36 are compressed into good electrical contact with the conductive support surface below.

[00055] Various arrangement can be provided for causing a flow of elastomer underneath the flanges 16, 17, for example, providing one or more gate openings (not shown) in upper portions of the side or back walls 13, 14, 15. One preferred arrangement, however, is to provide one or more flow paths, comprising notches 34 (Fig. 6) in the bottoms of side walls 13, 14 and flow channels 35 in outside surfaces of such walls, to allow an interconnecting portion, preferably in the form of a narrow strip 38 of elastomeric material, to flow underneath the walls 13, 14, upward along the

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outside surfaces thereof and then outward under the horizontal flanges. The notches 34 and channels 35 preferably are aligned with the screw holes 33, and channeling means are provided under the horizontal flanges and/or in the mold to cause the conductive elastomer to flow outward along the bottom of the horizontal flange and preferably to fully or partially encircle the screw hole 33 as shown at 36 in Figs. 6 and 9. The encircling contact areas 36 of the elastomer preferably project a short distance (for example, about 0.015-0.025 inch) below the bottom of the horizontal flange material 37 surrounding the screw hole 33 such that, when the grommet is installed in a service opening, the flange 16, 17 initially rests upon the encircling contact portions 36. When the grommet is tightened down with screws or other fasteners, the encircling contact areas 36 are compressed to establish a desired level of good electrical contact.

[00056] Preferably, the contact areas 36, interconnecting portions 38 and corrugated portions are integrally formed in the molding process, such that the interconnecting portions connect the corrugated portion with the contact areas forming a continuous electrical path for discharge of an electrical charge from the sealing member to the flooring or other grommet-supporting structure.

[00057] In the illustrated and preferred embodiment of the invention, the side walls 13, 14 of the frames 11, 12 are formed with vertical fins 39 which project from a position adjacent to the strips 38 of conductive elastomer extending vertically along the end walls. The fins 39 serve, among other things, to position the grommet in a service opening and to protect the conductive strips from abrasive contact with other surfaces which might degrade or interrupt the conductive pathway provided by the strips.

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[00058] Although typical usage of the grommet sections of Figs. 1 and 2 involves assembling the two half frames to form a grommet of closed configuration, there are various circumstances in which a single U-shaped grommet frame may be preferred. One such circumstance is shown in Fig. 16, wherein it is desired to seal a service opening 40 in a floor, cabinet, panel or other support surface structure 41, where the service opening 40 is defined in part by the surface structure 41 and in part by an adjacent boundary structure 42, such as a wall disposed, for example, perpendicular to the surface structure 41 and forming a confronting boundary surface. In such a case it is feasible, and in some cases preferable, to install a single half section of a grommet into the service opening, with the exposed outer edges of the corrugated portion of the sealing member 21 positioned against the boundary structure 42. For this configuration, a half grommet section formed with a female frame section 12 would be chosen in preference to one formed a male section 11, to enable the ends of the side portions 62, 64 of the frame section 12 to be positioned flush against the boundary structure 42.

[00059] Preferably, when the grommet half section 12 is installed in the service opening 40, the ends of the frame side walls 13, 14 are positioned against the confronting surface defined by the boundary structure 42. Because the corrugated free end portion of the corrugated portions of the sealing element projects slightly beyond the ends of the frame wall, this will cause the ends of the corrugations to be compressed slightly (e.g., 0.010 inch) to assure an excellent seal.

[00060] Although sealing grommets according to the invention can be employed in a variety of ways, a common usage is in connection with raised flooring structures of the type typically employed in data centers. Such raised flooring provides under-floor space for wiring and other service elements connected to servers and other electronic devices

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housed at the data center, and also forms a plenum space for supplying conditioned air under pressure for cooling of the devices. A typical such arrangement is shown schematically in Fig. 17, which illustrates a raised flooring structure 43 supported above a base floor 44, typically by spaced apart vertical supports (not shown). An equipment rack 45 is supported on the raised floor 43, and typically contains a number of devices (not shown) that may be operating on a 24/7 basis.

[00061] Closely adjacent to the equipment rack 45, the floor 43 is provided with one or more air discharge openings 46, which allow conditioned air supplied via a plenum space 47 between the base floor 44 and raised floor 43 to flow out of the plenum space. The discharge openings 46 are of a suitable size, shape, number and location to provide for a desired level of cooling air flow to the rack 45, typically upwardly along the front of the rack, allowing the devices to draw in the cooling air by means of internal fans. Also adjacent to the rack 45 is a service opening 48, through which wires, cables and other service elements 49, 50 are passed. The service elements 49, 50 extend through the plenum space 47 and exit through the service opening 48, which is separate from the air discharge openings 46 and may be spaced some distance therefrom. Elements extending through a given service opening may be connected to one or more racks, depending on the arrangement of a particular data center.

[00062] In the arrangement of Fig. 17, a sealing grommet 10, formed of a pair of grommet half sections 10, 11 is installed in the service opening 48 to allow the service elements 49, 50 to pass through the service opening while substantially sealing the opening against the unintended loss of conditioned air into the ambient space. The two half sections, which may be assembled on-site, enable a grommet to be installed without requiring existing service elements to be disconnected. Likewise, in order to install

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new service elements, or re-arrange previously installed elements, the grommet sections can be separated easily, if necessary, to facilitate access to and through the service opening 48.

[00063] Fig. 18 illustrates an alternate and simplified form of sealing grommet according to aspects of the invention, in which a corrugated form of grommet seal has neither cross (secondary) corrugations nor flanges at the free ends of the corrugations. The illustration of Fig. 18 shows a relatively large diameter (e.g., greater than one inch) service element passing through a standard 6 inch by 8 inch grommet opening sealed by two opposed, corrugated sealing members. It can be seen in Fig. 18 that the corrugated sealing members, although considerably displaced and distorted, are able to closely and sealingly envelop the service element and substantially close together along the central sealing line. The sealing grommet of the invention thus provides a significantly superior air barrier seal than sealing grommets of heretofore known types while retaining or improving upon other advantageous features of known grommets.

[00064] It will be evident that grommets and other seals incorporating the principles of the invention need not be in the specific form herein illustrated. A grommet section may, for example be formed in an extended length and may be adapted to be cut to desired lengths at a job site and/or joined with other sections, if desired. The seals may also be employed for purposes other than the accommodation of pass-through elements, as in forming a seal between two extended panel sections, such as a floor and wall.

[00065] In addition, although the sealing members of the invention may be manufactured by molding processes, and particularly co-

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molding to frame sections, other procedures may be employed to derive the desired forms of sealing members.

[00066] The illustrated form of corrugated sealing member is both efficient and easily manufactured. However, other repeating or non-repeating (e.g., variable) wave forms (or other shapes) may be utilized in the design and manufacture of corrugated sealing members. It is advantageous that the wave form of the corrugated portion has an arc length (L) significantly in excess of the width (W) of the corrugated portion (or of the opening between the side portions of the grommet frame). Preferably, the ratio of L to W is between about 2:1 to about 6:1 so that, when a pass-through element is accommodated in the grommet, the substantial "excess" arc length of the corrugated portion of the sealing member enables the edge of the sealing member to partially unfold at the location of the pass-through element and to partially surround and envelop the pass-through element to both seal around the pass-through element and to close the sealing line along which a pair of sealing members meet.

[00067] Where a grommet of closed configuration is assembled from a pair of opposed half sections, it is not necessary that the sealing line along which the respective sealing members meet be a straight line. In this respect, the corrugated free end portion could be of arcuate, wavy or other configuration (as viewed from above) as long as the edge configurations of a pair of sealing members are complementary such that, in the absence of a pass-through element, the corrugate free end portions contact each other over the full length of the sealing line.

[00068] While the grommet of the invention is best manufactured in two mutually engageable half sections and is most useful when manufactured in two sections, many of the benefits of the invention may be

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realized in structures in which one or more wave form sealing members are incorporated into a one-piece frame of closed configuration.

[00069] The various forms of the invention illustrated hereinabove relate to grommets with corrugated portions that are configured in flat form, where the propagation axis of the primary corrugations is linear. However, it will be understood that the corrugated portion the grommet may be formed as an arcs or cylinder, or wave forms, for example, in which case the propagation axis of the primary corrugations would be correspondingly non-linear, such as arcuate, cylindrical or wavy. For example, such a non-linear propagation axis could be an arc or spline in a plane parallel to a plane defined by the (X) and (Y) axes. Alternatively, the corrugated portion could be fan-shaped, with the propagation axis being an arc in a plane parallel to a plane defined by the (X) and (Z) axes. The function such grommets would be the same as above described, in that the corrugated free end portion of the non-linear corrugated portion would form a seal in cooperation with a boundary surface (planar or otherwise), for example, or with a second grommet part of similar or complimentary non-linear configuration, or a mating pair of arcuately configured sealing elements could be mounted in a single closed frame of corresponding arcuate shape.

[00070] Figs. 19-21 illustrate an embodiment of the invention in which corrugated sealing members 70-71 of the general type shown in Figs. 1-17 are configured to be mounted in a circular frame 72, advantageously formed by two semi-circular half-sections 73, 74. The corrugations 75 of the sealing members are aligned in the same direction, perpendicular to a sealing plane 76 extending between the sealing members 70, 71. The corrugated free end portion of each sealing member would project slightly beyond such sealing plane, absent the opposing sealing member. Thus, the sealing members are compressed when the frame sections are assembled. The characteristics of the sealing elements

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preferably are as above described with respect to operative ratios of width to arc length, amplitude to wave length, preferred materials, etc. To advantage, the main or primary corrugations 75 are formed with secondary or cross corrugations 83 as heretofore described in connection with the embodiment of Figs. 1-17.

[00071] The two corrugated sealing members 70, 71 are positioned to abut each other with their respective corrugated portions in phase, as shown best in Fig. 20. The corrugations 75 of the sealing members also preferably have downturned flanges 77 which maintain an effective seal even if the opposed corrugations become slightly misaligned in use.

[00072] As shown particularly in Figs. 20 and 21, the sealing members 70, 71 are formed with generally semi-circular, vertically extending flanges 81, 82, respectively, integral with the corrugations 75. The flanges 81, 82 serve the function of the back and side flanges of the previously described embodiment. In this respect, in a particularly preferred embodiment, the sealing members can be co-molded with the frames 73, 74 to provide an extremely strong bond between the frames and sealing members. Additionally, the side walls and/or outwardly extending horizontal flanges of the frames 73, 74 may be provided with openings (not shown) to permit a flow of the material of the sealing members (e.g., thermoplastic elastomer) underneath the outwardly extending horizontal flanges so that the material, preferably somewhat electro-conductive, makes good contact with the floor tile and provides a path for the dissipation of electrostatic charges from the sealing members.

[00073] The two half sections 73, 74 of the grommet frame are provided respectively with slots 79 and tongues 80 to accommodate

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assembly of the two half-sections around service elements (not shown) already in place in a service opening.

[00074] The circular grommet of Figs. 19-21 is intended for "tool-less" installation, in that it can be snapped or friction fit, or otherwise securely placed in an opening in a floor tile, cabinet, panel, etc. (not shown) without the use of a hand tool or the like. To this end, clip elements 78 may be formed on the exterior walls of the frames 73, 74 to engage the floor tile when the frame is inserted. Where appropriate, fastening elements (not shown) may be used to secure the grommet flanges to an underlying support surface

[00075] In another preferred embodiment of the invention, shown in Figs. 22-24, a sealing member 90 is of a cylindrical form, with the propagation axis of its corrugated waves 97 forming a circle and the oscillation axes of the waves being radially disposed. The sealing member has an integral, annular top flange 91 which is co-molded with or adhesively or otherwise joined with a backing plate 92. The backing plate 92 is provided with two or more spacer posts 93 arranged to pass through openings 94 in the annular top flange 91. The grommet, in operation, is positioned over a service opening 95 in a floor tile or other panel 96 and secured thereto by suitable screws or other fasteners (not shown) directed through the spacer posts. The length of the spacer posts advantageously is such that the lower ends of the corrugations 97 are slightly compressed against the surface of the tile or panel 96. In a preferred form, the corrugations 97 are formed with outturned flanges 98 in the same manner as previously described embodiments.

[00076] In the operation of the grommet of Figs. 22-24, the sealing member 90 of the grommet forms a seal surrounding the service opening 95. Cables and other service elements (not shown) can be passed

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through the opening and between the flanged lower ends of the corrugations 97 and the surface of the tile or panel 96. The deep corrugations of the sealing member cause and enable the material thereof to closely envelop and seal around the service elements in a highly efficient manner, with minimal leakage of conditioned air. The function of the circular grommet form is much the same as that of the half-grommet shown in Fig. 16, where the sealing element is confronted by a boundary surface, such as a wall. In the case of the circular grommet, the confronting boundary surface is the tile or panel.

[00077] If desired, the corrugations 97 of the grommet of Figs. 22-24 can be splayed outwardly from top to bottom in the form of a truncated cone instead of the illustrated cylindrical configuration.

[00078] A grommet of the general type shown in Figs. 22-24 may also be formed as a portion of a cylinder (i.e., an arc, not shown), positioned with the flanged ends of the corrugations placed in contact with a confronting boundary surface and a closure surface (not shown), either external or incorporated into the structure of the grommet frame or sealing member, extending across the chord of the arc.

[00079] Many of the principles, features and advantages of the invention can also be incorporated in to a grommet of circular configuration (not shown), in which a sealing element is mounted within a circular frame and has a corrugated portion formed with primary corrugations propagating in a circle about a center of the grommet and projecting radially inwardly from the circular frame, where the primary corrugations have a progressively diminishing wave length from outside to inside of the grommet. Secondary or cross corrugations, if utilized, would propagate radially with respect to the radially disposed corrugations.

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[00080] As discussed above, sealing grommets are commonly used in service openings in horizontal floor panels. Therefore, in the foregoing description, some features of the grommet have been defined with respect to horizontal and vertical directions, or upward and downward directions, or the like. However, it will be understood that such definitions are merely for convenience as the grommet can be used and installed in other orientations, such as in a service opening in a vertical wall panel, upside down in a ceiling panel, or in some other orientation. Therefore the definitions of the features of the grommet with respect to horizontal/vertical or upward/downwards or the like are not absolute orientations, but merely relative to the other features of the grommet.

[00081] It should thus be understood that the specific forms of the invention herein illustrated and described are representative but not limiting of the invention, and reference should be made to the following appended claims in determining the full and fair scope of the invention.

What is claimed is:

1. A sealing grommet, comprising:
 - (a) a frame having one or more frame sections;
 - (b) first and second sealing members connected to the frame, each sealing member forming an air barrier and having a corrugated portion;
 - (c) each corrugated portion having a set of corrugations, having a base portion, and having a corrugated free end portion opposite the base portion;
 - (d) the corrugated free end portion of each sealing member being resiliently deformable toward the associated base portion; and
 - (e) the first and second sealing members being positioned with the corrugated free end portions thereof in a closely abutting relationship and with the set of corrugations of the first and second sealing members being aligned in phase.
2. A sealing grommet as in claim 1, wherein
 - (a) each sealing element is formed with a back flange extending along and integrally joined with the base portion of the corrugated portion thereof; and
 - (b) the frame includes first and second back portions, and the back flanges of the first and second sealing elements are connected to the first and second back portions, respectively.
3. A sealing grommet as in claim 2, wherein

- (a) each sealing member is formed with integral side flanges at opposite sides thereof;
- (b) the frame includes spaced apart side portions; and
- (c) the side flanges of the sealing members are secured to and supported by the side portions of the frame.

4. A sealing grommet as in claim 1, wherein

- (a) each sealing member is formed of an electrostatically dissipative elastomeric material;
- (b) the frame has an inner portion connected to at least one sealing member and an outer portion adapted to engage with an electrically conductive grommet-supporting surface;
- (c) a contact portion formed of electrostatically dissipative elastomeric material is positioned on the outer portion of the frame; and
- (d) an interconnecting portion of electrostatically dissipative elastomeric material integrally joins the sealing member with the contact portion and provides a continuous electrical path from the one sealing member to the contact portion.

5. A sealing grommet as in claim 4, wherein

- (a) the one sealing member, the contact portion and the interconnecting portion are of unitary, molded construction; and
- (b) the frame defines a flow path to accommodate a flow of elastomeric material from the one sealing member to the contact portion.

6. A sealing grommet as in claim 5, wherein
 - (a) the frame has an outwardly extending flange on the outer portion thereof;
 - (b) the contact portion is positioned on an underside of the outwardly extending flange and projects below a bottom portion of the outwardly extending flange whereby, when the outwardly extending flange is secured to the grommet-supporting surface, the contact portion is placed under compression.
7. A sealing grommet as in claim 1, wherein
 - (a) each sealing member is of molded construction and formed of thin, flexible, web-like elastomeric material.
8. A sealing grommet as in claim 7, wherein
 - (a) the corrugated portion of each sealing member is of tapered thickness narrowing from the base portion to the corrugated free end portion thereof.
9. A sealing grommet as in claim 8, wherein
 - (a) the elastomeric material is a thermoplastic elastomer.
10. A sealing grommet as in claim 1, wherein
 - (a) the corrugations have wave lengths and amplitudes; and
 - (b) the amplitudes are equal to or greater than the wave lengths.

11. A sealing grommet as in claim 10, wherein
 - (a) a ratio of the amplitude to the wave length is in a range of from about 1:1 to about 2:1.

12. A sealing grommet as in claim 10, wherein
 - (a) each corrugated portion has a width along a propagation axis and an arc length; and
 - (b) a ratio of the arc length to the width is in a range of from about 2:1 to about 6:1.

13. A sealing grommet as in claim 12, wherein
 - (a) the frame has two back portions and two spaced-apart side portions; and
 - (b) the corrugated portion of each sealing member extends substantially from one side portion to the other side portion and from the corrugated free end portion thereof substantially to an associated back portion of the frame.

14. A sealing grommet as in claim 1, further comprising:
 - (a) the corrugations of the set thereof comprise primary corrugations;
 - (b) the corrugated portion of each sealing member having a set of secondary corrugations propagating orthogonal to a propagation axis of the primary corrugations;

(c) the secondary corrugations oscillating normal to a surface of the primary set of corrugations.

15. A sealing grommet as in claim 1, wherein

(a) the corrugated portions of the first and second sealing members are in compression against each other.

16. A sealing grommet as in claim 1, wherein

(a) the corrugated free end portion of the corrugated portion has an end flange portion; and

(b) the end flange portion follows a path of the set of corrugations and is disposed at an angle relative to a direction from the corrugated free end portion to the base portion of the corrugated portion.

17. A sealing grommet as set forth in claim 1, wherein

(a) said frame has two frame sections,

(b) each of said two frame sections mounting one of said first and second sealing members, and

(c) said two frame sections being releasably joinable to form said frame.

18. The combination of a sealing grommet, a surface structure and a boundary structure, the combination comprising:

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- (a) the grommet having a frame and having a sealing member connected to the frame, the sealing member forming an air barrier and having a corrugated portion;
- (b) the corrugated portion having a set of corrugations, having a base portion, and having a corrugated free end portion opposite the base portion;
- (c) the corrugated free end portion being resiliently deformable toward the base portion;
- (d) an opening in the surface structure, the opening being bounded by the surface structure and the boundary structure;
- (e) the surface structure and the boundary structure being in fixed positions relative to one another; and
- (f) the grommet being disposed in sealed relation to the opening and the corrugated free end portion of the corrugated portion of the sealing member being disposed in contact with or closely adjacent the boundary structure.