Sept. 22, 1970 W. A. MEIER 3,529,692

SOUND BARRIER

Filed Feb. 26, 1969 4 Sheets-Sheet 1

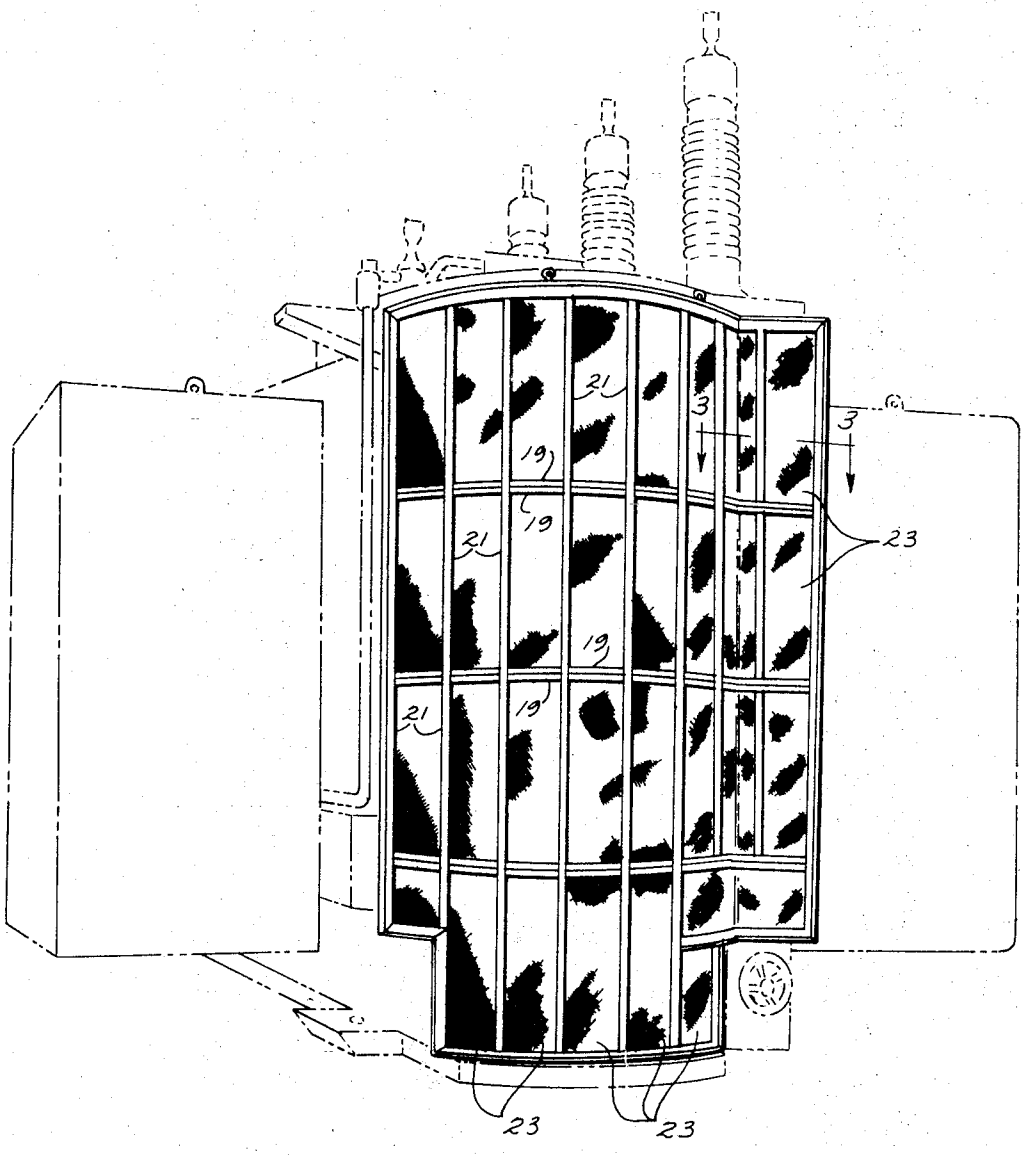
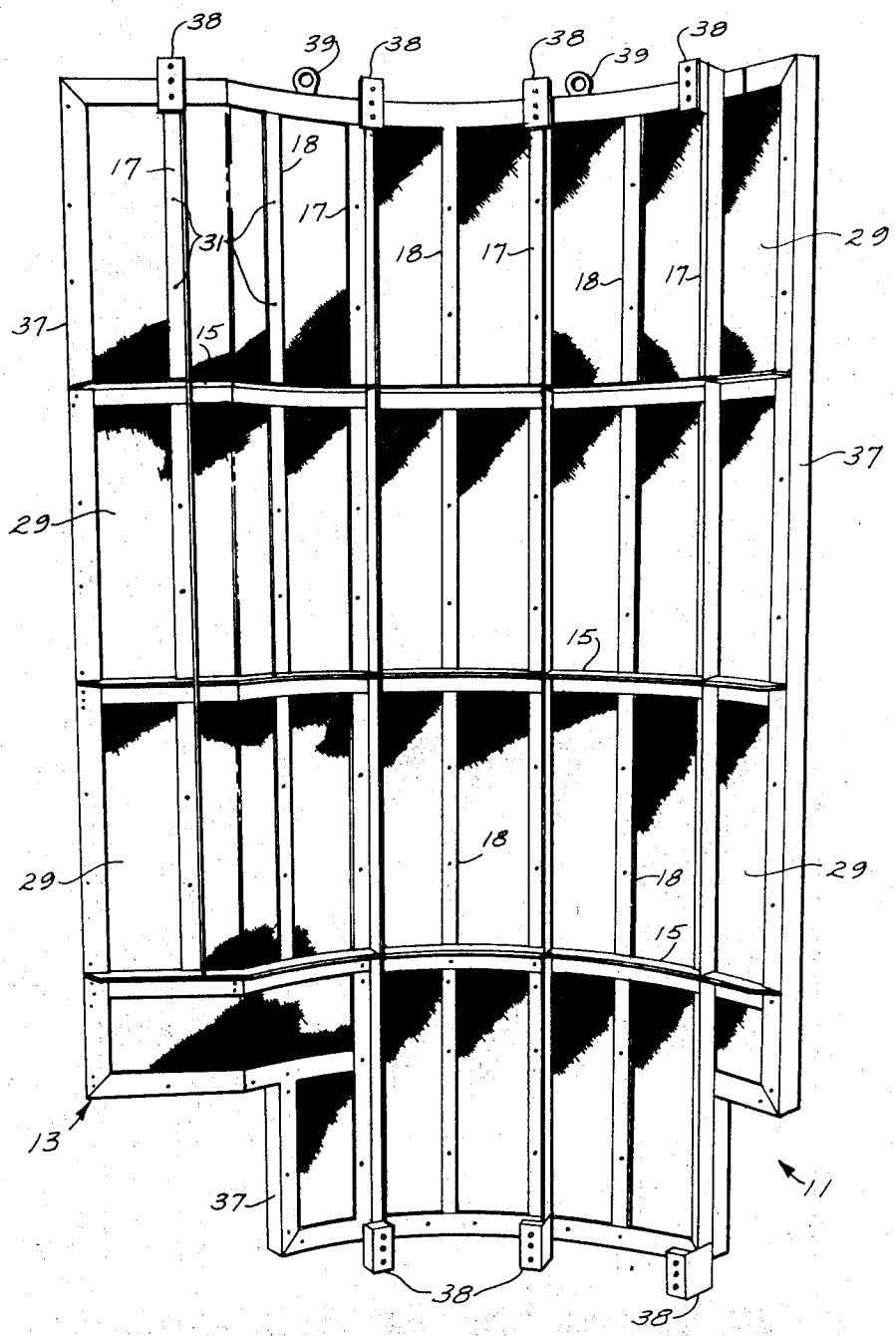


FIG. 1

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Koenig, Senniger,
Powers and Leavitt,
Attorneys.

FIG. 2


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Sept. 22, 1970 W. A. MEIER 3,529,692

SOUND BARRIER

Filed Feb. 26, 1969 4 Sheets-Sheet 3

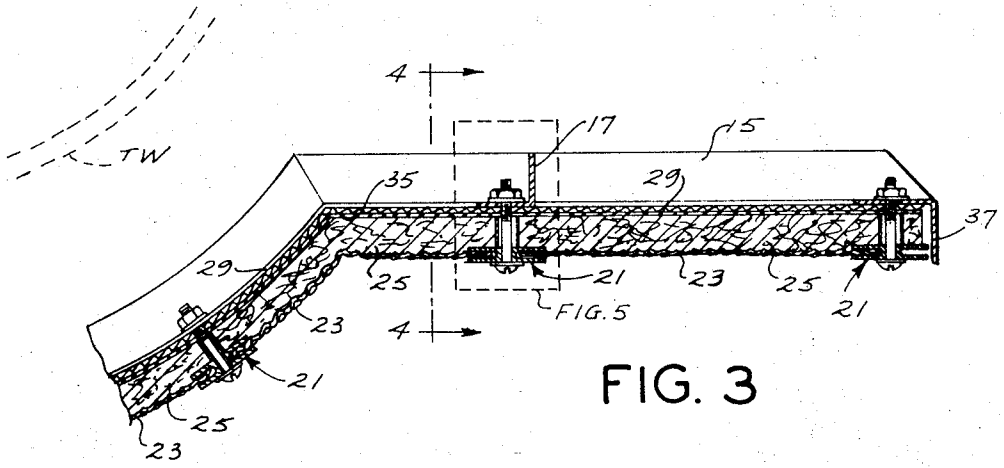


FIG. 3

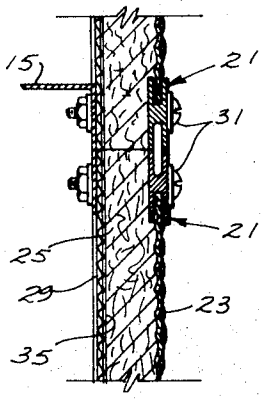


FIG. 4

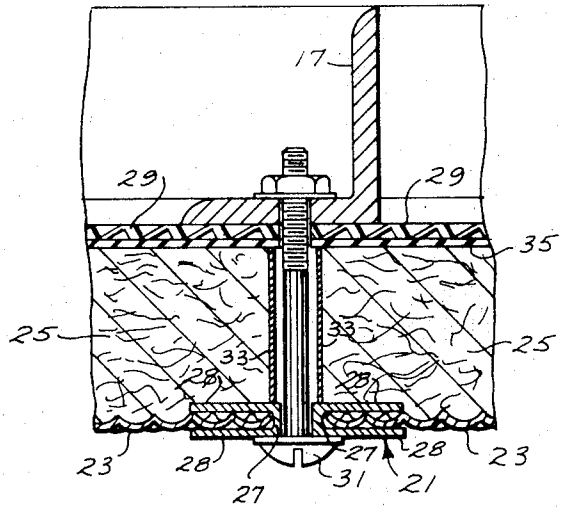


FIG. 5

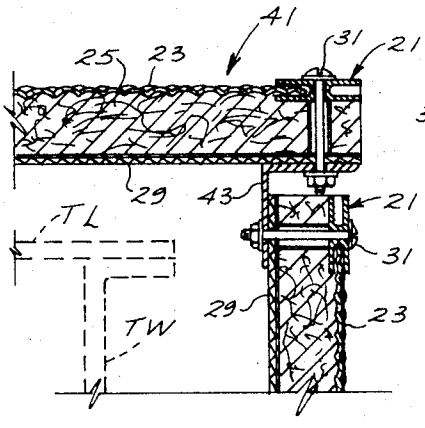


FIG. 6

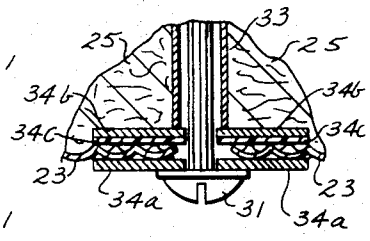


FIG. 5A

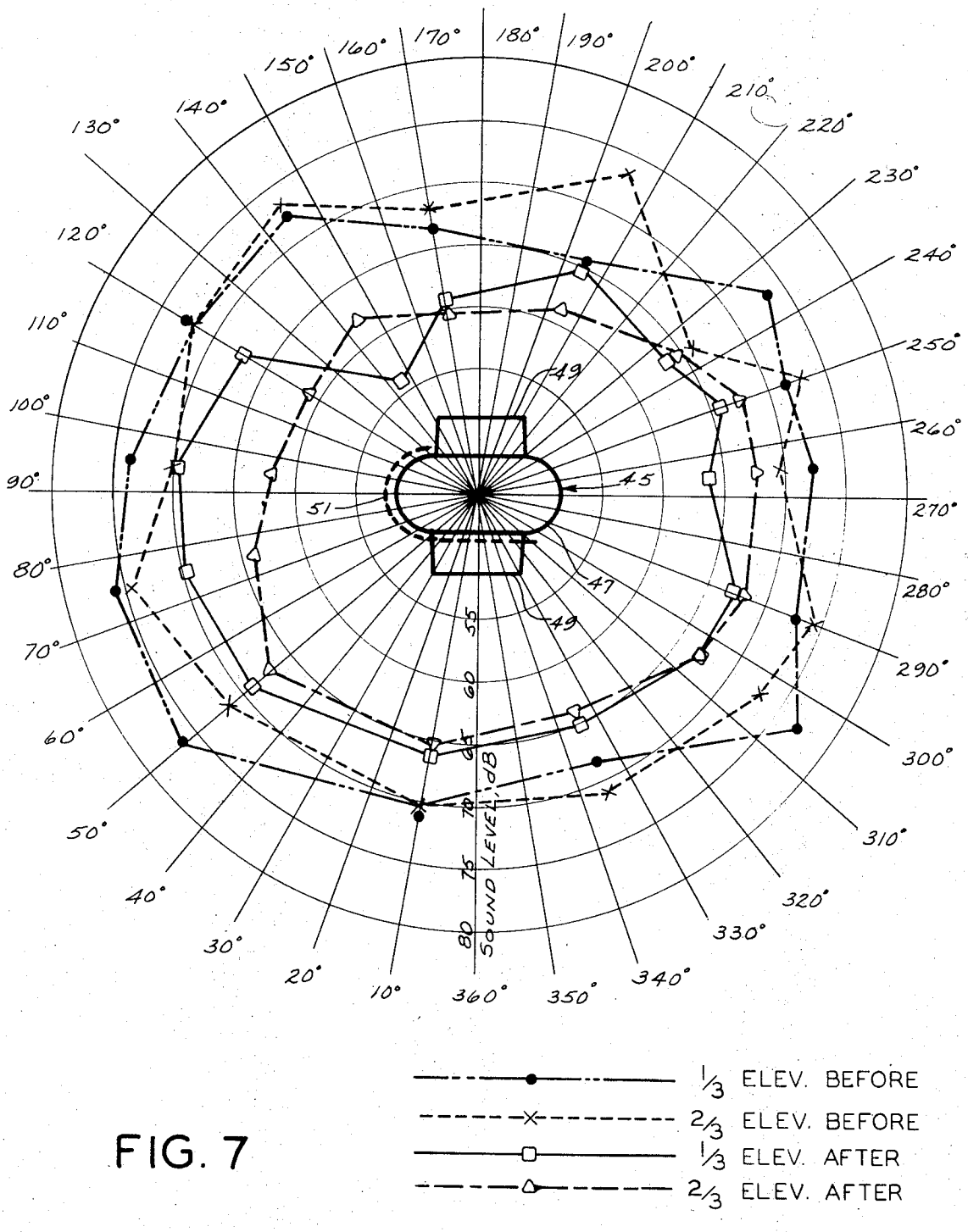

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SOUND LEVEL, dB
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2/3 ELEV. BEFORE
1/3 ELEV. AFTER
2/3 ELEV. AFTER

FIG. 7

United States Patent Office 3,529,692 Patented Sept. 22, 1970

3,529,692

SOUND BARRIER

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Int. Cl. E04b 1/86, 1/99
U.S. Cl. 181—33 23 Claims

ABSTRACT OF THE DISCLOSURE

A sound barrier is disclosed for use with apparatus that generates undesirable sound. The barrier includes a main frame of spaced members and an auxiliary frame formed by a grid of support members which are secured to the main frame. A plurality of relatively thin panels of lead are mounted in edge-to-edge relationship by the support members, the support members holding marginal portions of the lead panels so that they are mounted within the auxiliary frame by their edges.

BACKGROUND OF THE INVENTION

This invention relates to sound barriers, and more particularly to sound barriers employing lead as a barrier material.

It is frequently desired to reduce the sound or noise generated by apparatus of one kind or another. For example, certain kinds of apparatus generate a distracting irregular type of noise. Other types of apparatus, such as a rock crusher, create sound of such intensity that it may endanger the hearing of personnel in the surrounding area. Still other types of apparatus, e.g., large power transformers, may generate a pervading continuous low frequency sound which becomes highly annoying after a period of time. In applications such as these, an effective reduction in sound is often sought by the provision of a sound barrier.

As is known to those skilled in acoustics, lead is a material having characteristics ideally suited to the effective reduction of noise. By virtue of its low modulus of elasticity, i.e., limpness, high density and high internal losses resulting from mechanical hysteresis, lead is highly effective in absorbing and blocking sound energy. It is known that a panel attenuates sound in proportion to the logarithm of the squared product of the sound frequency and the panel surface weight. It may therefore be seen why the intrinsic high mass of lead is particularly advantageous in the construction of sound barriers or panels. Thus, essentially pure or "chemical" lead makes an excellent sound attenuator. However, the characteristics which make lead useful in this regard cause a variety of disadvantages when employing lead as a barrier material. For example, chemical lead is weak as a structural material, exhibiting relatively low ultimate tensile strength and tensile yield strength. Large panels of chemical lead tend to elongate, "creep," or sag over a period of time. These tendencies gravitate against the use of chemical lead panels in a "free-standing" state, or because of size limitations, make their use relatively uneconomical. For these reasons, barriers employing chemical lead have disadvantageously required lamination of

the lead to a structurally more rigid material such as sheet steel or wood. Another problem in the use of lead barriers has been the difficulty of suitably securing the sheets of chemical lead to supporting means, the problem being compounded by the tendency of chemical lead to creep, causing the elongation of fastening holes or the like thereby presenting the likelihood that the bolts or other fastening means will pull out. In this regard, it is to be appreciated that it is highly desirable, in the interests of achieving the greatest possible limpness of the lead panels, that sheets of lead so used be supported only at their edges. This further gravitates against the use of conventional fastening means such as bolts or nails and the like, since a greater number of bolts, for example, will be required to preclude the possibility of their pulling out.

Particularly difficult acoustic problems have occurred in the use of large power transformers which, as has been noted, may radiate an annoying hum which may be heard at a considerable distance from such a transformer. Heretofore, brick wall enclosures have sometimes been provided for such transformers as to which this annoying sound has been the subject of complaints by, for example, adjacent land owners. However, such brick walls are relatively expensive and occupy considerable volume, a requirement that may, in some instances, preclude their use. Furthermore, while it provides a barrier for the sound in one direction, such a wall tends to reflect the sound in other directions, with the resultant possibility that the sound may be concentrated in another direction even though quieted in one direction by the wall. Another type of sound barrier which has been suggested for such a transformer has employed sheets of lead laminated to sheet steel. However, this type of barrier is relatively expensive and difficult to assemble and the resultant rigid laminate panel construction has a high modulus of elasticity, undesirably reducing its effectiveness as a sound barrier.

SUMMARY OF THE INVENTION

Among the objects of the invention may be noted the provision of a sound barrier employing lead as a barrier material; the provision of such a barrier which may be conveniently constructed of panels of lead; the provision of such a barrier wherein a plurality of strengthened lead panels are conveniently mounted by their edges in edge-to-edge relationship whereby they are essentially free-standing; the provision of such a barrier which may quickly and inexpensively be constructed of relatively large size and with polygonal geometry; the provision of such a barrier which may readily be constructed to conform to a variety of curved surfaces; the provision of such a barrier which is highly effective in blocking the sound generated by large apparatus such as large power transformers; the provision of such a barrier having greatly improved mechanical properties; and the provision of such a barrier which is highly economical, durable and long-lasting in operation, and aesthetically pleasing. Other objects and features will be in part apparent and in part pointed out hereinafter.

Briefly, a sound barrier of this invention for apparatus that generates nundesirable sound includes a main frame for the barrier having a plurality of spaced members. An

auxiliary frame for the barrier is constituted by a grid of support members which is secured to the spaced members which comprise the main frame. Relatively thin panels of lead are mounted within the auxiliary frame by their edges, the support members of the auxiliary frame holding marginal portions of the lead panels so that they are supported in edge-to-edge relationship and are thereby mounted within the auxiliary frame by their edges.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view in perspective of a sound barrier of this invention, the barrier being represented as mounted to a large power transformer which is illustrated in dashed lines;

FIG. 2 is a view in perspective taken from the rear of the barrier of FIG. 1, illustrating certain features of the barrier;

FIG. 3 is a cross section of the barrier taken along line 3—3 of FIG. 1;

FIG. 4 is a vertical cross section taken along line 4—4 of FIG. 2;

FIG. 5 is an enlarged cross section of a portion of the view of FIG. 3, illustrating details in the assembly of the barrier;

FIG. 5A is an enlarged cross section of an alternate support arrangement for holding the edges of panels of the barrier;

FIG. 6 is a vertical cross section similar to FIG. 4 showing the top portion of another embodiment of the barrier of FIG. 1 which includes an additional horizontal portion overhanging the top of the transformer; and

FIG. 7 is a polar sound level diagram illustrating the measured intensity of the sound generated by a large power transformer with and without the provision of the barrier constructed around a portion of the transformer according to this invention, the intensity being measured at two elevations at intervals around the transformer.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, a sound barrier of this invention is shown mounted to the front wall of a large power transformer, the transformer being illustrated in outline by dashed lines. This transformer may, for example, comprise a large, heavy-duty type having a power rating in the order of about 1000 kva. (kilovolt-amperes) into the mva. (megavolt-amperes) range. Such a transformer is illustrated solely by way of example and, as will appear, a barrier of this invention may be used in conjunction with various types and sizes of noise-generating apparatus.

As appears from FIG. 1, and the somewhat larger rear view of FIG. 2, a sound barrier of this invention comprises a main frame **13** for the barrier having a plurality of spaced horizontal members **15** and spaced vertical members **17** and **18** forming a substantially rectilinear grid. An auxiliary frame comprises a grid of horizontal support members **19** and vertical support members **21**, these, too, forming a rectilinear grid. The grid constituted by the main frame is substantially in registry with the grid constituted by the support members **19** and **21**. These support members are secured, as by bolting, to the spaced members of the main frame.

In accordance with this invention, a plurality of relatively thin panels **23** of lead, preferably of a type of strengthened lead which will be described presently, are mounted in edge-to-edge relationship by the support members **19** and **21**, these support members holding marginal portions of the lead panels so that they are mounted within the auxiliary frame solely by their edges. These panels comprise the first layer of a multilayer sound barrier of this invention. As appears from the cross-sectional view of FIG. 3, the barrier includes in addition a layer **25** of fibrous sound-absorbent material, this second layer of the barrier lying adjacent the lead panels **23** and being int erposed between the panels and the front wall TW of the transformer or other apparatus to be shielded. A screen or metallic mesh **29** of expanded aluminum or the like, providing a third layer, retains the sound-absorbent material. The support members **19** and **21** are secured through the second and third layers to the structural members **15**, **17** and **18** of the main frame to maintain the three layers in an assembled relationship.

It should be here understood that while the preferred embodiment is a multilayer barrier, a sound barrier of this invention may simply comprise a single layer constituted by a main frame for the barrier, an auxiliary frame of the horizontal support members **19** and **21** and the plurality of relatively thin panels **23** of lead, the support members mounting the lead panels within the auxiliary frame by their edges.

The specific construction of a multilayer barrier of this invention may be seen more clearly by reference to FIGS. 3, 4 and 5. As appears therein, the lead panels **23** are mounted side-by-side on the auxiliary frame by the horizontal support members **19** and vertical support members **21**. As is particularly illustrated in the enlarged cross section of FIG. 5, showing a portion of the cross section shown in FIG. 3, these support members comprise channel members which are H-shaped in cross section. The channel members include a web **27** from which extend pairs of flanges **28**, the flanges defining aligned, opposed pairs of channels for receiving marginal portions of the lead panels **23**. The support or channel members **19** and **21** and the structural members **15**, **17** and **18** are drilled at intervals. The channel members **19** and **21** are bolted to main frame members **15**, **17** and **18** by bolts **31**. Spacers **33** space the panel assembly from the main frame members a suitable distance to accommodate the layer of fibrous material **25** and the screen **29**. The chasnel members may be of any suitable material but, to preclude the possibility of substantial sound leak paths through the channel members and to provide for maximum limpness, are preferably of the same type of strengthened lead which comprises the panels **23**. Channel members of such lead are readily extruded into suitable lengths. It will be appreciated that the channel members need not be H-shaped in cross section and, in fact, various other types of assemblies, such as metal strips, could be used to provide means for holding and retaining the edges of the panels **23**, as long as sound leak paths are substantially prevented.

For example, FIG. 5A illustrates an alternative means of holding the edges of the lead panels **23**. In place of the channel members, a pair of strips **34*a*** and **34*b*** are held between the heads of the bolts **31** and the spacers **33**. A layer **34*c*** of a resilient material such as neoprene or the like may be used for providing a yielding frictional retention of the edges of the panels **23**.

The sound-absorbent material **25** may, for example, comprise fiber glass, rock wool, lava slag, or other cellular (open or closed cell types), synthetic resin, or fibrous materials. To prevent the absorption of moisture, the fiber glass is coated with a layer of moisture-resistant material **35** such as neoprene or plastic on the exposed surfaces of the fiber glass, i.e., either those surfaces exposed through screen **29**, or all surfaces. Screen **29** preferably comprises an expanded metal mesh, e.g., expanded aluminum.

As illustrated in FIG. 2, the horizontal members **15** and vertical members **17** of the main frame **13** may be constituted by suitable steel angle stock, for example. The vertical members **18** may be of flat steel stock.

The sound barrier is preferably provided with a protective edge **37** around the top, bottom and side edges of the barrier. The lead panels, being of a lead material, are somewhat soft and easily damaged at their edges. Accordingly, this feature provides suitable protection for the

panels at the edges of the barrier. This protective edge **37**, which provides the main frame with additional horizontal and vertical structural members, is constructed by orienting angle stock so that it overlaps the edges of the barrier around the periphery thereof, this feature being seen most clearly in FIGS. 2 and 3.

The main frame **13** is provided with suitable mounting brackets **38** for mounting the barrier by its peripheral edges to the apparatus to be shielded. If desired, these mounting brackets **38** may be conventional sound absorbent mounts or means for resiliently mounting the entire barrier to the apparatus to provide acoustic isolation of the barrier from the apparatus where this may be advantageous because of unusually severe vibration or severe acoustic problems. Other means of mounting, e.g., a force-free coupling (such as a pendulum mount) may also be employed, either in place of or in addition to the mounting brackets **38**. Lifting eyes **39** facilitate handling and installation of the barrier.

The various elements of the main frame may readily be field- or shop-assembled by welding, though other methods of assembly, e.g., bolting, could be employed. It will be seen that the construction of the present sound barrier facilitates the mounting of the barrier to the apparatus to be shielded, e.g., a large transformer, such that the apparatus can readily be moved or relocated with its barrier.

As is indicated by FIG. 3, a barrier of this invention may readily take various shapes so that it will conform with the shape of the apparatus with which it is used, the lead panels **23** being readily bent and secured to a frame of suitable shape.

As has been pointed out, the relatively large size lead panels **23** are mounted solely by their edges, that is, they are essentially free-standing to provide the limpness desired for maximum acoustic benefit. This is made possible through the use of strengthened lead. Preferably, this strengthened lead is a dispersion-strengthened lead made according to U.S. Pat. 3,320,664. This patent discloses the process of coating fine lead particles with lead oxide in the range of 0.7% to 16.0% by weight, calculated by PbO, by forming in situ on the surfaces of the finely divided lead particles a film or coating of the lead oxide, and thereafter breaking the lead oxide films into finely divided particles and dispersing them in a lead matrix. This process results in a dispersion-strengthened lead having a tensile strength in the range of from approximately 3200 to approximately 8500 p.s.i. such that it has a creep resistance and yield strength much greater than chemical lead, but substantially retains the limpness, modulus of elasticity and density of chemical lead, those qualities which contribute to making lead an excellent acoustic barrier material. This material exhibits a modulus of elasticity (Young's modulus) of from about 2.0 to 2.2×10^6 p.s.i., approximately that of chemical lead. Also, it is to be understood that other types of materials having characteristics such as these, e.g., foamed lead, could likewise be employed for the panels.

The panels **23** of this dispersion-strengthened lead may be of a width of at least 12 inches and a suitable length, e.g., several feet. Such panels are internally stressed by virtue of their own weight and the effect of other environmental forces to stresses which may be as great as from about 200 p.s.i. to perhaps as great as 2000 p.s.i. The approximate minimum tensile strength of this dispersion-strengthened lead of 3200 p.s.i. therefore provides a sufficient margin of strength for panels of such size, and in fact, even larger widths of this material can be safely used. Chemical lead, possessing a creep rate of 3% per year at room temperature when stressed to 300 p.s.i., cannot be suitably used in this free-standing condition for panels having dimensions such as these. By contrast, this dispersion-strengthened lead will not appreciably creep or elongate in use when employed in the construction of a barrier of this invention. For example, this dispersion lead exhibits a creep rate of only 0.1% per year when stressed to 2000 p.s.i. Yet the acoustically absorptive properties of this material in barrier form are not significantly different from chemical, or pure, lead.

The lead panels **23** may be of a thickness of 0.062 inch, for example. As appears from FIGS. 3, 4 and 5, the panels may be embossed to provide a rough or pebbled finish which provides the panels with greater strength and possibly improved sound-dispersive qualities. In addition, the pebbling gives the panels an aesthetically pleasing appearance and provides for improved paint adherence.

In installing the barrier, it may in some instances be preferable to space the barrier a predetermined distance from the apparatus to be shielded, particularly where the fundamental and harmonic frequencies, and therefore the wavelengths λ, of the noise generated thereby can be determined in advance. Typically this is the case with power transformers (60 Hz.), which generate greatest noise or sound amplitude at frequencies of 120, 240, and 360 Hz., etc., with noise of one frequency frequently being most prominent. In such cases, sound absorption, attenuation and blocking frequently can be improved if the distance between the lead panels and the apparatus to be shielded is a multiple of $K\lambda$, where K is a function of the acoustical characteristics of the barrier and the apparatus. In the shielding of transformers, it may be relevant to consider the effective acoustic distance between the lead panels and the sound source, e.g., the transformer core, since it is the core from which sound is principally generated, chiefly because of lamination air gaps (with resultant magnetically induced mechanical forces thereacross) and magnetostrictive forces.

FIG. 6 is illustrative of another embodiment of this invention wherein an overhanging horizontal portion **41** is provided for the barrier. This horizontal portion may be provided where it is desired to provide sound barrier protection across the top of apparatus. The dotted line structure indicated generally at TL is representative of the cover of a transformer tank or the top of other apparatus. It may be seen from this figure that the horizontal portion **41** extends back over the top of the apparatus to provide a sound barrier for preventing noise which emanates from the top of the apparatus from freely traveling over the top edge of the vertical portion of the sound barrier. Horizontal portion **41** is secured to the vertical barrier by means of an angle member **43**, this angle member being secured in some suitable fashion as by bolting (as shown) by means of the bolts **31** or by welding.

By way of example, a sound barrier constructed in accordance with the teachings of this invention has been found to be particularly effective in reducing the prevading, annoying loud hum generated by a large power transformer. The polar diagram of FIG. 7 illustrates experimental data representing the measured intensity of sound generated by such a large power transformer both with and without the provision of a barrier constructed around a portion of the transformer in accordance with the teachings of this invention. The power transformer, which had a power rating of several tens of mva., was installed in a power substation. The transformer is indicated generally at **45** and the tank of the transformer is designated **47**. Radiators **49** extend outwardly on either side of the transformer. A dotted line **51** is representative of the barrier constructed around one end of the transformer and extending back along one side wall of the transformer tank **47** between the radiator core members of one of the radiators **49** and the tank wall. The barrier was vertically mounted a few inches from the wall of tank **47** to provide for air flow and to permit painting of the transformer as desired. The barrier extended from just a few inches from ground level to a few inches above the upper edge of the transformer tank wall. In the con-

struction of the barrier, panels of dispersion-strengthened lead were employed having a width of twelve inches, a length varying from about two feet to about four feet and having a thickness of 0.062 inch. Fiberglas having a thickness of about 1½ inch was employed. Standard NEMA (National Electrical Manufacturers Association) sound tests were conducted, first without the barrier and then after the barrier was installed, both tests being made under similar conditions with the transformer operative. Sound level measurements were taken at intervals of generally every three feet around the transformer at a distance of one foot therefrom at elevations of one-third and two-thirds of the transformer height, in accordance with the usual procedure of such tests. The legend of FIG. 7 indicates the measurements conducted at the one-third and two-thirds elevations before and then after installation of the barrier. Although the barrier did not completely surround the transformer, the diagram indicates that an effective reduction in noise was achieved around the entire periphery of the transformer. This shows the effectiveness of the barier in preventing reflected sound from being reradiated from the barrier in the opposite direction and thus indicates that the barrier is a minimal reflector of sound. Ambient noise level averaged 40 to 50 db when the transformer was inoperative. In operation, the average sound level at both the one-third and two-thirds elevations before installation of the barrier was 71.9 db. The average at both levels after installation of the barrier was 65.2 db, indicating an over-all reduction in the average sound intensity of 6.7 db.

It was especially desired to reduce the sound over the sector covering approximately 20° to 90° on the diagram at a distance of some 150 to 160 feet or greater. In this sector, prior to construction of the barrier, the sound generated by the transformer was loud and annoying. Use of the barrier caused a reduction of the sound intensity in this sector varying from about 3.5 to 12.0 db. In fact, barrier attenuation at certain frequencies brought the sound level down below ambient noise levels, illustrating the highly effective reduction of sound achieved by a sound barrier of this invention at a distance from the transformer. It was because of this sector of primary interest that the barrier was not constructed around the full periphery of the transformer.

From the foregoing, it may be seen that a barrier of this invention can be simply, quickly and economically constructed without expensive or complicated assembly procedures. The barrier may readily be constructed of relatively large size and, because of the flexibility of assembly provided by convenient sizes of bendable individual lead panels, the completed barrier may take on unusual or polygonal geometry and can readily be made to conform to a variety of shapes of apparatus or curved or planar surfaces. By virtue of its simple mechanical construction and because it eliminates the need for wood and other disadvantageous laminating materials for supporting the lead panels, the barrier is highly economical, durable and long lasting in operation. In addition, its appearance is aesthetically pleasing.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A sound barrier for apparatus that generates undesirable sound, comprising a main frame for the barrier, said frame having a plurality of spaced members, an auxiliary frame comprising a grid of support members, the support members being secured to said main frame, and a plurality of relatively thin panels of lead, said support members providing means for supporting the lead panels in edge-to-edge relationship, said support members holding marginal portions of the lead panels whereby the lead panels are mounted within said auxiliary frame by their edges.

2. A sound barrier as set forth in claim **1** wherein said panels comprise strengthened lead.

3. A sound barrier as set forth in claim **2** wherein said panels comprise dispersion-strengthened lead containing lead oxide in the range of 0.7% to 16.0%.

4. A sound barrier as set forth in claim **3** wherein said support members comprise dispersion-strengthened lead containing lead oxide in the range of 0.7% to 16.0%.

5. A sound barrier as set forth in claim **1** wherein said panels are embossed.

6. A sound barrier as set forth in claim **1** further comprising a layer of sound-absorbent material which is relatively thick in relation to said panels, said layer being interposed between the panels and the apparatus and being secured between the panels and said main frame.

7. A sound barrier as set forth in claim **1** wherein said main frame forms a grid substantially in registry with the grid constituted by said support members.

8. A sound barrier as set forth in claim **7** wherein said main frame includes means for mounting the barrier to said apparatus.

9. A sound barrier as set forth in claim **8** wherein said means for mounting the barrier includes resilient means for acoustically isolating the barrier from the apparatus.

10. A multilayer sound barrier for apparatus that generates undesirable sound, comprising a main frame for the barrier, said frame comprising a first grid of spaced members, an auxiliary frame comprising a second grid of support members substantially in registry with the first grid, a first layer of relatively thin panels of lead, said support members holding the lead panels in edge-to-edge relationship, a second layer of a sound-absorbent material, the second layer lying adjacent the first layer between the first layer and the apparatus, and a third layer comprising a screen for retaining said sound-absorbent material, the screen lying adjacent the second layer between the second layer and the apparatus, said support members holding marginal portions of the lead panels and being secured to said spaced members through the second and third layers whereby the first, second and third layers are secured together and to the main frame and the lead panels are supported by their edges.

11. A multilayer sound barrier as set forth in claim **10** wherein said panels comprise strengthened lead.

12. A multilayer sound barrier as set forth in claim **11** wherein said strengthened lead has a tensile strength of at least 3200 p.s.i.

13. A multilayer sound barrier as set forth in claim **10** wherein said support members comprise strengthened lead.

14. A multilayer sound barrier as set forth in claim **13** wherein said panels and said support members are comprised of dispersion-strengthened lead containing lead oxide in the range of 0.7% to 16.0%.

15. A multilayer sound barrier as set forth in claim **10** wherein said sound-absorbent material is fiber glass.

16. A multilayer sound barrier as set forth in claim **15** wherein said fiber glass is coated on at least one exposed surface with a moisture-resistant material.

17. A multilayer sound barrier as set forth in claim **10** wherein said screen is a metallic mesh.

18. A multilayer sound barried as set forth in claim **10** wherein said first and second grids are substantially rectilinear.

19. A multilayer sound barrier as set forth in claim **15** wherein said frame is steel and provides peripheral overlapping protective edges for the barrier, whereby said panels are protected at the edges of the barrier.

20. A multilayer sound barrier as set forth in claim 19 wherein the barrier is mounted by said peripheral edges.

21. A multilayer sound barrier as set forth in claim 10 wherein said sheets are embossed.

22. A multilayer sound barrier as set forth in claim 10 wherein said first layer is spaced a predetermined distance from the apparatus.

23. A multilayer sound barrier as set forth in claim 10 wherein said barrier includes a horizontal portion at least partially overhanging the apparatus.

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R. S. WARD, JR., Primary Examiner

Notice of Adverse Decision in Interference

In Interference No. 97,700 involving Patent No. 3,529,692, W. A. Meier, SOUND BARRIER, final judgment adverse to the patentee was rendered Aug. 31, 1972, as to claims 1, 2, 3, 4, 5, 7 and 8.

[*Official Gazette October 31, 1972.*]