Dec. 31, 1963 J. H. GILDARD III, ET AL 3,115,948

PANEL FOR THE REDUCTION OF SOUND TRANSMISSION

Filed Dec. 14, 1960

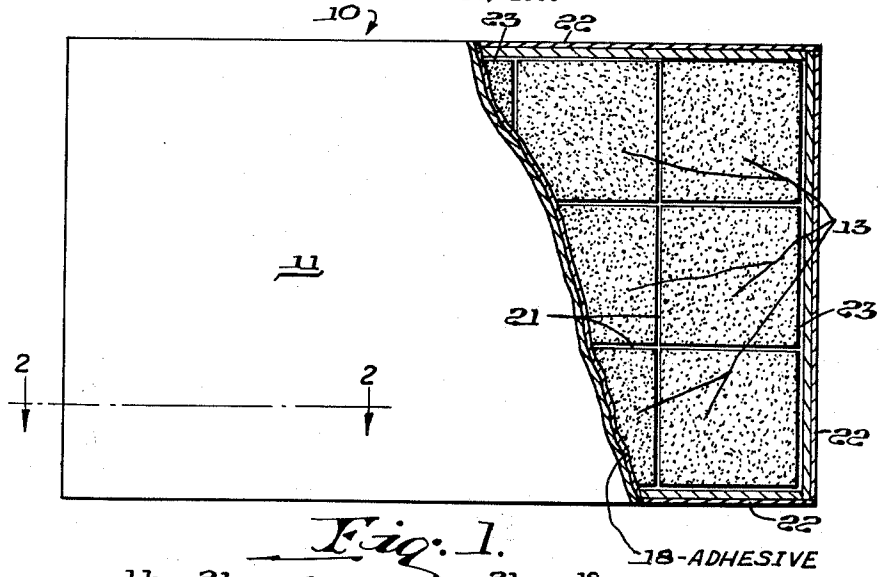


Fig. 1.

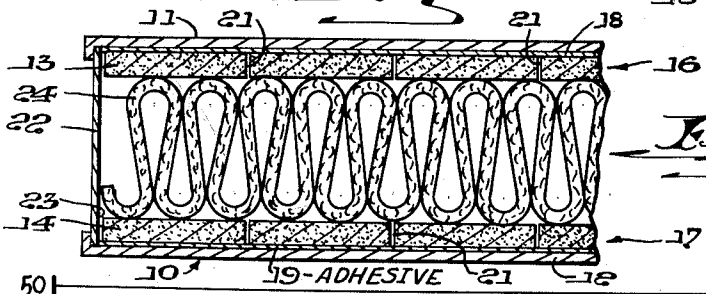


Fig. 2.

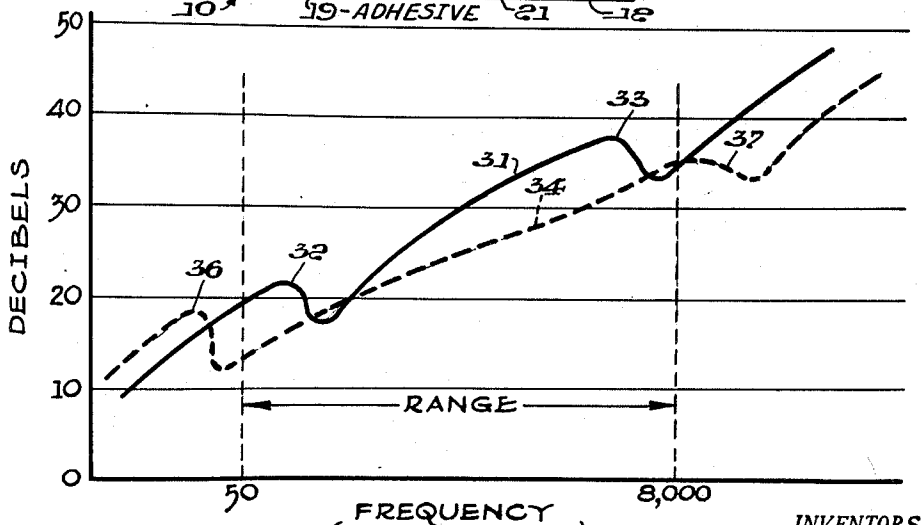


Fig. 3.

INVENTORS.
JAMES H. GILDARD, III
RICHARD D. LEMMERMAN.
BY
Leo L. MacLean
their
ATTORNEY.

United States Patent Office 3,115,948 Patented Dec. 31, 1963

3,115,948

PANEL FOR THE REDUCTION OF SOUND TRANSMISSION

James H. Gildard III, Baltimore, and Richard D. Lemmerman, Gibson Island, Md., assignors to Koppers Company, Inc., a corporation of Delaware

Filed Dec. 14, 1960, Ser. No. 75,741
4 Claims. (Cl. 181—33)

This invention relates to an acoustical panel and, more particularly, to the construction of a panel for the reduction of sound transmission therethrough.

To isolate a given area from an adjacent area wherefrom objectionable noise emanates in order to thereby maintain relative quiet in the given area, it is a common expedient to interpose a suitable sound barrier to prevent the penetration of the objectionable noise into the given area. The nature of the particular barrier employed determines the efficiency with which it performs the necessary function of preventing the entry of sound through such barrier. The capability of such a wall to perform this function is characterized in terms of "sound transmission loss."

It is well known that a simple single plate wall achieves sound transmission loss in accordance with the quantity of its mass. Expressed mathematically, the sound transmission loss of a single plate, or single element, wall improves with increasing mass in accordance with the equation: TL (db)$=24+14\log_{10} M$, where TL (db) is the sound transmission loss in decibels and M is the mass of the wall in lb./sq. ft. This equation defines the value of sound transmission loss at 500 cycles for a single element wall. Therefore, if the value of M is high, as would be the case with a solid masonry wall, a high degree of sound transmission loss can be attained. However, such a wall imposes a heavy floor load and is, of course, of a permanent nature. Architecturally, each of these characteristics may prove objectionable particularly where flexibility of space is desired as in modern school buildings and hotel dining areas where in the interest of mobility, it is often more expedient to employ light, semi-permanent walls of panel construction or even movable panel partitions such as may be interposed or removed as desired.

Since a single element wall, being dependent as it is upon mass law, provides only low values of sound transmission loss when practical weights are employed (i.e.: a single element wall weighting 4 lbs./sq. ft. achieves 30 decibels (db) of sound transmission loss at 500 cycles; a single element wall weighing 10 lbs./sq, ft. achieves only 36 db of sound transmission loss), various design schemes have been employed to escape the limitations of the mass law.

As a result the design of the complex wall evolved. This design seeks to combine two or more individual single element walls into a partition in such a manner as to produce a cumulative effect of the performances of the separate single walls. If an ideal acoustical environment could be provided between these two (or more) single element walls, the individual sound transmission loss performance values of these single element walls would be additive in their effect. However, in practice, such an ideal acoustical interspace between single element walls cannot be achieved and the cumulative sound transmission loss of a combined system of single element walls is not a simple addition of the individual performance values, but rather some value considerably less than the arithmetic sum thereof.

Consequently, an object of the present invention is the provision of a complex panel design wherein the walls thereof possess a relatively low B/M ratio (where B is the bending stiffness and M is the mass of the wall) yielding a high composite sound transmission loss for the complex panel unit.

Another object of the present invention is to achieve a complex wall panel having a substantially uniform high rate of increase of sound transmission loss per octave of increasing sound frequency.

A further object of the present invention is to provide a complex acoustical panel wherein the panel walls are damped out of phase.

Still another object of the present invention is the provision of a complex acoustical panel with an improved sound transmission loss spectrum wherein the fundamental resonance frequency of the single element wall components is shifted into the very low frequency region and in which the coincident bending wave frequency of the single element wall components is shifted up into the high frequency regions of the spectrum.

Thus, the present invention encompasses the semi-rigid combination of a light, thin, durable facing sheet with at least one layer of a material having a high value of M and a low value of B into a composite wall and utilizing two such composite walls as opposite sides of a panel with the interspace therebetween being completely filled with sound absorbing material of a particular density so as to damp the composite walls out of phase.

Other objects and features of the invention will become apparent to those skilled in the art in the following detailed description of a preferred embodiment of the invention also illustrated in the accompanying sheet of drawings in which:

FIG. 1 is a plan view of a preferred embodiment of the present invention with a portion of the top thereof broken away,

FIG. 2 is an enlarged view of a section taken on line 2—2 of FIG. 1, and

FIG. 3 is a graphic comparison between the sound transmission loss over the frequency spectrum for a single element wall and the sound transmission loss over the frequency spectrum of a wall of equal mass constructed in accordance with the present invention.

Referring now to the drawings, wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in FIGS. 1 and 2 an acounstical panel 10 for the reduction of sound transmission therethrough constructed in accordance with the present invention.

As shown, panel 10 has two imperforate parallel walls 11, 12 of light gage air-tight material such as metal, plastic, glass, etc. forming the panel faces and separated by an interspace, for example, of from 2 to 6 inches. Bonded to the inner surface of each of these walls 11, 12 are square pieces 13, 14 of a material having a high density and having low to moderate bending stiffness. Gypsum plaster in the form of plasterboard 3/8" thick is used in the preferred embodiment because of its economy and the ease with which it can be obtained. Other materials such as high density hardwood in squares can be used and will serve equally well. Wet gypsum plaster can be deposited on the walls 11, 12 and then separated into 12" squares by paper mold or cutting tools to yield similar results but this lengthly operation is prohibitive.

These square pieces 13, 14 are bonded to the light guage walls 11, 12 to form composite walls 16, 17 with an adhesive which is fully disclosed in U.S. Patent No. 2,918,442 and which has been indicated herein by the thin layers 18, 19, this adhesive having been carefully selected for its high holding power in the plane transverse to walls 11, 12 of panel 10 and its small interface slip in the plane parallel to walls 11, 12. It is important that the adhesive used set up at room temperature becoming from 80–90%, solid without the use of a catalyst. In this manner a semi-rigid, slightly

elastic permanent bond is secured between pieces 13, 14 and walls 11, 12. Thus, it has been found that "rubber-type" adhesives which employ rubber in an organic solvent are equally suitable in the practice of this invention so long as they meet the criteria set forth above. Although the particular shape of pieces 13, 14 is not critical the area thereof should be sufficiently small to further break up any lateral bending stiffness inherent in the gypsum plasterboard as would be the case if it were employed as one large sheet. The plasterboard, therefore, is cut into pieces approximately 12 inches on a side and fastened to the adhesive layers on walls 11, 12 so that the individual pieces 13 (and 14 as well) are separated from each other by gaps 21 which do not exceed 1/16". If the gaps 21 exceed 1/16" there is tendency for sound to "leak through" from the exposed portions of walls 11, 12. Further, pieces 13, 14 are similarly spaced from imperforate side walls 22 by gaps 23 each of which is a finite distance not exceeding 1/16". Side walls 22 are employed to provide an enclosure in conjunction with walls 11, 12 holding these walls 11, 12 in spaced relationship. So long as the stiffness which would accompany the use of large sheets is avoided, the pieces 13, 14 may even be placed in abutting relationship.

In order to insure high and dissimilar dampings of elemental walls 11, 12 the interspace between composite walls 16, 17 is completely filled with a mineral wool having a density from 1.5 to 3 lbs./cu. ft. This mineral wool is employed in the form of blanket 24 which in this preferred embodiment is composed of glass fibers and has a density of 2.5 lbs./cu. ft. Although blanket 24 is represented symbolically as being arranged in loose folds, such is not the actual case as blanket 24 completely fills the interspace. Being within the density range recited, blanket 24 is sufficiently compact to prevent the formation of a compliant air column in the interspace between composite walls 16, 17 which air column, if allowed to exist, would drive both composite walls 16, 17 in vibration sympathy. Further, blanket 24 is not so dense of compressed that it can serve as any significant mechanical coupling between the two composite walls 16, 17.

When one wall such as composite wall 16 inflexes under the acoustical load from a noise source the inflection created is damped by blanket 24. During the same acoustical cycle in which composite wall 16 inflexes toward and is damped by blanket 24, composite wall 17 is deflected away from blanket 24 and receives no benefit therefrom as a damping medium. When the acoustical cycle reverses itself, however, composite wall 16 deflects toward the noise source and away from blanket 24 while composite wall 17 inflexes toward and is damped by blanket 24. In this manner the two walls are damped out of phase.

By employing this manner of complex panel design the use of steel or other material of a lighter gauge than has previously been possible is permitted since the walls 11, 12 need only be of sufficient thickness to support the particular material of high density and low or moderate bending stiffness (in this case, gypsum plasterboard) used for loading walls 11, 12 to increase the elemental mass thereof. Thus, although substantially increasing the mass of the single element walls 11, 12 of the complex panel 10 the bending stiffness thereof is maintained at a low value. This accomplished first, by using light guage steel; second, by loading this light guage steel with a material having a low moderate bending stiffness; third, by applying the loading material in discrete pieces separated from one another by frequent interruptions (gaps 21, 23), not exceeding 1/16" in width, and four, by employing as an adhesive for bonding the loading material to the steel a type of adhesive providing a strong yet semi-rigid, slightly elastic permanent bond.

Thus, in designing a typical panel according to the present invention it is simply necessary to compute the total M which need be supplied by each composite wall to meet design conditions. Next, that combination of plasterboard and face sheet is selected which will yield the required value of M while employing the thinnest guage of face sheet material, preferably steel, which will satisfy the structural demands to be made thereon. In this manner the most economical panel is produced with a minimum amount of steel and a maximum amount of plasterboard. In constructing this composite wall it is desirable to increase the value of bending stiffness by as little as possible. By selecting an adhesive setting up to about 80 to 90% solid to produce a bond compatible with each material being joined and having bond strength of about 1000 p.s.i. in tension and about 500 p.s.i. in shear and by accurately cutting the plasterboard into squares before bonding them to the face sheet, the increase in the value of bending stiffness can be limited to one-half or less of the increase in the value of the mass M. Thus, if the mass of the face sheet is increased by 100%, the bending stiffness of the face sheet can be prevented from increasing by more than 50%.

As an indication of the efficiency to be attained by use of the construction encompassed by the present invention the results of tests by an independent nationally-known acoustical laboratory are repeated below:

Frequency (c.p.s.):	Transmission loss (db)
125	40.0
175	42.0
250	47.0
350	50.0
500	49.0
700	48.5
1000	50.0
1400	(51.0)
2000	53.0
2800	(55.0)
4000	57.0
Average	49

FIG. 3 illustrates the alteration produced on the frequency spectrum of the sound transmission loss characteristics of a single element wall as a result of properly altering the *B/M* ratio in the manner of this invention. Therein is shown the theoretical sound transmission loss frequency spectrum 31 for a single element wall of mass M_1 wherein infractions, or dips, occur at points 32, 33 with infraction 32 indicating the fundamental resonance frequency of such a wall and infraction 33 occurring at the frequency of coincident bending wave therefor.

Since both of these infractions, or dips, are functions of the ratio of mass (M_1) to bending stiffness of the wall and the material of which it is composed, by varying the *B/M* ratio these infractions can be driven out of the range of frequency interest, in this case the range between 50 and 8,000 cycles per second. After reducing the *B/M* ratio by substituting a composite wall constructed in the manner of the present invention having the same mass M_1 as the single element wall but having a lower value of bending stiffness, an altered frequency spectrum will result assuming approximately the profile of graph 34 which is shown as a broken line. Therein it may be seen that the infraction formerly occurring at the fundamental resonance frequency has been shifted into the low frequency regions to point 36 while the frequency of coincident bending wave has been driven into the high frequency regions as indicated by point 37.

Thus, by using the present invention one may employ ordinary building materials and combine them in a unique manner to produce a panel having enhanced capacity to reduce sound transmission therethrough.

Obviously many modifications and variations of the present invention are possible in the light of the above

teachings. It is therefore to be understood, that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed:

1. A high performance sound transmission loss panel comprising two imperforate face walls, side wall members supporting said face walls in spaced relationship defining an enclosure therewith, a plurality of separate pieces of high density, low bending stiffness material semi-rigidly adhered to the inner surface of each of said face walls substantially covering said inner surface, each piece being separated a finite distance from adjacent pieces and each piece covering a relatively small portion of said inner surface and the balance of said enclosure being completely filled with light-weight insulating wool.

2. A high performance sound transmission loss panel substantially as recited in claim 1 wherein the light-weight insulating wool is mineral wool having a density range of from about 1.5 to 3.0 lbs. per cu. ft.

3. A high performance sound transmission loss panel comprising imperforate face walls, side wall members supporting said face walls in spaced relationship defining at least one enclosure therewith, a plurality of separate pieces of high density, low bending stiffness material bonded to the inner surface of each of said face walls substantially covering said inner surface, each piece being separated a finite distance from adjacent pieces and each piece covering a relatively small portion of said inner surface, adhesive material for bonding said pieces

having the characteristic of setting from about 80 to about 90% solid and mineral insulating wool having a density in the range from about 1.5 to 3.0 lbs. per cu. ft. completely filling the balance of said enclosure.

4. A high performance sound transmission loss panel substantially as recited in claim 3 wherein the high density, low bending stiffness material is gypsum plasterboard.

References Cited in the file of this patent

UNITED STATES PATENTS

1,910,810	Nash	May 23, 1933
2,029,441	Parkinson	Feb. 4, 1936
2,069,413	Leadbetter	Feb. 2, 1937
2,160,066	Frische	May 30, 1939
2,178,729	Shields	Nov. 7, 1939
2,323,336	Knorr	July 6, 1943
2,451,396	Macleod	Oct. 12, 1948
3,087,570	Watters et al.	Apr. 30, 1963
3,087,574	Watters	Apr. 30, 1963

FOREIGN PATENTS

555,616	Belgium	Mar. 30, 1957
1,248,397	France	Oct. 31, 1960

OTHER REFERENCES

Kurtze et al.: "New Wall Design for High Transmission Loss or High Damping," The Journal of the Acoustical Society of America, vol. 31, No. 6, June 1959, pages 739–748.