March 28, 1950 H. F. OLSON 2,502,016

DIFFRACTION TYPE SOUND ABSORBER

Filed Nov. 30, 1943 6 Sheets-Sheet 1

FIG. 1.

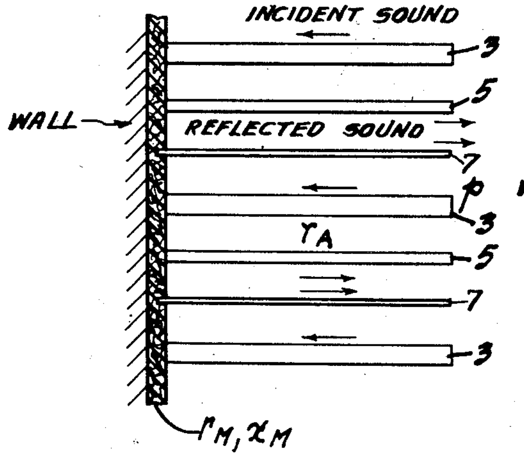


FIG. 2.

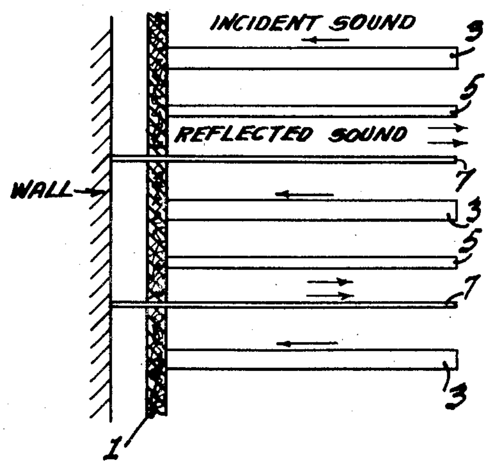


FIG. 3.

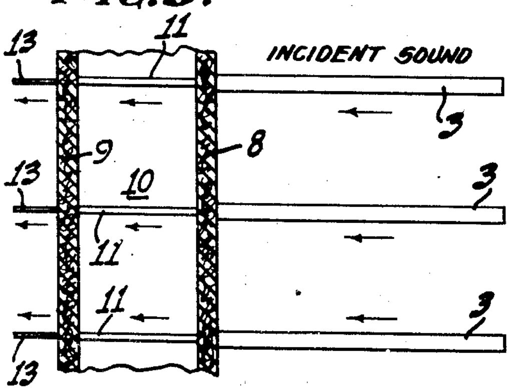
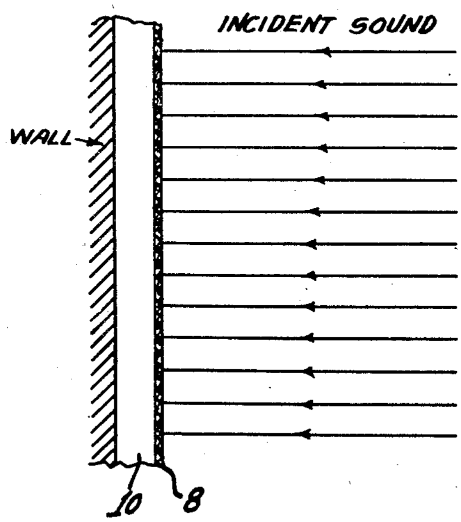


FIG. 4.



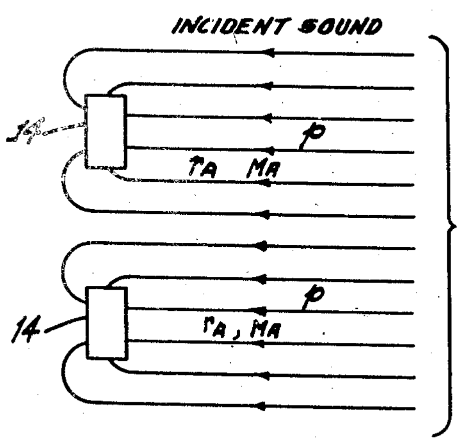


FIG. 5.

Harry F. Olson, Inventor

By C. D. Tuska

Attorney

FIG. 10.

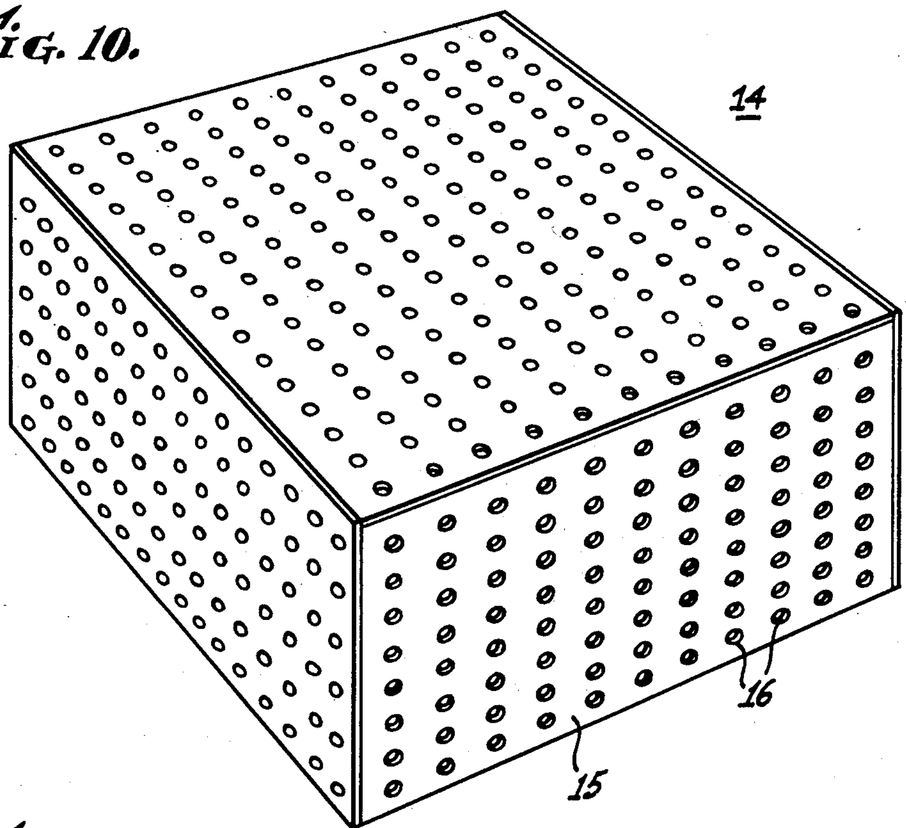


FIG. 11.

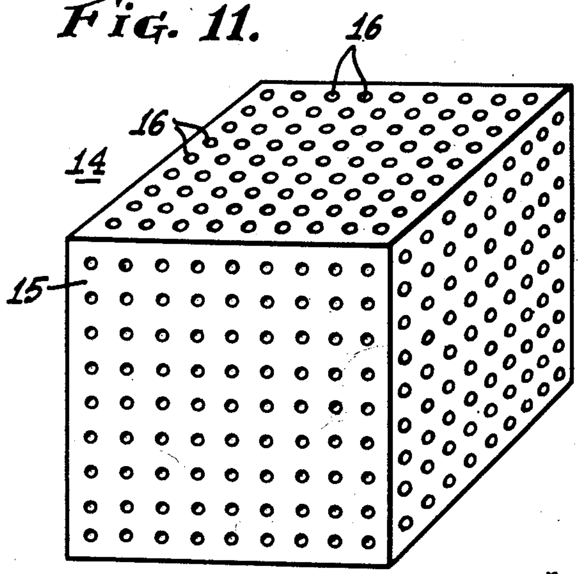
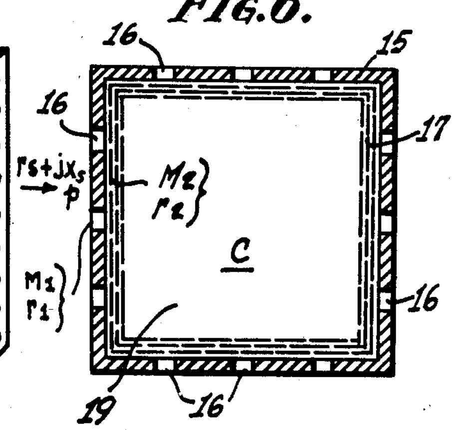


FIG. 6.



Inventor
Harry F. Olson
By
C. D. Tuska
Attorney

March 28, 1950 H. F. OLSON 2,502,016

DIFFRACTION TYPE SOUND ABSORBER

Filed Nov. 30, 1943 6 Sheets-Sheet 3

FIG. 15.

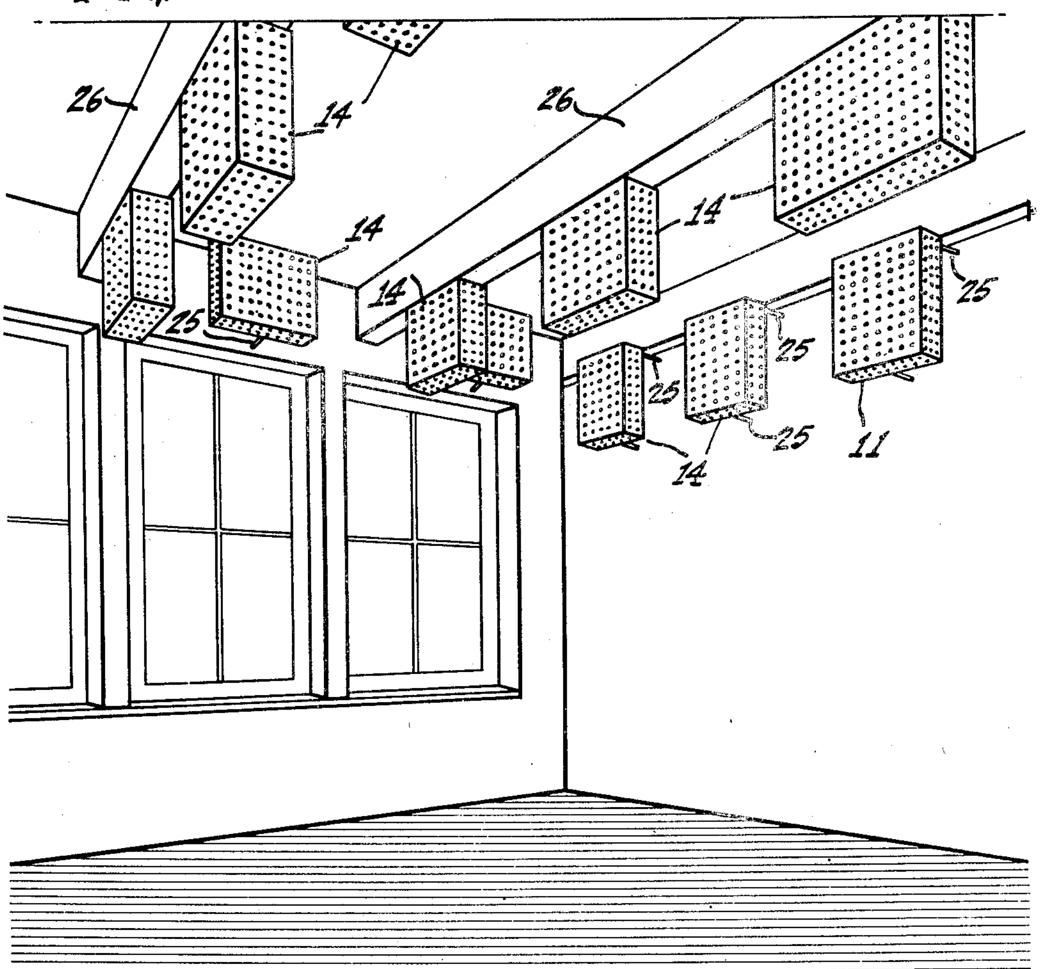
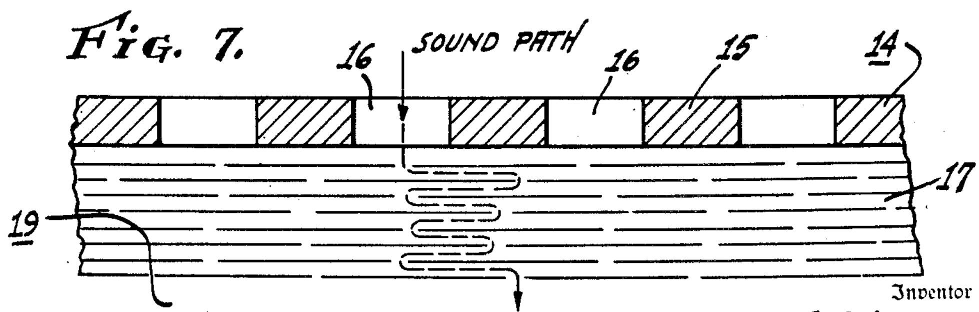


FIG. 7.



Inventor

Harry F. Olson

By

C. D. Tuska Attorney

March 28, 1950 H. F. OLSON 2,502,016

DIFFRACTION TYPE SOUND ABSORBER

Filed Nov. 30, 1943 6 Sheets-Sheet 4

Fig. 8.

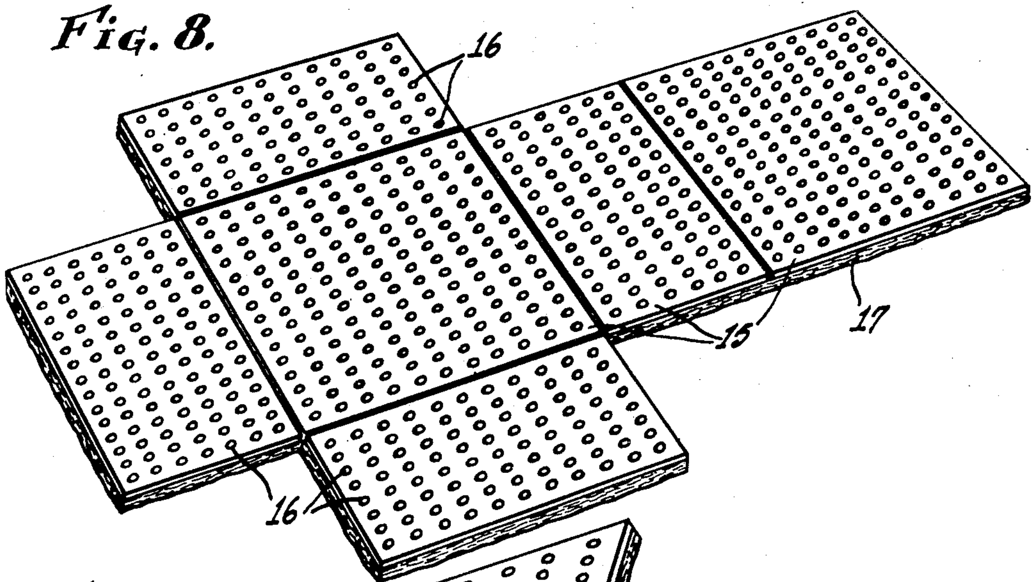
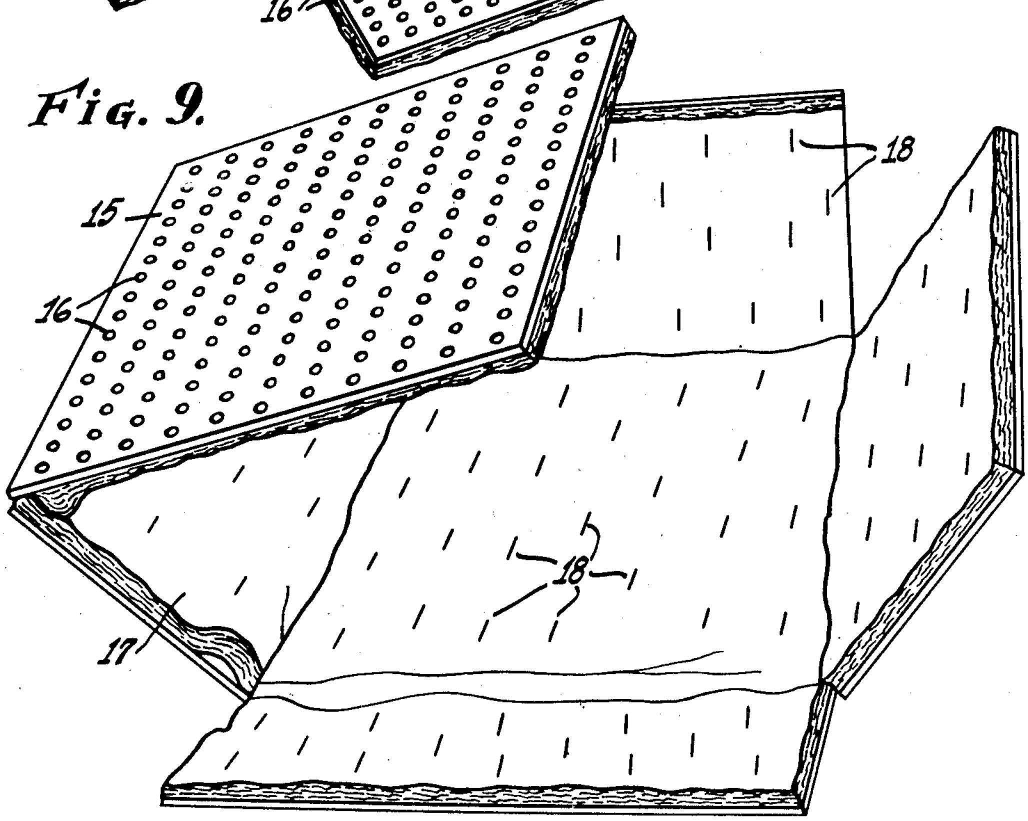


Fig. 9.



Inventor
Harry F. Olson

By C. D. Tuska

Attorney

March 28, 1950 H. F. OLSON 2,502,016

DIFFRACTION TYPE SOUND ABSORBER

Filed Nov. 30, 1943 6 Sheets-Sheet 5

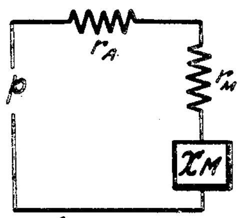


FIG. 13a.

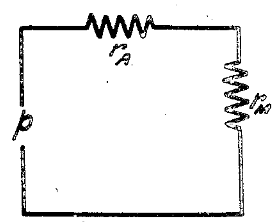


FIG. 13b.

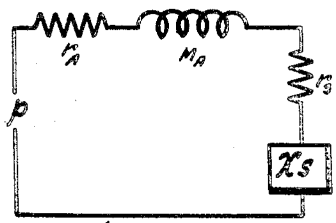


FIG. 14a.

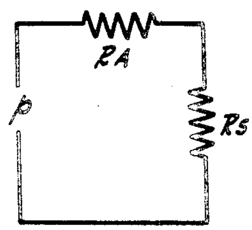


FIG. 14b.

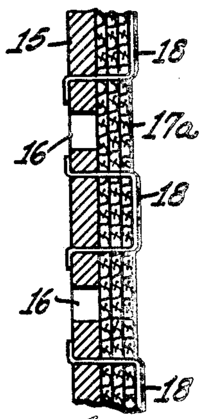


FIG. 18.

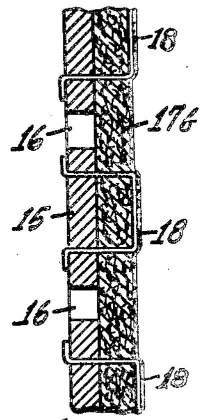


FIG. 19.

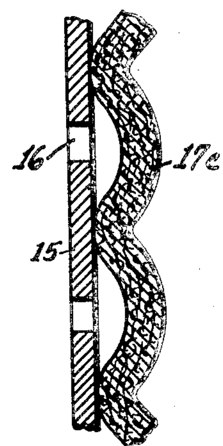


FIG. 20.

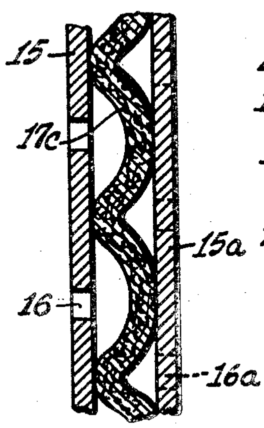


FIG. 21.

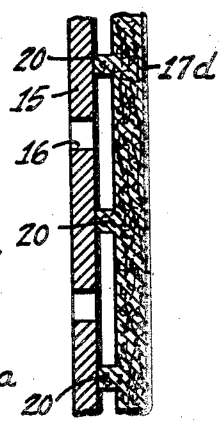


FIG. 22.

FIG. 23.

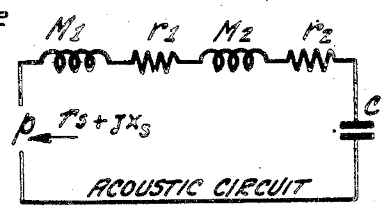


FIG. 12.

Inventor

Harry F. Olson

C. D. Tuska

Attorney

March 28, 1950 H. F. OLSON 2,502,016

DIFFRACTION TYPE SOUND ABSORBER

Filed Nov. 30, 1943 6 Sheets-Sheet 6

Fig. 17.

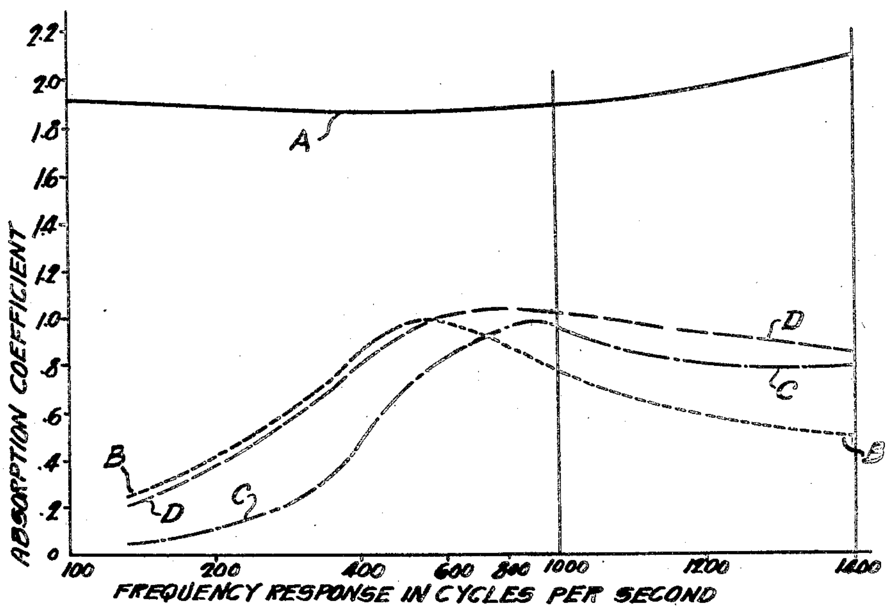
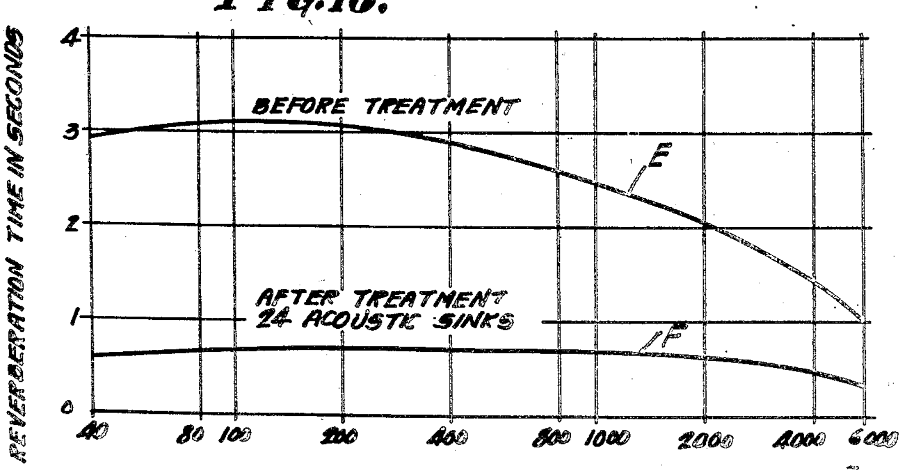


Fig. 16.



Inventor
Harry F. Olson

By

C. D. Tuska

Attorney

Patented Mar. 28, 1950

2,502,016

UNITED STATES PATENT OFFICE

2,502,016

DIFFRACTION TYPE SOUND ABSORBER

Harry F. Olson, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application November 30, 1943, Serial No. 512,320

13 Claims. (Cl. 181—33)

1

This invention relates to acoustic absorbers, and more particularly to an acoustic absorber of the diffraction type.

The practice of providing sound absorbing materials in rooms, auditoriums, offices, apartments, factories, etc. is well known. Conventional sound absorbing materials used in this connection are usually designed for dual purposes, namely, as a building or wall material and as a sound absorber. To be satisfactory for wall structures, these materials must be quite rigid, and in order to provide sufficient rigidity, the inherent properties of these materials are such as to impart to them acoustical impedances which are high compared to the characteristic acoustic impedance of air in the free atmosphere, being usually from ten to twenty times as great. As a consequence, a large amount of incident sound energy is reflected by these materials, so that the sound absorbing efficiency thereof is relatively low.

In most cases, conventional materials are used against a wall, which results in a further reduction in efficiency. Moreover, conventional sound absorbing materials are usually used over relatively large areas and this further militates against greatest efficiency. To obtain better efficiency, the sound absorbers should be arranged in "spots," so to speak, whereby to take advantage of the phenomenon known as diffraction for improving the efficiency of the absorbers. However, existing materials are not particularly suitable for use in this "spot" fashion, being usually relatively heavy and cumbersome, difficult to install, and inefficient.

The primary object of my present invention is to provide an improved diffraction or "spot" type acoustical absorbing unit which is free from the aforementioned and other similar limitations which characterize prior art absorbers.

More particularly, it is an object of my present invention to provide an improved diffraction type acoustical absorber which readily lends itself to use as a "spot" type absorber and which can be installed easily even by an unskilled person.

Another object of my present invention is to provide an improved diffraction type acoustical absorber which, for a given amount of absorbing material, provides an extremely low reverberation time compared to absorbers of the prior art.

Still another object of my present invention is to provide an improved acoustical absorber as above set forth which is highly effective at the low and high ends of the audio frequency spectrum, as well as in the intermediate range, in contrast to conventional absorbing materials

2

which are effective over a rather limited intermediate range only. This makes my improved absorbers particularly useful for installations where either low or high frequency noises, or both, are in abundance, as in factories, industrial offices, plants, restaurants, bowling alleys, and the like, while being also especially suitable in auditoriums and other places where people congregate in relatively large numbers, offices, apartments and the like.

A further object of my present invention is to provide an improved acoustical absorbing unit as above set forth which, while designed primarily as an acoustical absorber, may also be made decorative or artistic in appearance for use in homes, theatres, museums, and other large auditoria.

Still a further object of my present invention is to provide an improved acoustic absorbing unit as aforesaid which can be rendered decorative by the application of paint to the outer surface thereof without impairing the absorbing qualities thereof, in contrast to conventional absorbers, the efficiency of which is usually reduced by the application of paint or the like thereto due to the hard surface which the dry paint provides.

Another object of my present invention is to provide an improved acoustical absorbing unit of the type set forth which can be easily removed for cleaning and the like and equally easily remounted for use.

A further object of my present invention is to provide an improved acoustic absorber as aforesaid which is extremely light in weight.

It is also an object of my present invention to provide an improved acoustical absorber which has an extremely high absorption coefficient, which has a much lower cost per unit of absorption than do acoustic absorbers of the prior art, and which is highly efficient in use.

In accordance with my present invention, the absorber comprises a casing which encloses a relatively large fluid filled space and the wall structure of which is constituted at least in part by a material which is pervious to acoustical waves. This material is of a character such that it offers a relatively large dissipative impedance to the passage of sound waves therethrough from the exterior of the casing to the interior, while the space enclosed by the casing is of sufficiently large volume to offer a relatively small impedance to the passage of the sound waves through the casing. The absorber units may be made in the form of box-like structures or in any other suitable form, and any desired number of such units may be mounted at suitable points or "spots" throughout a room which is to be corrected acoustically.

The material of which the casing is made may take various forms. In one construction, this material is constituted by an outer layer of cardboard having a plurality of openings therein of such dimensions as to permit sound waves to pass therethrough substantially freely, the absorbing material backing up and lining the cardboard layer. In this particular modification, the absorbing material is constituted by a plurality of layers of thin paper having fine slits therein disposed at random and in sufficient communication with each other to provide a plurality of continuous passages which establish communication between the exterior of the casing and the space therein. The inner, sound dissipating layer is of a limp material and may be stapled or otherwise suitably secured to the outer, rigid, cardboard layer to provide a rigid, self-contained, self-supporting structure.

In another form of the invention, the material is constituted by a felted, fibrous material the fibers of which are intertwined in sufficiently compact relation to provide a plurality of passages of small cross-sectional dimensions affording communication between the exterior of the casing and the space therein. In any case, the small passages in the absorbing material provide a very high acoustical resistance which dissipates the sound energy passing therethrough, the large volume of fluid in the space within the casing having sufficient capacitance to provide a low impedance to the incoming sound waves whereby the waves will enter the passages and the energy thereof will be readily dissipated.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with additional objects and advantages thereof, will best be understood from the following description of several embodiments thereof, when read in connection with the accompanying drawings in which

Figures 1 and 2 are bar graphs showing, in a general way, the absorptive and reflective properties of certain types of sound absorbing wall structures,

Figures 3, 4 and 5 are similar graphs showing the absorptive properties of absorbers formed in accordance with my present invention,

Figure 6 is a central, sectional view through one form of absorbing unit constructed in accordance with my present invention,

Figure 7 is an enlarged fragmentary view, partly in section, of a portion of the wall structure of the unit shown in Fig. 6,

Figure 8 is a perspective view of a blank from which an absorber such as shown in Fig. 6 may be constructed,

Figure 9 is a view thereof in partially assembled form,

Figures 10 and 11 are perspective views of two completed absorbing units each of somewhat different shape and each formed from a blank similar to that shown in Fig. 8,

Figure 12 is an electric wiring diagram showing, by way of illustration, the electrical system analogous to the acoustical system of Fig. 6,

Figures 13*a* and 13*b* are similar electrical wiring diagrams corresponding to the acoustical system of Fig. 1,

Figures 14*a* and 14*b* are similar wiring diagrams corresponding to the acoustical system of each of the units shown in Fig. 5,

Figure 15 is a view showing a plurality of absorbing units in accordance with my present invention mounted in a room requiring acoustical treatment,

Figure 16 is a graph showing the reverberation time of the room of Fig. 15 both before treatment and after treatment thereof,

Figure 17 is a graph showing the comparative absorption coefficients of several prior art acoustic absorbing materials and also of my improved absorber, and

Figures 18 to 23, inclusive, are fragmentary sectional views showing other forms of absorber casing wall structures constructed in accordance with my present invention.

Referring more particularly to the drawings, wherein similar reference characters designate corresponding parts throughout, there is shown, in Fig. 1, a wall faced or lined with conventional absorbing material 1. In this figure, the bars 3 indicate the incident sound and the bars 5 and 7 indicate the sound reflected by the material 1. The width of the several bars 3, 5 and 7 is shown in approximately proportionate relation to indicate that there is less sound reflected by the surface of the material 1 and still less from within the material 1 than is received by this material. A reduction in the amount of reflected sound by the relatively high impedance absorbing material 1 of the prior art may be obtained by spacing the material 1 from the wall, as shown in Fig. 2. In practice, however, it is not feasible to provide a large space between the absorbing material 1 and the wall, so that the condition represented by Fig. 1 is the one usually encountered.

Fig. 3 illustrates diagrammatically the sound absorptive qualities of an absorber constructed in accordance with my present invention and comprising a pair of wall members 8, 9 spaced from each other a distance to provide a space 10 of relatively large volume. As shown in Fig. 3, the incident sound represented by the bars 3 strikes the front surface of the wall 8 and only a relatively small amount thereof, as shown by the bars 11, is transmitted to the space 10. Such sound as is transmitted by the wall 8 then strikes the wall 9 which absorbs additional energy from the sound waves and transmits only a negligible quantity thereof, as represented by the extremely thin bars 13. This is so because, as will be pointed out hereinafter in greater detail, the acoustic impedance of the material of my improved absorbing units is substantially the same as the characteristic impedance of the air.

It will be noted that the sound transmitted by a single layer of the material of which my improved absorbers are made, as shown by the bars 11 of Fig. 3, is somewhat higher than that transmitted by a single layer of the prior art absorbing materials. However, if two layers are used, as shown in Fig. 3, the net amount of sound transmitted is negligible, as shown by the thin bars 13. By placing a single sheet 8 of my improved absorbing material at a substantial distance from the wall to provide a space 10 of relatively large volume, as in Fig. 4, the same effect is produced as in Fig. 3 because the sound which is transmitted by the layer of material 8 strikes the wall, is reflected thereby back to the material 8, and must pass through the latter once more. Thus, the sound passes through the absorbing material 8 twice before entering the room again and is therefore almost entirely dissipated.

When used as a wall material as shown in Fig. 4, the absorption per unit area of the absorbing material **8** is approximately unity. On the other hand, if the material is applied in "spots," or as discrete units **14** spaced from each other as shown in Fig. 5, the efficiency is considerably improved due to diffraction of the sound. The absorption per unit area under these conditions is considerably greater than unity. Obviously, therefore, from an economic standpoint, it is desirable to take advantage of the phenomenon of diffraction to improve the efficiency.

One of the ways in which use may be made of diffraction is to "scatter" the sound absorbing material throughout the room in the form of small, box-like units. One such unit, which I have termed an "acoustic sink" because of its ability to absorb the sound energy received by it, is shown in Figs. 6 to 11, inclusive. This comprises a closed, hollow casing having a composite wall structure which includes an outer layer of cardboard or other suitable sheet material **15** and an inner layer **17**. The layer **15** is approximately ⅛'' thick and is provided with a plurality of openings **16** which are large enough to permit the passage of acoustical waves therethrough substantially freely, the openings **16** being suitably distributed over the entire area of the layer **15**. The inner layer **17**, which constitutes the absorbing material proper, is suitably secured to the inner surface of the outer wall material **15** and may be constituted by any one or more of a variety of sound absorbing materials which I have found suitable. Among these is one constituted by approximately 60 layers of very thin paper having a plurality of natural holes or perforations therein which are arranged at random, so that they do not line up, but which have sufficient communication with each other to provide a plurality of continuous, irregular passageways through which sound waves may pass from the exterior of the unit **14** to the interior thereof, as clearly shown in Fig. 7. Thus, the material **17** forms a system of long, narrow slits through which the sound waves must pass to reach the space within the unit **14**.

The sound absorbing layer **17** is itself a limp material and therefore not self-sustaining. It is for this reason that I provide the outer, rigid layer **15** of cardboard or the like and secure the absorbing layer **17** thereto by means of staples **18** or in any other suitable manner, as by stitching, or the like. After securing the sound absorbing layer **17** to the outer, supporting layer **15** to form the wall structure of the absorbing unit **14**, the composite wall structure may be blanked out in the form shown in Fig. 8 and thereafter assembled by bending up the sides, top and ends, as shown in Fig. 9, to provide a closed casing, as shown in Figs. 10 and 11, the latter form being cubical, and the former being in the shape of a rectangular parallelepiped.

The casing **14** thus provided by the composite wall structure **15**, **17** encloses a cavity or space **19** of relatively large volume which is filled with air or any other suitable, compressible fluid. If the inertance of the air in the openings **16** is M_1, the acoustic resistance offered by the openings **16** is r_1, the inertance of the passageways formed by the slits or the like in the absorbing layer **17** is M_2, the acoustical resistance offered thereby is r_2, and the acoustical capacitance of the air in the space **19** is C, then the corresponding electrical system will be as shown in Fig. 12. The acoustic elements which control the performance of the acoustic sink are M_2, r_2 and C, since the inertance M_1 and the resistance r_1 are small compared to the inertance M_2 and the resistance r_2. The impedance of the absorber or sink **14** is the sum of the input acoustic resistance and the acoustic reactance designated, respectively, as r_s and x_s.

The effect of diffraction in improving the efficiency of acoustic absorption by the use of an absorbing unit or sink as above described will be readily understood by means of the following theoretical consideration of the acoustic impedance concept when considered in connection with Figs. 1, 3, 13*a*, 13*b*, 14*a* and 14*b*: In the case of Fig. 1, it is assumed that the surface of the material **1** is relatively large, (that is, that it covers the walls or the ceiling or both in a room). Under this condition, the acoustic resistance r_A of the air is its characteristic impedance. The acoustic impedance of air is 42 acoustical ohms per square centimeter. The acoustic resistance and acoustical reactance of the absorbing material **1** are designated as r_M and x_M, respectively, and the corresponding electrical system is shown in Fig. 13*a*. The dissipation or power P which is lost in a sound wave of pressure p due to r_M is given by the equation:

$$P=\frac{r_M p^2}{(r_A+r_M)^2+x_M^2} \quad (1)$$

Referring to Equation 1, it will be seen that maximum absorption is obtained when $x_M=0$ (corresponding to Fig. 13*b*) and $r_A=r_M$. For these conditions, Equation 1 reduces to

$$P=\frac{p^2}{4r_M}=\frac{p^2}{4r_A}=\frac{p^2}{168} \quad (2)$$

Reference will now be made to the improved acoustic sink **14** of my present invention and particularly to Fig. 5. The air impedance contains both a resistive and reactive component. Therefore, in this case, the sound waves are convergent. The resistive component of the air is designated as r_A and the reactive component of the air due to its inertance is designated M_A. The acoustic circuit is shown in Fig. 5 and the corresponding electrical analogue in Fig. 14*a*. The impedance of the acoustic sink **14** is composed of the acoustic resistance r_s and acoustic reactance x_s which may be obtained from Fig. 6. In order to obtain a direct comparison with conventional acoustic materials, it may be assumed that the reactive component x_s is negative and equal in magnitude to the acoustic reactance due to M_A. The acoustic circuit then is reduced to one corresponding to Fig. 14*b*.

As a specific example, let it be assumed that the sink is approximately a cubic foot in volume and that the frequency under consideration is 100 cycles per second. Under these conditions, the acoustic resistance r_A is approximately 4 acoustic ohms. To obtain maximum absorption, r_s should also be equal to 4 acoustic ohms. For this condition, the dissipation in r_s is

$$P=\frac{r_A p^2}{(r_A+r_s)^2}=\frac{r_A p^2}{(2r_A)^2}=\frac{p^2}{4r_A}=\frac{p^2}{16} \quad (3)$$

Comparing Equations 2 and 3, it will be seen that the dissipation in the acoustic sink of my invention is approximately 10 times that of conventional material with 100 per cent absorption. In the above example, it has been assumed that the areas under consideration are equal. In other words, for this condition, the acoustic sink absorbs 10 times as much sound per unit area as conventional materials.

The preceding analysis shows that the characteristic impedance of the air is reduced by using unit sound absorbers and separating them in space. The characteristic impedance of the air may be considered to be the internal impedance of a generator which has an internal driving pressure p. As the above analysis shows, this means that it is possible to absorb more sound per unit area under these conditions because the effective internal impedance of the generator is smaller. The desirability of building the absorbers in units and appropriately distributing them throughout the room is therefore apparent. In this way, maximum use can be made of the absorbing material.

As pointed out heretofore, most absorbing materials known heretofore are made to serve dual purposes. They are designed to serve both as wall materials and as acoustic absorbing materials. For this reason, acoustic materials of the prior art are not as efficient acoustically as it is possible to obtain by designing for maximum sound absorption. Furthermore, it is rather difficult to incorporate a large space between the wall and the sound absorbing material, and therefore absorbing materials are usually placed directly against or very close to the wall, as in Fig. 1. Consequently, the acoustic reactive component x_M of most materials is usually quite large, and this results in a further loss in efficiency.

Referring again to Fig. 6, it will be seen that, in the acoustic sink of my present invention, the reactive components are due to the inertance of the holes **16**, the inertance of the material **17** and the acoustic capacitance of the volume of air in the space **19**. In general, the reactance due to the inertance is quite small. Therefore, the controlling reactance is due to the acoustic capacitance. The acoustic capacitance of a volume of air is given by the equation

$$C=\frac{V_2}{\rho c} \qquad (4)$$

where

ρ=density of air
c=velocity of sound
V=volume of the enclosure (the space **19** in the present case).

Equation 4 shows that the acoustic impedance can be made small by making the volume of the space **19** large. This volume can be made practically any appropriate value in the acoustic sink. The most logical value would be such that the reactance due to the acoustic capacitance would be substantially equal to the reactance due to the combined inertance of the holes **16**, the material **17** and the air load at the lowest frequency to be absorbed.

Referring to the acoustic circuit of Fig. 6, the acoustic resistance r_1 due to the holes **16** is negligible. Therefore, the important acoustic resistance is r_2. The acoustic resistance due to the material **17** should be equal to the average characteristic acoustic resistance of the air in order to obtain maximum absorption. The acoustic resistance of the material depends upon the type of material used. A slit can be made to exhibit practically a pure acoustic resistance as shown by the following equation:

$$Z_A=\frac{12\mu w}{d^3 l}+j\frac{6\rho w\omega}{5ld} \qquad (5)$$

where

μ=viscosity coefficient (1.86×10^{-4} for air),
ρ=density, in grams per cubic centimeter,

d=thickness of the slit normal to the direction of flow, in centimeters,
l=width of the slit normal to the direction of flow, in centimeters,
w=length of the slit in the direction of flow, in centimeters,
$\omega=2\pi f$, and
f=frequency, in cycles per second.

This is the type of resistance shown in Figs. 6 to 11, inclusive. The air enters the holes **16** in the outer, cardboard wall portion **15** and follows a tortuous path through the layers of paper or the like **17**, as clearly shown in Fig. 7. The holes in the paper allow the air to pass from one layer of paper to another layer, these layers being shown by single broken lines in Fig. 7 for the sake of clearness. The slits are formed by the layers of paper.

An acoustic resistance can also be obtained from an aperture or tube of small diameter. The acoustic impedance of a tube of small diameter is given by

$$Z_A=\frac{l}{\pi R^2}\left(\frac{8\mu}{R^2}=\frac{4}{3}j\omega\rho\right) \qquad (6)$$

where

R=radius of the tube, in centimeters,
μ=viscosity coefficient (1.86×10^{-4} for air),
$\omega=2\pi f$,
f=frequency, in cycles per second,
l=length of the tube, in centimeters, and
ρ=density, in grams per cubic centimeter.

In the case of cloth or other finely screened material, the material has holes of small diameter between the crossed threads. Equation 6 shows that such a material constitutes an acoustic resistance due to these small holes. The magnitude of the acoustic resistance may be adjusted by an appropriate size of holes in the apertures between threads and by the number of layers of cloth or the like. It has been found that cloth is a very good acoustic resistance, and a sink employing a number of layers of cloth or similar material **17a** as the sound absorbing layer is shown in Fig. 18.

Hair felt or a material known commercially as "Ozite" is a combination of slit and hole type of acoustic resistance. A wall structure employing hair felt or the like **17b** and suitable for use as the casing of my improved absorbing unit **14** is shown in Fig. 19. This is also a good acoustic resistance, the effect being enhanced by vibration of the hairs or fibers themselves.

Porous material, that is, material with fine holes, may also be made from a porous paper such as blotting or filter paper, as shown in Figs. 20, 21, 22 and 23. The material may or may not be sufficiently rigid to be self-sustaining, and if it is not, it may be secured to an outer, cardboard layer as above described with reference to Figs. 6 to 11, inclusive. One material which I have found especially suitable is a felted material made from wood pulp fibers and sulphite, the fibers being accreted by suction from a pulp solution in known manner. This material, like blotting paper and the like, is constituted by a plurality of intertwined fibres of various lengths and arranged indiscriminately in random directions to provide a plurality of irregular, random passages of very small cross-sectional dimensions. These passages afford communication between the exterior of the casing comprising each of the units **14** and the space **19** enclosed thereby and provide the requisite dissipative impedance to the acoustical energy received thereby.

In Fig. 20, the wall structure of the casing is constituted by a porous material 17c of the type just previously described, the material 17c being preferably corrugated and glued to the outer cardboard layer 15. If desired, an inner cardboard layer 15a may be also glued to the corrugated material 17c, as shown in Fig. 21. The cardboard layer 15a is similar to the outer cardboard layer 15, being provided with openings 16a which correspond to the openings 16.

In the modification of Fig. 22, the sound absorbing material 17d is provided with ridges 20 which may be glued to the outer cardboard wall member 15. In general, the felted type of sound absorbing material has sufficient rigidity to be self-sustaining, and does not require the supporting cardboard layer 15. In such case, the cardboard layer may be entirely dispensed with and the acoustic sinks made solely of a single layer of porous material 17e, as shown in Fig. 23.

Fig. 17 shows the relative absorption coefficients of three conventional sound absorbing materials and also my improved acoustic sink. The three curves B, C and D show the absorption coefficients of three standard materials which may be identified, respectively, as AMA type V, AMA type VI, and AMA type IV. It will be seen that these materials are quite ineffective in the lower region of the audio spectrum and are only fairly effective in the region between 500 C. P. S. and 1000 C. P. S., falling off again above 1000 C. P. S. The curve A, on the other hand, clearly shows that my improved acoustic sinks not only possess a higher absorption coefficient in the mid-frequency range, but that they are vastly more effective in both the lower and the higher frequency ends of the audio spectrum.

In Fig. 15, there is shown a room treated with a plurality of acoustic sinks 14 in accordance with my present invention. The sinks are all mounted adjacent to the ceiling, certain ones being mounted on the walls of the room in spaced relation thereto by means of brackets or the like 25, and certain other ones being mounted on the beams or panels 26 which depend from the ceiling. The sinks mounted on the walls are spaced therefrom to afford the incident sound ample opportunity to reach all the surfaces of the sink so that advantage may be taken of diffraction. The curve E of Fig. 16 shows the reverberation time of the room depicted in Fig. 15 before treatment with the sinks of my present invention, and the curve F shows the reverberation time of the same room after twenty-four such sinks were mounted therein at distributed points or "spots" in the room. It will be noted from the curves of Fig. 16 that the reverberation time was reduced in the low frequency region from approximately 3 seconds to approximately 0.6 second, and that a very substantial reduction was also obtained in the reverberation time at the higher frequencies.

From the foregoing description, it will undoubtedly be apparent to those skilled in the art that I have provided an improved sound absorbing unit which is not only highly efficient in use, but which is very compact and is easy to install and to take down. Although I have shown and described a number of modifications of my present invention, it should be apparent to those skilled in the art that many other variations thereof, as well as changes in the ones described, are possible. For example, where the material 17 is of a rigid nature, it may be made up into a box-like structure separately from the outer, cardboard layer 15 and placed within the box formed by the latter, after which the entire unit is sealed or otherwise suitably secured along the edges to provide a unitary, self-contained structure. Where the sound absorbing material is of the limp type, it may be desirable, in some cases, to provide an inner, as well as an outer supporting wall structure, as in Fig. 21. In such case, an inner box which is next adjacent to the space 19 may first be formed and placed within the outer box formed by the layer 15, the material 17 being interposed in the space therebetween. So far as the layers 15 and 15a are concerned, the openings 16 and 16a therein may be circular, as shown, or they may be of any other suitable shape. In all forms of the invention thus far described, a minimum amount of material 17, 17a, etc. may be used to provide the requisite acoustic resistance because it is terminated by the acoustic capacitance of the space 19. In other forms of my present invention, a single layer of relatively rigid, non-porous material may be used for the casing wall structure and a plurality of diaphragms or other similar vibratory members mounted over openings therein, the diaphragms or the like being exposed at the front to the atmosphere and at the rear to the space 19. When incident sound strikes such diaphragms, the latter are set into vibration and offer sufficient impedance to the sound to dissipate the energy thereof. Thus, in a sense, the vibratory diaphragms render the wall structure pervious to the sound waves in a manner similar to the porous structures.

Other changes and modifications, including pyramid-like, conical, spherical and other similarly shaped hollow casing structures, will, no doubt, readily suggest themselves to those skilled in the art. I therefore desire that my invention shall not be limited except insofar as is made necessary by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. A diffraction type acoustic absorber comprising a self-contained, closed casing enclosing an air-filled space therein, said casing being constituted by an acoustically porous material having a plurality of fine passages therethrough of such fine dimensions that they offer a relatively large dissipative impedance to the passage of said waves therethrough between the exterior of said casing and said space, and said space having a volume of such magnitude that the air therein offers a relatively small impedance to the passage of said waves through said casing.

2. A diffraction type absorber according to claim 1 characterized in that said casing comprises a laminated wall structure of which said material forms a part.

3. A diffraction type absorber according to claim 1 characterized in that said casing has a wall structure comprising a layer having a plurality of openings therein of sufficient size to permit the passage of sound waves therethrough substantially freely and a layer of said material lining said first named layer.

4. A diffraction type absorber according to claim 1 characterized in that said casing has a wall structure comprising a layer having a plurality of openings therein of sufficient size to permit the passage of sound waves therethrough substantially freely and a layer of said material lining said first named layer, and characterized further in that said material is disposed between said first named layer and said space.

5. A diffraction type absorber according to claim 1 characterized in that said material is a relatively limp one, and characterized further in that said casing has a wall structure comprising a layer of rigid material having a plurality of openings therein of sufficient size to permit the passage of sound waves therethrough substantially freely and a layer of said limp material secured to said first named layer, said rigid material maintaining said limp material around said space.

6. A diffraction type absorber according to claim 1 characterized in that said passages are of slit-like formation and are arranged at random in said material.

7. A diffraction type absorber according to claim 1 characterized in that said material is constituted by a plurality of layers of thin sheets each provided with a plurality of slit-like openings therein, said openings being arranged at random throughout said sheets but having sufficient communication with each other to provide a plurality of continuous passageways between the exterior of said casing and said space therein constituting said passages.

8. A diffraction type absorber according to claim 1 characterized in that said material is constituted by a plurality of intertwined fibers arranged indiscriminately in random directions and in relatively compact relationship whereby to provide said plurality of passages each of small cross-sectional dimension.

9. An acoustic absorber according to claim 1 characterized in that said passageways are disposed at random throughout said wall structure.

10. An acoustic absorber according to claim 1 characterized in that said passageways are irregular in shape and extend in random directions through said wall structure.

11. An acoustic absorber according to claim 1 characterized in that said body has an overall acoustic impedance approximately equal to the characteristic acoustic impedance of air in free atmosphere whereby a minimum of the sound wave energy received thereby is reflected therefrom.

12. An acoustic absorber according to claim 1 characterized in that the reactance offered by the

air in said space due to the capacitance thereof is substantially equal to the reactance provided by said wall structure and the load thereon at substantially the lowest frequency to be absorbed by said body.

13. A diffraction type acoustic absorber comprising a self-contained, closed casing enclosing a fluid filled cavity therein, said casing comprising a unitary structure capable of being suspended in the ambient for reception of acoustical wave energy incident thereon from any direction and being constituted by an acoustically porous material having a plurality of fine passages therethrough of such fine dimensions that they offer a relatively large dissipative impedance to the passage of said waves therethrough between the ambient and said cavity, and said cavity having a volume of such magnitude that the fluid therein offers a relatively small impedance to the passage of said waves through said casing.

HARRY F. OLSON.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,385,741	Dillon	July 26, 1921
1,483,365	Mazer	Feb. 12, 1924
1,726,500	Norris	Aug. 27, 1929
1,816,769	Fisk	July 28, 1931
1,832,741	Sersen et al.	Nov. 17, 1931
1,851,208	Nicolson	Mar. 29, 1932
1,903,201	Steur et al.	Mar. 28, 1933
1,926,679	Kellogg et al.	Sept. 12, 1933
2,101,568	Woodbury	Dec. 7, 1937
2,160,638	Bedell et al.	May 30, 1939
2,221,001	Lucius	Nov. 12, 1940
2,308,869	Eckardt	Jan. 19, 1943

FOREIGN PATENTS

Number	Country	Date
8529/27	Australia	Aug. 7, 1928
102,914	Australia	Jan. 30, 1938
406,384	Great Britain	Mar. 1, 1934
409,502	Great Britain	May 3, 1934
381,676	Italy	July 17, 1940

Certificate of Correction

Patent No. 2,502,016 March 28, 1950

HARRY F. OLSON

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 7, lines 41 and 42, for the equation

$$C=\frac{V_2}{\rho c} \quad \text{read} \quad C=\frac{V}{\rho c^2}$$

and that the said Letters Patents should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 12th day of September, A. D. 1950.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.