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W. C. HOWE

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MAGNETIC SHIELDING FOR TRANSFORMERS AND THE LIKE

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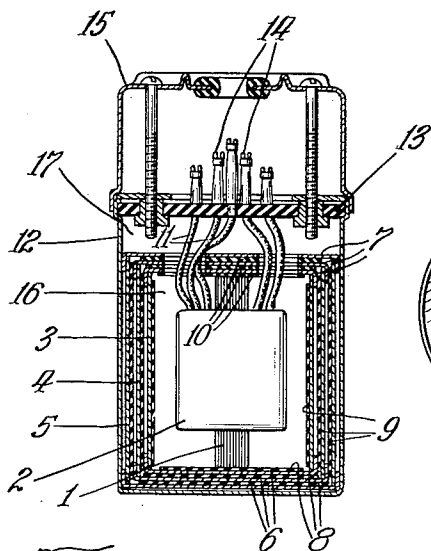


Fig. 1.

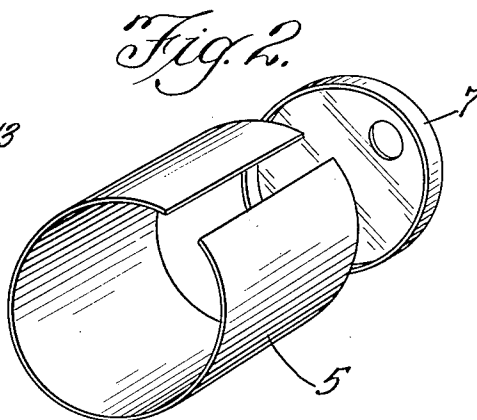


Fig. 2.

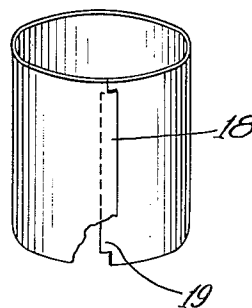


Fig. 3.

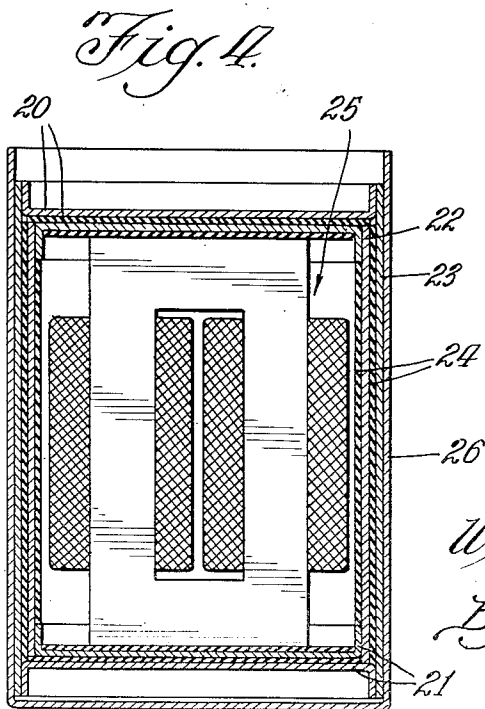


Fig. 4.

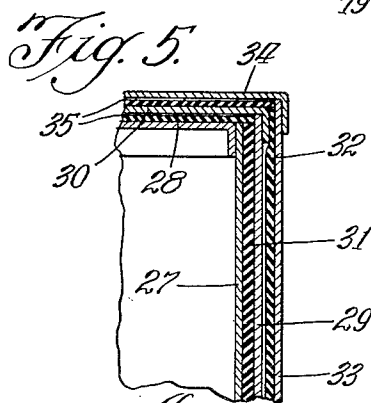


Fig. 5.

Inventor:
 Wilfred C. Howe
 By: Teseh and Wank
 Attys.

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MAGNETIC SHIELDING FOR TRANSFORMERS AND THE LIKE

Wilfred C. Howe, Chicago, Ill., assignor, by mesne assignments, to Maguire Industries, Incorporated, New York, N. Y., a corporation of New York

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1 Claim. (Cl. 173—35)

This invention relates to magnetic shielding for electrical apparatus, such as transformers.

A changing magnetic field is induced in the space surrounding an electrical conductor carrying a changing current, such as an alternating or otherwise pulsating current. It is often necessary or convenient to mount transformers or other apparatus operated by magnetic induction or which might be affected by a changing magnetic field in proximity to such conductors and therefore within the changing magnetic field. Such conditions are frequently encountered, for example, in the construction of electronic amplifying equipment such as that used in the radio art and in connection with automatic or semi-automatic controlling, regulating and/or recording apparatus. Conditions are frequently met where the voltages induced by extraneous magnetic fields in audio or signal transformers are of such magnitude that they either impair the usefulness of the signal voltage by making difficult or impossible its accurate measurement or, where sound reproduction is involved, that they cause objectionable noise corresponding to the extraneous induced currents.

Various means for minimizing the effect of such extraneous fields are known. In one method shells of magnetically permeable material are used to provide a path for the magnetic flux around the electrical coils to thereby provide a zone within the shell which is comparatively free from magnetic disturbances. When the field is relatively uniform, it is possible to minimize its effect by so designing the core and coils of a transformer that voltages caused by the extraneous field tend to cancel themselves. This arrangement is generally referred to as a "hum-bucking" construction and forms no part of the present invention although it is illustrated in Fig. 4. The present invention is directed to the magnetic shielding method of minimizing extraneous magnetic field interference. When the phrase "magnetic shielding" is employed therein in the specification and claim, it contemplates magnetic means for minimizing interference caused by extraneous magnetic fields.

Since interference caused by extraneous magnetic fields occurs most commonly in the operation of transformers, particularly audio transformers, the invention will be described as embodied in such a unit.

The object of this invention is to provide a magnetic shield construction and arrangement which is highly efficient yet inexpensive to manufacture. A specific object is to provide magnetic shielding

structures which require neither welding nor difficult and expensive drawing or spinning of the metal from which the shielding is fabricated. A further object is to provide such shielding which is well adapted for use in the multiple shielding of electrical apparatus, a feature of the invention residing in the compactness of the assembled units.

In the accompanying drawing:

Fig. 1 is a front elevation, partly in section, illustrating an embodiment of the invention;

Fig. 2 is a perspective view of an end cap and cylindrical element of a shield;

Fig. 3 is a perspective view of a modified form of cylindrical element of the shielding;

Fig. 4 is a front elevation in half section showing a modified embodiment of the invention; and

Fig. 5 is a fragmentary sectional view of a further modification of the invention.

Any magnetically permeable material may be used for the magnetic shielding of transformers. However, the different metals available for this purpose exhibit a wide range of magnetic permeability. Other variable factors remaining constant, the efficiency of magnetic shielding is directly proportional to the magnetic permeability of the material from which the shielding is made. Homogeneity, both with respect to chemical composition and physical structure, and therefore electrical characteristics, of the metal, and symmetry of the shielding are equally important factors affecting the efficiency of the shielding. Welding introduces both chemical and physical nonhomogeneity and extensive working results in localized physical alteration of the metal. For these reasons welded structures are not desirable and metal which has been drawn or otherwise worked must be carefully annealed after each working step and after the shaping processes have been completed.

The present invention contemplates the use of a special nickel-iron alloy, known in the market as "Mumetal" in the fabrication of magnetic shielding. This particular alloy exhibits high magnetic permeability characteristics, particularly at the low flux densities generally encountered in extraneous fields. It is subject to the disadvantage, however, that it may be drawn or otherwise shaped only with great difficulty with the result that shielding made from this metal has been almost prohibitively expensive.

A complete audio transformer assembly embodying the invention is illustrated in Fig. 1. A core 1 and coils 2 are enclosed within nested magnetic shields 3, 4, and 5. Each of these shields

comprises a cylindrical side wall such as is shown in Figs. 2 and 3 and bottom caps 6 and top caps 7. The shielding, including both cylindrical elements and end caps, are made of the metal described above which is highly permeable to magnetic flux. The several shields 3, 4, and 5 are magnetically insulated from each other and from core 1 and coils 2 by means of separators 8, 9, and 10. These separators are of nonmagnetic material, fibrous sheet material, such as paper, or nonmagnetic metals, such as copper, being suitable. Alternatively, nonmagnetic films may be coated directly on to a surface of the shielding; for example, such surfaces may be painted or copper plated. In the embodiment of Fig. 1, it is sufficient to so coat the outer surfaces of the end caps since it is only these surfaces which engage the next outer shell. Suitable aligned holes are provided in top caps 7 and separators 10 through which the transformer leads 11 are brought.

The shielded transformer assembly is preferably arranged in a casing 12 which may constitute a fourth magnetic shield in which case it should be magnetically insulated from the adjoining shield 5. This outer casing 12 may also be of nonmagnetic material to provide electrostatic shielding only for the transformer unit. Such a casing may be drawn from aluminum or zinc, for example, and need not necessarily be insulated from the outer magnetic shell 5. The several cylindrical elements are preferably so arranged that the butt joints are staggered around the circumference of the unit. A suitable mounting panel 13 of insulating material, such as Bakelite, terminals 14 and a suitable static shielding assembly 15 complete the unit illustrated in Fig. 1. In assembling the transformer, the spaces 16 and 17 are usually filled with a pitchy compound not shown in the drawing.

It may be pointed out that the present invention is directed to the construction of magnetic shielding per se, illustration and description of complete electrical units including the shielding being included in this specification only to insure a complete understanding of the invention.

As stated above, each complete shield comprises a cylindrical element and end caps. Sheet Mumetal 0.014 to 0.020 inch in thickness is the preferred material from which the elements of the shielding are made. Other thicknesses and materials may be used, the statement of preference being based on present considerations of material, fabrication and assembling costs, strength of the shield, etc. The cylindrical element is formed from a rectangular strip of the metal by means of a simple rolling process. For purposes hereinafter explained, the set curvature imparted to the metal in this process is preferably such that external pressure must be applied to bring the ends of the strip together into abutting relationship as the unit is being assembled to thereby provide a complete cylindrical member. The cap members are formed from discs of the metal by a shallow drawing or spinning operation. The tools required for this operation are simple as is the operation itself since the flange thus provided need not be deeper than about $\frac{1}{8}$ inch. All formed elements of the shielding may be annealed, preferably in a nonoxidizing atmosphere.

In assembling the transformer, a separator strip 9 is arranged around the coils 2. The cylindrical element of shield 3 is then fitted around the separator and a bottom cap which is lined by a separating disc 8 is slipped over the bottom

circular edge of the cylindrical element. As explained above, the cylindrical element is so made that slight radial compression is necessary to bring the ends of the element into abutting engagement and to reduce the diameter of the element sufficiently to fit into the end caps. Thus, in the final assembly the cylindrical element is somewhat strained and exerts an outward radial pressure which results in sustained and uniform engagement of the edge portions of the cylindrical element of the shield and the inside surfaces of the end cap flanges. The overlap joint thus provided offers considerably less reluctance to the flow of magnetic flux than a simple butt joint. The shell formed by the cylindrical element of shield 3 and the bottom cap and containing the core and coils of the transformer may be filled with transformer compound after which the first top cap is fitted over the top end of the cylindrical element. The remaining separators and shields are then fitted in order over the inner shield assembly and the whole placed in outer casing 12. The space 17 is then preferably filled with transformer compound and the assembly completed.

Since only those magnetic flux lines passing through one or more of the coil turns affect the voltages induced in the conductors forming the coils, it will be understood that low reluctance magnetic paths provided by the shielding in a direction generally axial of the shielding are of considerably greater importance than low reluctance paths circumferentially of the shielding. For this reason interruption of the circumferential magnetic paths at the abutting edges of the cylindrical element is relatively unimportant. Under some circumstances, however, it may be desirable to minimize this interruption. This may be accomplished by means of the modified form of cylindrical element illustrated in Fig. 3. In this modification a slightly longer rectangular sheet is used to form the cylindrical element to provide an overlap joint in the final assembly. The corners of the sheet are preferably notched to provide tongues 18 and 19 equal in width to the distance between the end cap flange edges in the final assembly. This design does not increase the overall volume occupied by the shielded unit since the outer surface of the tongue 18 lies in the same plane as the outer surfaces of the end caps and only a single thickness of the material of the cylindrical element is covered by the end cap flanges. Axial symmetry of shields of this design is somewhat impaired, but, for most purposes not to an objectionable extent.

A single shield or a plurality of shields may be used in any particular unit depending on the degree of magnetic isolation desired. It has been found that for most purposes more than three shields are unwarranted. The invention is not limited to use with any particular coil or core arrangement; it may be used with either shell or core type transformers or other electrical apparatus requiring magnetic shielding.

A modified embodiment of the invention is illustrated in Fig. 4. This is a multi-shielded unit designed for maximum radial compactness. It differs from the embodiment illustrated in Fig. 1 principally in that the top and bottom cap members 20 and 21 are inserted inside of cylindrical shielding elements 22 and 23 instead of capping over the outside of these members. A careful study of the drawing shows how space is saved in this way by an amount equal to the thickness of the cap flanges. In the device of Fig. 4 the

several shields are separated from each other only by the thickness of a nonmagnetic insulating film 24. The core and coil assembly 25, illustrated as of the balanced or "hum-bucking" construction, and magnetic shields 22 and 23 are housed within an outer casing 26 which may be of magnetic material to provide additional magnetic shielding or of nonmagnetic material to provide electrostatic shielding, as desired. In the former case, a separator should be used between element 23 and casing 26.

If reasonably close tolerances are observed in the manufacture of the various elements forming the shields and casing of the unit illustrated in Fig. 4, the cylindrical elements 22 and 23 of the magnetic shields will be sandwiched between the end cap flanges and the outer casing 26 in such a way that contact engagement between the flanges of the end caps and the end portions of the cylindrical elements of the shields will be maintained. It may be desirable, however, in forming the cylindrical elements, to roll them to a curvature slightly greater than that of the assembled elements so that it will be necessary to open them somewhat in assembling the transformer unit. Under these circumstances a continuous inward radial pressure will be exerted against the outer surfaces of the end cap flanges in the same manner but in the opposite direction to that described in connection with the unit of Fig. 1.

A further modified arrangement in a multiple shielding assembly is illustrated in Fig. 5. In this embodiment of the invention the inner magnetic shield consists of cylindrical element 27 and inside end caps 28. The intermediate shield comprises cylindrical element 29 and end caps 30 which are adapted to fit over the ends of the cylindrical element. Cylinders 27 and 29 are separated by a layer of resilient material 31. Any suitable nonmagnetic resilient material may be used for this layer; for example, a fibrous felt material or sponge rubber. This material is compressed by pressure exerted inwardly on cylindrical element 29 in the assembling process. With this arrangement the end portions of element 27 are continuously urged inwardly against the flanges of end caps 28 and the end portions of element 29 are continuously urged outwardly against the flanges of end caps 30.

If an additional shield is to be provided, a second resilient layer 32 extending the full length of the intermediate shield, including the caps, is sandwiched between the intermediate shield and

the cylindrical element 33 of the outer shield. End caps 34 complete the outer shield and support the end portions of cylindrical element 33 which latter are urged outwardly by the compressed layer of resilient material 32. Any suitable non-metallic separators 35 may be used to magnetically insulate the end caps from each other. The thickness of each cylindrical separator element should be uniform throughout its circumference, but thinner layers may be employed to separate the end caps.

If it is desired to employ the magnetic shielding and/or separators (when metallic separators are used) as electrostatic shielding means, the several shields and/or separators may be grounded at a single point on each, preferably at one end of each shield.

Although the cylindrical element of the various shields are shown to be circular in cross section, it is understood that some variation in this particular is permissible and a cylindrical element that is somewhat elliptical may be employed.

It will be readily appreciated by those skilled in the art that the invention herein described provides magnetic shielding means involving low fabrication costs and requiring a minimum of disturbance of the metal. The shield structure is symmetrical in any plane parallel to the axis of the cylindrical element of the shield, with the result that the extraneous flux lines are provided with a path of low reluctance around the coils of the electrical apparatus. In short, the invention provides a highly efficient and compact, yet inexpensive, shielding construction.

I claim:

Multiple magnetic shielding comprising a plurality of nested magnetic shielding shells, each of said shells comprising a rectangular sheet of magnetically permeable metal formed into a cylindrical element, the straight edges of said sheet being in unattached proximity with each other in the formed element and end caps having peripheral flanges for each said cylindrical element, the flanges of the end caps of an inner shell internally lapping the end portions of the cylindrical element of said shell, the flanges of the end caps of the next outer shell externally lapping the end portions of the cylindrical element of said next outer shell, and resilient separator means sandwiched in a state of compression between the cylindrical elements of said inner shell and said next outer shell.

WILFRED C. HOWE.