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[54] **ACOUSTIC WALL COVERINGS**
8 Claims, 8 Drawing Figs.

[52] **U.S. Cl.** ..... **181/33 G,** 181/33 GA
[51] **Int. Cl.** **E04b 1/84**
[50] **Field of Search** 181/33, 33.1, 33.11, 33.12

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ABSTRACT: A sound-absorbing wall covering for regulating sound-absorption of a room is made in long sheets or rolls of a flexible laminate consisting of a flexible decorative skin such as vinyl adhered to a soft, porous backing material, preferably a foam polymeric material. Certain areas of the skin contain many very small perforations while the adjoining areas of the skin are imperforate; the perforate-to-imperforate areas typically being in the ratio of 1 to 1, thereby providing in a single sheet, in effect, a multipurpose sound-absorber. After installation, a room may be "fine-tuned" for sound by closing some of the holes in the perforated area.

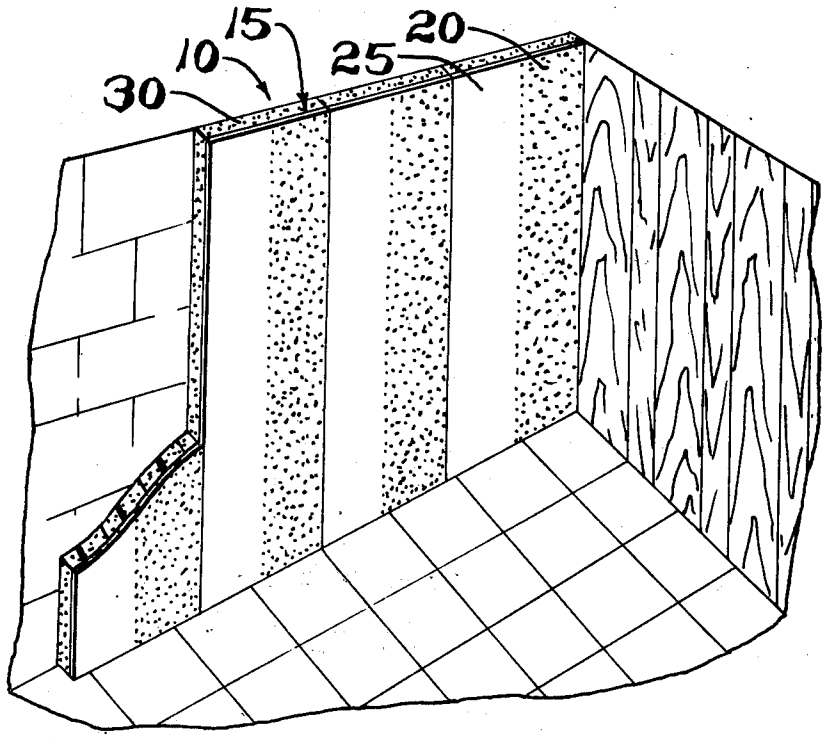
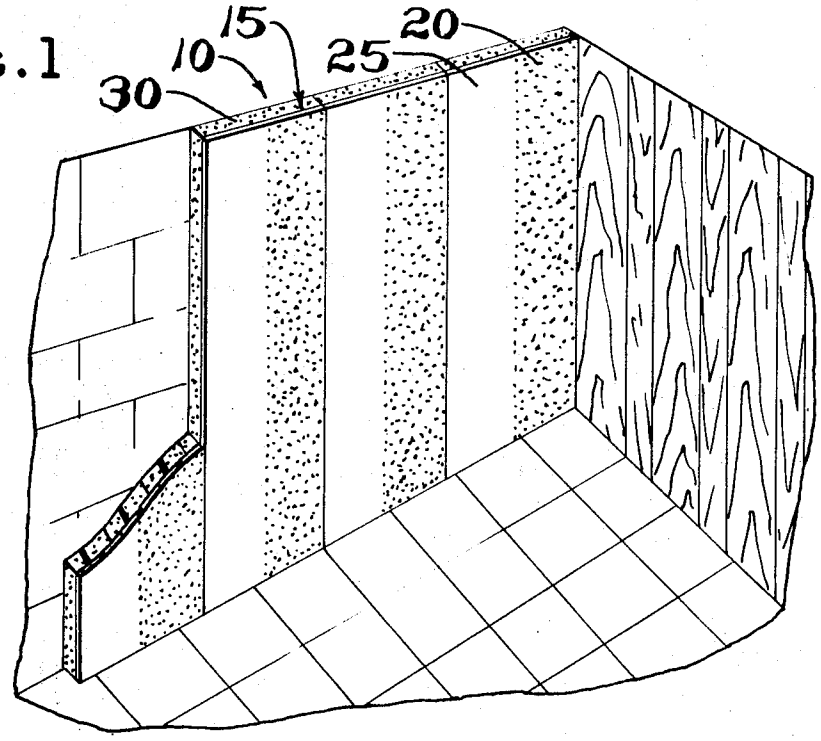


FIG. 1



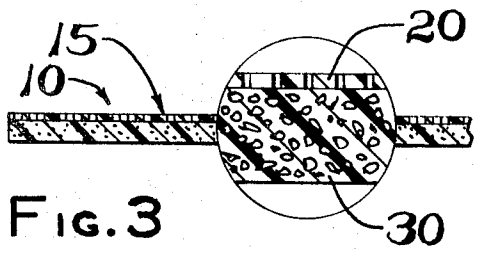


FIG. 3

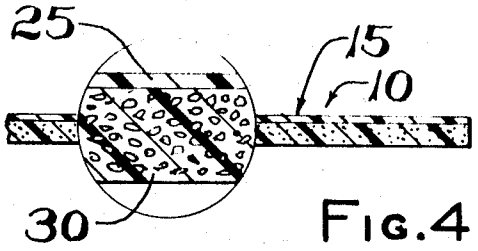


FIG. 4

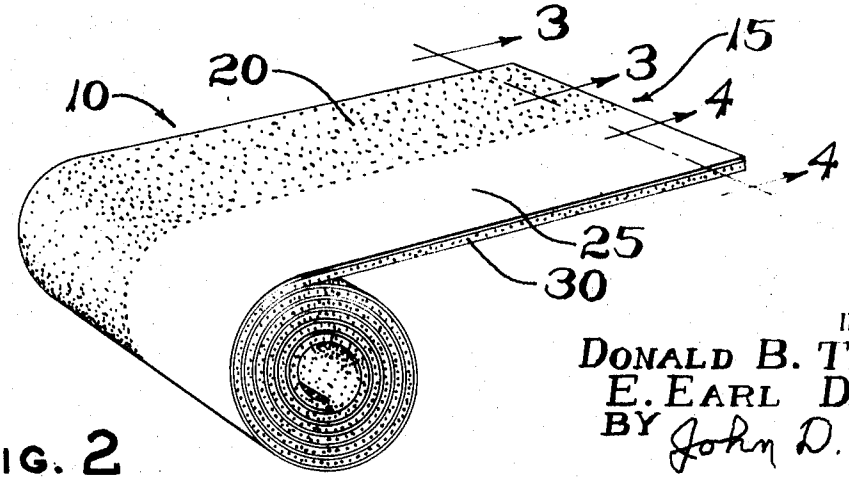
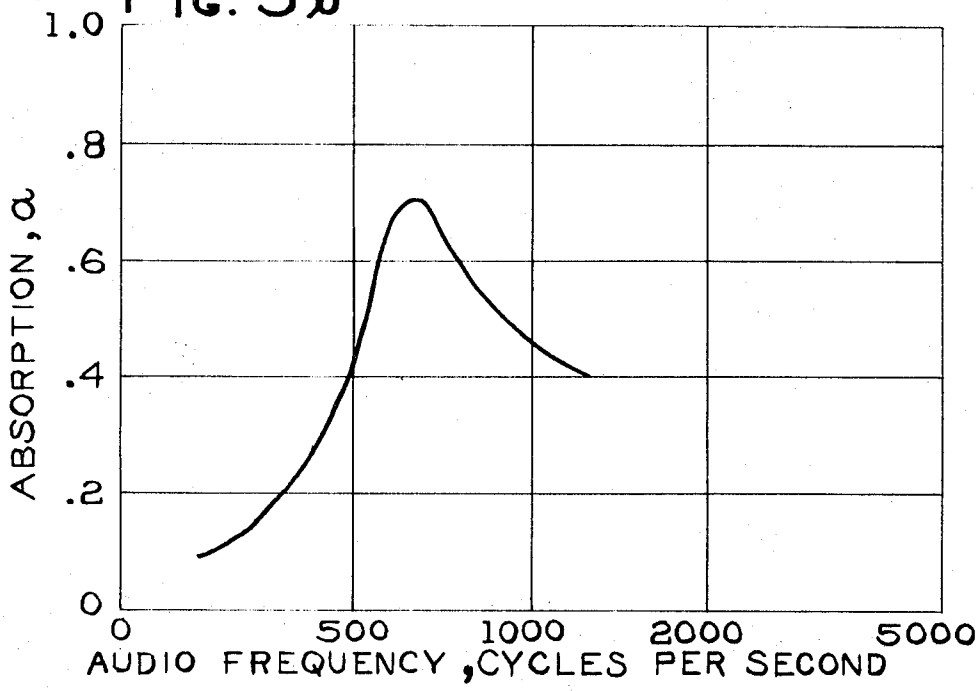


FIG. 2

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FIG. 5b



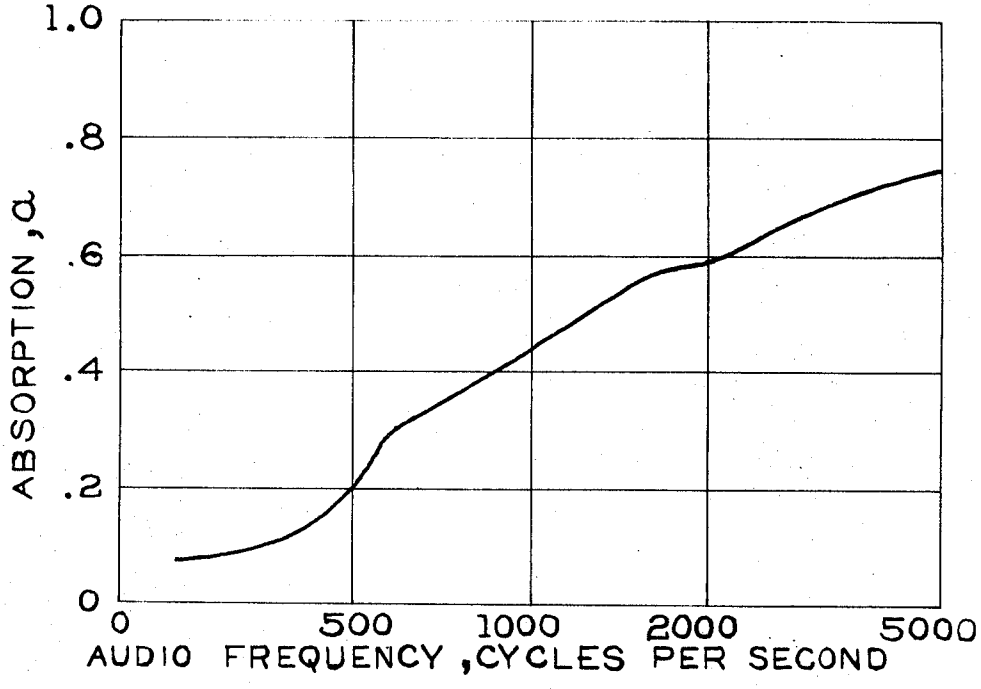
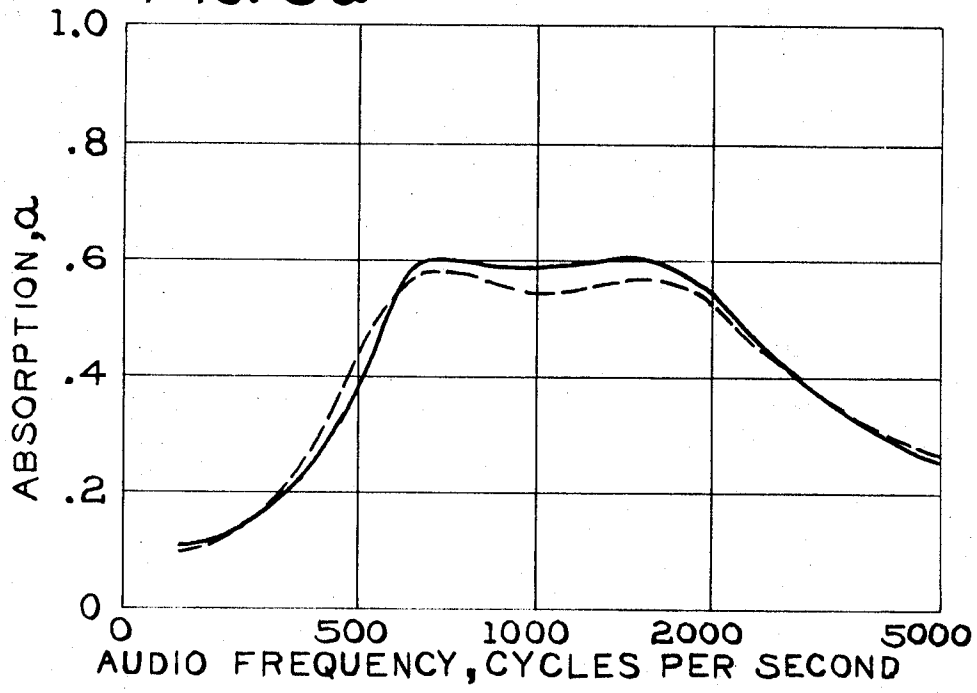


FIG. 5a

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FIG. 5d



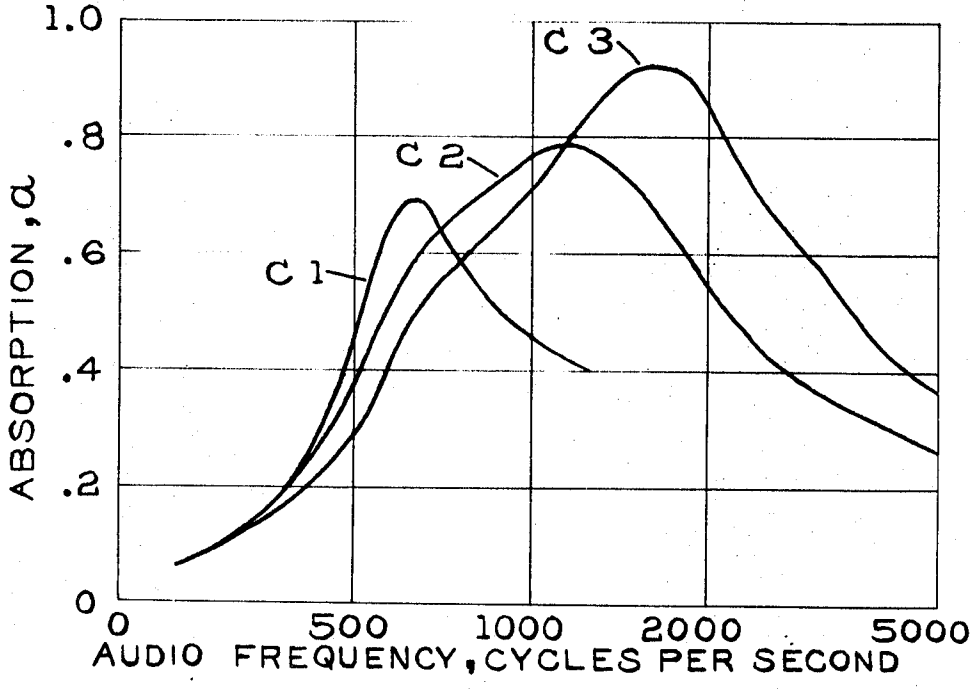


FIG. 5c

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ACOUSTIC WALL COVERINGS

This invention relates to sound-absorbing wall coverings for regulating the sound-absorption characteristics of a room. These coverings provide for absorption of sound energy in the audible frequency spectrum (sonic energy with frequencies between about 50 and 5,000 cycles per second) and are especially useful in concert halls, auditoriums, offices, residences, and even factories. Significantly, these coverings provide both the desired acoustic energy absorption, and also the decorating motif. Their use does not require a prejudicial trade-off for aesthetics, durability, or maintenance costs.

From the acoustical viewpoint, these coverings are equally useful for vertical walls, room ceilings, or even floors; and the term "wall" is used broadly in this specification to refer to any room surface areas exposed to sonic energy. In practice, these coverings are ordinarily used on vertical wall surfaces to complement presently available acoustic ceilings and floor carpets. Many of the latter, in themselves, have good sound absorption properties but they are not effective for the proper acoustical treatment of an entire room when they are used only on floors and ceilings.

BACKGROUND OF THE INVENTION

Although the theoretical principles have been recognized for some time, room acoustic treatment has remained to some degree an empirical art, and optimum acoustical treatment rarely ever has been achieved in a given room. The usual analysis used to determine the amount of sound energy absorption required in a room at a given frequency is the following:

$$\text{Reverberation Time } (RT) = 0.05V/Sa \qquad (1)$$

where

V is the total volume of the room;

S is the total surface area of the room exposed to sound;

a is an average absorption coefficient of the room; (It is obtained by multiplying the absorption coefficient of each separate surface by its area; then summing these products and dividing the result by the total areas.); and

RT is the time required for the sound intensity to fall to one-millionth of its original intensity.

The generally accepted criteria for Reverberation Time of a room is that it be independent of frequency. The acoustician tries to select his materials in such a fashion that a "flat" curve of Reverberation Time plotted against frequency is obtained. Empirical values have been established which indicate psychologically acceptable values of Reverberation Times for different rooms (e.g. an opera hall, a conference room, concert hall).

Bad or undesirable room acoustics is indicated either by a high Reverberation Time, a low Reverberation Time or a tilted Reverberation Time versus frequency characteristic. Also undesirable room acoustics can occur if there is a poor distribution of absorption materials which results in a poor diffusion of sound throughout the room. To achieve a reasonably uniform diffusion of sound in a room, it is desirable to distribute sound-absorbing material over a number of separate areas of the available surface regions of the room, and not just the ceilings or floors.

In the acoustical design of a concert hall, for example, the acoustician has traditionally tried to combine and distribute in the hall an assortment of draperies, carpets, furniture, upholstery, wall and ceiling covers to provide the desired sound energy absorption effect consistent with a pleasing aesthetic appearance and the acoustic effects resulting from the presence of an audience. Obviously, he must also conform to building codes on fire protection requirements, and the realities of maintenance and cleaning. After the initial concert experiences in a newly decorated hall, the portable items of decoration usually must be adjusted or regrouped in an attempt to improve the acoustic effects. Sometimes this regrouping activity can continue indefinitely in the hope of achieving the desired acoustic effect.

The prior art has recognized the sound absorption properties of many architectural materials such as foamed rubber, pile carpeting, draperies, curtains, fiberglass batts, and particular effort has been made in recent years in developing effective acoustic ceiling materials. Effective acoustic control of an entire room, however, cannot be obtained merely by treating its ceiling or its floor or both. The walls constitute a major proportion of the surface area of a room, and good distribution of absorptive materials requires that they be treated as well.

Much of the prior art materials which are known to be adequate sound-absorbers have been deficient in various respects for general use as acoustical wall coverings. For example, the layer thickness of some absorbers in conjunction with their mounting systems can severely reduce the useable volume in a given room. The operations of installation and assembly with other absorbers can be expensive and complicated. Carpeting can be hung on walls but is less than attractive to most people; and is expensive and difficult to clean. Urethane foam has been proposed but is not durable, and neither can it be decorated effectively. Similarly, acoustic ceiling tile is unattractive and lacks durability as a wall covering. In any event, all of these materials require careful placement and reorganization to provide good room acoustics.

SUMMARY OF THE INVENTION

According to this invention a sound-absorbing wall covering is provided which has excellent acoustical characteristics, and all other mechanical and aesthetic properties necessary for this purpose. A unique feature of this improved covering is that the covering has at least several types of absorbers combined into a single, common, integral sheet. Another unique feature of this improved covering is that after installation, the sound absorption characteristics of the room may be easily and quite accurately adjusted. That is to say, the covering of this invention provides for accurate "fine-tuning" of the acoustical properties of a room after the initial installation. A novel feature is that when the walls are treated, the need for large energy absorption coefficients associated with a material are neither necessary nor desirable. Excellent spatial distribution of the absorbing material necessarily results from the application of these coverings.

This improved wall covering consists simply of a soft porous backing material such as a resilient polymeric foam with a thin, flexible, durable outer skin against which the sonic energy of the room is directed. The preferred foam backing material is a so-called "open-cell" foam, the properties of which are more fully described in the following portions of this specification. The skin is preferably a flexible film such as any of the standard vinyl decorative wall coverings.

Successful sound absorption is obtained by perforating only certain limited areas of the flexible skin while leaving other areas solid or imperforate. The perforations are very small, and, depending on the texture of the exposed surface of the skin, these perforations may not even be visible except on very close-range inspection. The size of the individual perforations, and the areas of the skin in which they are grouped are also more fully discussed in the remaining portions of this specification.

These wall coverings are intended to be installed on the walls of a room or on large objects in a room much like ordinary wallpaper is applied. The particular wall area of a room which is so covered will depend basically on the function of the room and the corresponding acceptable Reverberation Time (cf. equation 1). Sufficient wall covering can be provided to slightly "over-absorb" the high-frequency sound. Then, the room may be "fine-tuned" by closing a proportion of the tiny skin perforations, or groups of perforations, until the desired acoustic effects for the room are achieved. Selectively closing a certain number of the perforations changes the sonic characteristics of the room by augmenting the high-frequency sound and reducing the low frequency. This may be

done with paint or suitable sealants applied directly to the exposed surface of the skin.

The invention will be further described with reference to the accompanying drawings which show, by way of example, the details of one sound-absorbing wall covering made in accordance with and embodying this invention, and which represents the preferred mode of practicing this invention.

FIG. 1 is a partial perspective view showing an interior corner of a room with a covering installed on one wall;

FIG. 2 shows a roll of the wall covering approximately in the form in which it is manufactured and delivered to an installation site;

FIG. 3 shows a cross section with a "magnified" portion of the wall covering, the section being taken along the line 3—3 of FIG. 2 in a perforated area of the skin;

FIG. 4 is a view corresponding to FIG. 3 but taken along the line 4—4 of FIG. 2 in an imperforate area of the skin; and

FIG. 5*a*, 5*b*, 5*c* and 5*d* show various graphs used in explaining the mode of operation of these wall coverings.

Referring to the drawings, the acoustic wall covering **10** is a laminate consisting of a flexible decorative skin **15** which has a perforated area **20** (see FIG. 2) and an imperforate area **25**, (see also FIG. 3), and which is adhered to a relatively thin layer of a nonrigid, porous, soft, resilient, flexible, open-cell foam material **30**.

The preferred skin **15** for the wall covering is a flexible film of polymeric material such as the common decorative vinyl wall coverings now widely available in vast variety of colors, textures, and finishes. These materials have been proven as effective, durable wall coverings and are economically within the range which makes them suitable for these acoustic coverings. Nearly any of the conventional flexible wall coverings could be used as a skin if their mechanical properties are otherwise acceptable for a given installation.

The skin **15** is adhered directly to the foam backing material **30** so that the foam is coextensive in area with the skin. The thickness of the foam material **30** is typically about three-eighths inch but it may range from as little as one-sixteenth inch to as much as one inch. Thicker foam backings are advantageous for their acoustical properties but ordinarily such thicker foams will increase cost. The foam material is an open-cell foam, meaning that the foam is made so that most of the cells or open spaces in the body of the foam are in communication with the adjoining spaces. A typical "open-cell" foam has at least 80 percent of its individual air cells ruptured and therefore in communication with an adjoining air cell.

The foam material is flexible and preferably with visco-elastic properties at ordinary room temperatures to augment the absorption of sonic energy. (Visco-elastic materials show both an elasticity and a viscosity upon mechanical stressing.)

The density of the foam material is typically 5 pounds per cubic foot and may vary from 1.0 to 10.0 pounds per cubic foot depending on the particular applications. The foam backing material **30** will be selected to provide adequate resistance to sagging. Many flexible resilient foamed polymers may be used for this purpose. The backing foam **30** will also have low compression set.

The static modulus of the foam is preferably less than that of an equivalent thickness of air.

The cover perforations **20** are represented by the stipled area in FIGS. **1** and **2**, and are shown in detail in the enlarged region of FIG. 3. Each perforation should be clearly made so that it extends completely through the skin **15** to the underlying foam layer **25** to provide communication with the open cells (not shown) in the foam backing material **30**. In a typical wall covering using a vinyl film cover, the perforations **20** may be individually die-cut holes which initially have a maximum average width of about 28 mils. Normally, these holes are cut in the film skin **15** before the latter is laminated with the foam backing **30**. In the laminating operations these holes normally tend to become smaller, so that in the final finished product, the holes **20** may have a maximum average width in the order of 20 mils. A hole of this size is scarcely visible to a human eye with normal vision. The presence of such holes may be further concealed through the use of decorative textures on the surface of the skin layer **15** so that the holes appear visually to blend into the ornamental pattern.

The width of the holes may range in size from 5 to about 60 mils. The selection of the size of the holes depends not only on the acoustic properties desired but also on aesthetics and the durability of the skin layer **15**. It is ordinarily desirable to make the holes as small and as unobtrusive as possible for visual appearance. However, an unusually small hole (like 5 mils) may tend to become plugged with the laminating adhesive during the operation of laminating the skin **15** to the foam **30**, so that processing considerations suggest the use of the larger 20-mil size hole.

Of acoustic significance is the size of the areas in which these holes are located in the cover. As shown particularly in FIGS. **1** and **2**, the perforated area of the covering material is approximately 50 percent of the entire surface of the skin **15**, the perforations being grouped into approximately one-half of the lateral width of the skin **15** for its entire length. In the installation shown in FIG. **1**, therefore, the acoustic wall covering will have vertical perforated areas extending from ceiling to floor, alternating with imperforate vertical areas of approximately the same size.

Arranging the perforations as shown in the drawings is acoustically effective and most economical for manufacturing a standard wall covering. As explained in the foregoing, after a covering is installed on some or all the room walls to provide the general level of acoustic treatment, it is possible to achieve acoustic "fine-tuning" by closing some of the perforations by spreading paint or a transparent resin over them on skin **15**. The perforated area can thus be progressively reduced until the desired sound absorption characteristic is achieved.

The individual perforations **20** are spaced reasonably uniformly one from another in the perforated areas. There may be from 5 to 60 holes per square inch in the perforated area depending on the absorption characteristic desired of a particular covering. It is important to appreciate that in the drawing the stipled areas shown in FIGS. **1** and **2** are to indicate only the regions in which the perforations are located, and are not intended to represent the actual distribution of the perforations **20**.

The ratio of the perforated areas to the imperforated areas in the illustrated covering is 1 to 1, but may vary to as much as 1 to 5.

The smallest practical dimension of any perforated area, whatever its shape, should be about 2 feet.

There is no practical need to actually determine the smallest area, however. For production purposes it is most practical to perforate about one-half the total area of the skin as shown in FIGS. **1** and **2**, and this wall covering applied to the walls of an office, conference room or living room, will probably provide satisfactory acoustics. If it doesn't, then the acoustics can be adjusted by progressively sealing or closing some of the perforations as necessary.

A preferred skin material is film which weighs at least 15 ounces per lineal yard of a strip 54 inches wide.

In summary, we have found that an acoustic wall covering with excellent absorption characteristics is obtained from the following components:

A. Foam

1. Hycar 1551 (a synthetic rubber foam which is a copolymer of acrylonitrile and butadiene made as of 1968 by The B.F. Goodrich Company, Akron, Ohio);
2. Density range—6.6±0.6 pounds per cubic foot;
3. Static Modulus—$1.7\pm0.7\times10^5$ dynes per square centimeter;
4. Thickness—11 / 32±1/32 inch;

B. Vinyl skin-

1. of expanded type vinyl;
2. weight, including a cloth backing and adhesive of 34.0±10 ounces per lineal yard at a 54-inch width;
3. Perforations uniformly spaced at 20 holes per square inch in the perforated areas;

4. The size of the perforations are 20.0±5 mils maximum width (i.e. diameter);
5. The perforated areas are in the ratio of 1:1 with the non-perforated areas, and both areas are of identical geometry, in all areas of the covering material;
6. The minimum dimensions of all perforated areas is 2 feet by 2 feet;

The sequence of graphs shown in FIG. 5 show some test results obtained with various acoustical wall coverings. These curves also illustrate the performance characteristics of the coverings of this invention, and why they are useful for acoustic problems.

FIG. 5*a* shows how bare open-cell foam, alone, functions in absorbing sound at various frequencies. The foam sample used in this text was Hycar 1551 at a thickness of 0.36 inch. If a thicker foam sample is tested under the same conditions, the curve is essentially the same shape but displaced laterally to the left. A thinner foam results in the curve being shifted toward the right. The curve shows bare foam absorption is most effective for higher frequencies and very poor for lower frequencies. The shape of this curve is characteristic of any soft porous material, such as fiberglass batts, carpeting, etc.

FIG. 5*b* is a similar plot except that it shows the effect of covering the exposed bare foam (of the same thickness) with an imperforate flexible polymeric skin, (specifically a solid vinyl of 37 ounces per lineal yard in a 54-inch wide strip). This curve shows maximum absorption at a pronounced peak midway through the frequency range with lesser absorption at the low and the high frequencies. If heavier weight skins are used, the resulting plot is essentially the same shape except that the peak is shifted leftward so that maximum absorption occurs at lower frequencies. Thus, the shape of this curve is typical of that obtained by an imperforate skin over a soft resilient backing material, the exact values varying with the density and thickness of the backing, the weight of the cover, and other relevant factors.

FIG. 5*c* shows the results of perforating the skin of the laminate tested in FIG. 5*b*. The latter curve (i.e. the FIG. 5*b* curve) is also reproduced on FIG. 5*c* (see curve C-1) for comparison. If the entire skin is perforated with 20-mil nominal diameter holes at a distribution of 10 holes per square inch, the peak of the curve is broadened, and is shifted rightward toward the higher frequencies as shown in curve C-2. Curve C-3 on this plot shows the effect of increasing the number of holes to 20 holes per square inch throughout the cover. These data show that the absorption frequency characteristics can be adjusted by a suitable choice of the number of holes per unit area of the skin.

Finally, the solid line curve in FIG. 5*d* shows the corresponding performance of a product of the type claimed in this specification. Specifically a foam-vinyl skin laminate like that described for FIG. 5*b* was perforated at a distribution of 20 holes per square inch along 50 percent of its area and the remaining area was imperforate, as depicted in FIGS. 1–4. The size of the holes were 20 mils nominal diameter. The test curve (in solid lines) shows that the resulting absorption is high and flat over the most important part of the speech range. This curve is a combination or blending of the FIG. 5*b* (all solid skin) curve with the curve C-3 of FIG. 5*c* (all perforated skin). This is a very valuable result and enables the acoustician, therefore, to use a single material to achieve a result he has desired but previously he could only obtain by repeated combinations and regroupings of different materials like draperies, rugs, etc. in a room.

The experimental curve (the solid line) of FIG. 5*d* agrees remarkably with a curve calculated from theoretical considerations for the same laminate. The theoretical or calculated curve is shown in FIG. 5*d* in broken lines.

The general shape of the FIG. 5*d* solid curve is characteristic of other laminates we have similarly tested in which we varied the cover weight, the flexibility of the cover, the number of holes per unit area, the thickness and density of the foam, and the static modulus of the foam. Our experiments consistently show that there is a definite acoustical advantage in using coverings of the class claimed in this specification.

All the foregoing tests have been made by the reverberation-room method as used by the University of Michigan in 1968. The edges of the samples used were enclosed to avoid distortions for edge effects.

The absorption factor, *a*, in the foregoing curves is the same factor used to define Reverberation Time (See equation 1).

As indicated in FIG. 5*d*, in addition to the broad "flat" absorption characteristics of these coverings throughout the medium frequencies of the sound spectra, these coverings have a comparatively small absorption of both the low-frequency sound and the high-frequency sound. This means that these wall coverings are more effective for absorbing the intermediate frequencies and this is no disadvantage because the normal furnishings and conventional sound-absorbing materials contribute significantly to the absorption of the high-frequency sonic energy. Therefore, the much smaller absorption by these wall coverings of high frequencies is desirable to provide a balanced design. The low-frequency sonic energy is best absorbed by light interior partitions in a room or specially constructed low-frequency sound-absorbers.

We claim:

1. An acoustic wall covering comprising:
   a. A flexible, porous backing material which has an open-cell structure at least throughout substantially all of the regions adjoining one side face of the material; and
   b. A skin of flexible material adhered throughout its area to said side face of the backing material; and
   c. A series of perforations through said skin communicating the exposed area of it with said open-cell side of said backing material;
   d. The perforations being grouped in discrete areas of the skin and adjoining substantial skin areas which are imperforate.

2. An acoustic wall covering according to claim 1 and further characterized in that:
   a. said porous backing material has a compressibility equal to or less than an equivalent thickness of air.

3. An acoustic wall covering according to claim 1 and further characterized in that the backing material is a foamed polymeric material at least about one-sixteenth -inch thick.

4. An acoustic wall covering according to claim 1 and further characterized in that:
   a. the perforated areas of said skin are approximately in about a 1:1 ratio with the imperforated areas thereof.

5. An acoustic wall covering according to claim 1 and further characterized in that:
   a. the maximum dimension of the individual perforations ranges in size from about 5 to about 60 mils.

6. An acoustic wall covering according to claim 1 and further characterized in that:
   a. the ratio of the perforated areas to the imperforate area of the skin may range from about 1 to 1 to about 1 to 5.

7. An acoustic wall covering according to claim 1 and further characterized in that:
   a. the minimum dimension of each perforated or each imperforated area of the skin is about 2 feet.

8. An acoustic wall covering according to claim 1 and further characterized in that the number of holes in the perforated areas range from about 5 holes to about 60 holes per square inch.

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