

Jan. 22, 1963

G. PENNATI

3,074,339

SOUND-PROOFING, VENTILATING AND CONDITIONING

Filed Oct. 25, 1960

2 Sheets-Sheet 1

Fig. 1

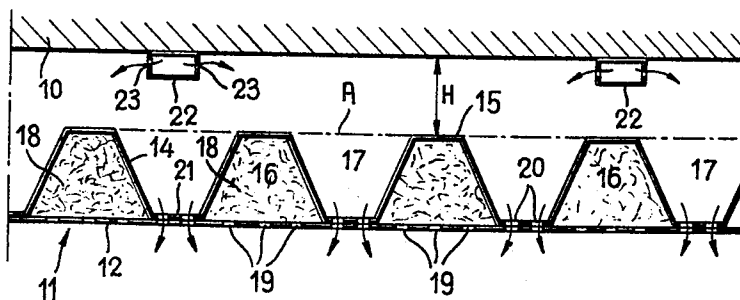


Fig. 2

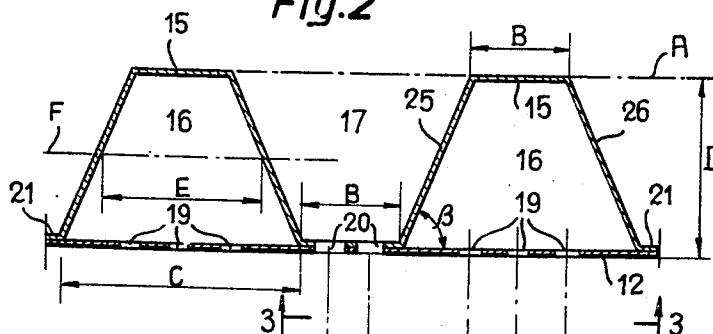
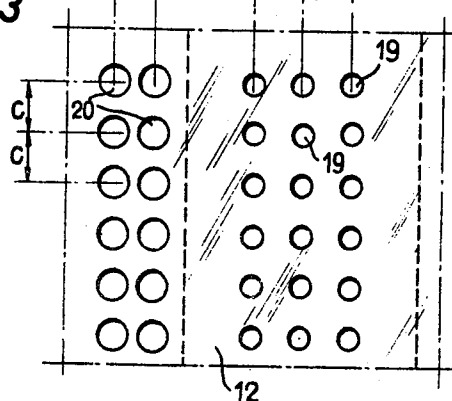


Fig. 3



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Fig. 4

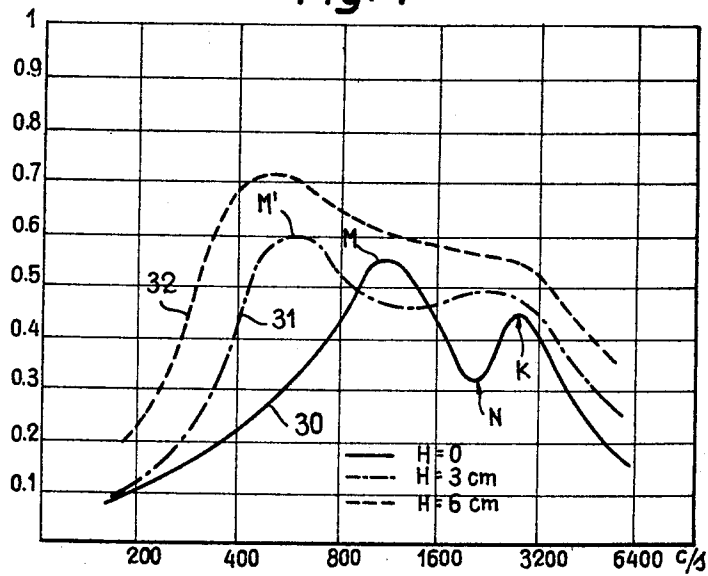
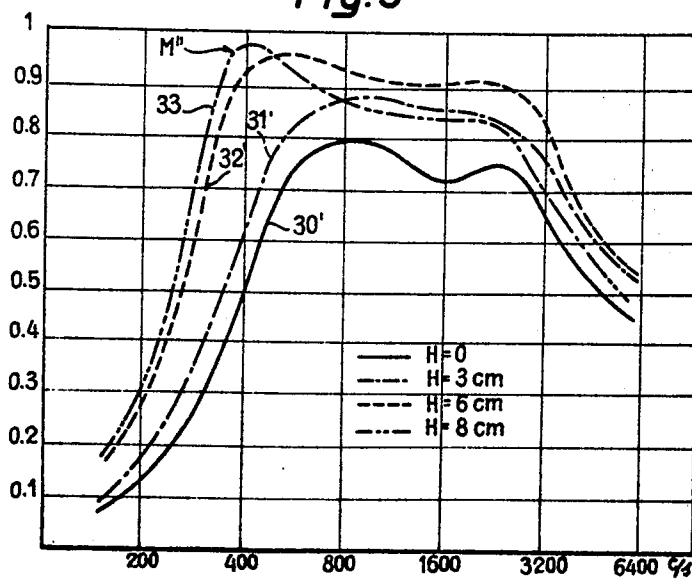


Fig. 5



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SOUND-PROOFING, VENTILATING AND CONDITIONING

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Filed Oct. 25, 1960, Ser. No. 64,923

Claims priority, application Italy Dec. 24, 1959

4 Claims. (Cl. 98—40)

This invention refers to the technique of sound-proofing, ventilating or conditioning of enclosures, such as dwelling houses, offices, shops, workshops, compartments of railway cars, etc. Generally the technique of sound-proofing by means of sound absorbing panels is not compatible with ventilation or conditioning of the enclosures. For instance lining with sound absorbing panels, is effective only if very narrow openings or spaces are left for the outlets of the conditioned or ventilating air jets, wherefore ventilation results in harmful draughts. On the other hand constructions for shower-like ventilating or conditioning, requiring wide diffusing surfaces having innumerable air passages, are excellent under almost all aspects but are unsuitable for receiving sound-proofing panels on the said surfaces.

The present invention eliminates the above difficulties by providing, in combination with a boundary of a room, for example a wall of a room, to be ventilated or conditioned, construction according to the invention comprising a sound-absorbing panel comprising a smooth sheet arranged in parallel spaced relationship to the boundary or wall, and a corrugated sheet secured to the non-exposed face of the smooth sheet to provide channels alternately opening and closing towards the said wall. Two sets of openings bored in the sheets connect the channels with the room, and one of said sets provides communication between the room and means located in the clearance or space between the sound-absorbing panel and wall to permit the delivery of ventilating or conditioning air to the room.

The above defined general characteristic feature of the invention is a new departure from conventional sound-proofing by means of panels embodying multiple resonators, first of all by the introduction in this technique of resonators having an open cavity, formed by the open channels with their respective openings, and utilisation of the latter for shower-like delivery of the ventilating or conditioning air supplied to the clearance between the panels and room wall.

Further characteristic features, advantages and the manner of carrying out the invention will be understood more clearly from the appended description with reference to the accompanying drawing which is given by way of example only and wherein:

FIG. 1 is a vertical cross section view of the improved construction in connection with the ceiling of a room to be sound-proofed and conditioned;

FIG. 2 is a fragmentary cross section view of the sound-proofing panel employed by the construction according to FIG. 1;

FIG. 3 is a fragmentary view on line III—III of FIG. 2, and

FIGS. 4 and 5 are explanatory diagrams, in which the abscissae are graduated in period/sec., the ordinates referring to the values of the absorption factor which

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is defined by the fraction of the total intensity of the incident waves on the panel absorbed by the panel. The absorption coefficient is therefore without dimensions and constantly smaller than 1 (one).

In FIG. 1, 10 denotes the ceiling of a room to be sound-proofed and ventilated or conditioned.

A sound-absorbing panel generally indicated by 11, is located in a parallel spaced relationship to the ceiling. The panel comprises a flat aluminum sheet 12. The non-exposed face of this panel faces the ceiling 10 and an aluminum sheet is firmly attached to this non-exposed face, for example, by electric point welding or rolling. The second sheet has undulations disposed between the ceiling and first-mentioned sheet. The spacing of the ceiling 10 and panel 11 is measured between the ceiling and a plane A extending through the free crests 15 of the trapezoidal channels formed on the second sheet. This clearance is indicated by H in FIG. 1. The unit formed by the two sheets 12, 14 therefore provides two alternating sets of channels of a trapezoidal cross sectional shape, the channels 16 closing towards the ceiling 10, the channels 17 opening towards the ceiling and being actually and virtually defined by the sheet 14 and plane A respectively. The channels 16 are non-inverted channels with respect to the first-mentioned outer sheet and the channels 17 are inverted channels with respect to the first sheet. The inverted channels 17 are in direct communication and open directly into the space formed between the sheets and the room boundary which in the example illustrated is a room ceiling. The closed channels 16 contain a fibrous filling 18, such as glass wool, slag wool, vegetable fibres or other suitable material.

The panel 11 has bored therein in registry with the channels two sets of circular passages, namely passages 19 connecting the closed channels 16 with the room, to which end they are bored in the flat sheet 12 only, and passages 20 connecting the open channels 17 with the room, to which end they are bored in the flat sheet 12 as well as through the crests 21 of the corrugated sheet 14 which are welded to the sheet 12.

In the clearance between the ceiling 10 and panel 11 spaced conduits 22 are formed, each having a number of lateral openings 23 extending substantially parallel with the ceiling, the said conduits being connected with a source of ventilating or conditioned air. The clearance between the panel and ceiling acts as a cushion in which conditioned air accumulates under a slight overpressure and is discharged shower-like to the room through the passages 20 associated with the open channels 17.

While the principle of ventilation and conditioning does not require any further explanation, sound-proofing is rather more involved, at least as far as the choice of means affording highest efficiency of the arrangement is concerned.

The closed channels 16 together with their respective passages 19 constitute a plurality or family of resonators known per se in this technique. Another set or family of resonators would be constituted by the channels 17 if, instead of opening towards the ceiling, they were closed by the latter ($H=0$) or a panel materializing the plane A in a previously known manner. However it was found that notwithstanding their being open the channels 17 are capable of effectively and advantageously acting as resonators, provided certain conditions are fulfilled.

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Firstly, the resonators should respond to relatively low frequencies, while the resonators constituted by the closed channels 16 should respond to relatively high frequencies. Therefore the holes 19 associated with the individual closed channel 16 are larger in number than the holes 20 associated with the open channels.

Secondly the clearance H should range within given limits, for in the majority of cases the sound frequencies to be absorbed are distributed in the band from about 400 to about 4,000 cycles per./sec. It was ascertained experimentally that the clearance H should range between about 2 and 8 cm., its optimum value apparently being 6 cm. as further explained hereafter.

Reverting to the specific construction shown in FIGURES 1 to 3, which has given astonishingly satisfactory results, the length B of the smaller bases of the trapezoidal sections of all channels 16, 17 are the same, the larger bases being all of the same length C. The sloping angle β of the side walls (25, 26) to the flat sheet 12 generally ranges between 45° and 75° , the depth D of all channels approximately equalling their average width E, measured on the transverse middle plane F.

Bearing the above fundamental rules in mind, the dimensions shall be so correlated that the cross sectional area of each channel approximately ranges between 8.5 and 13 sq. cm.

The passages 19 and 20 shall be distributed so that they each have associated therewith a volume of 2-4 c.b.c. of their respective individual closed channels and the latter have associated therewith a volume of about 5-7 c.b.c. of their respective individual open channels. Moreover it is of importance for the passages 19 to be preferably distributed so as to be constantly included in the straight projection of the wall 15 of their respective closed channels on the smooth sheet 12.

By way of example the numerical data of the panel illustrated on the drawing are as follows:

$$B=20 \text{ mm.}; C=48 \text{ mm.}$$

$$E=\frac{20+48}{2}=34 \text{ mm.}; D=35 \text{ mm.}$$

the angle β amounting to about 68° .

The openings 19 of a diameter of 4 mm. are distributed in three rows extending along the channel 16 the rows being spaced by

$$a=10 \text{ mm.} \frac{B}{2}$$

The openings 20 of a diameter of 6 mm. are distributed in two rows spaced by $b=8$ mm. The clearance c along the length of the channels 16, 17 is the same with all the openings 19, 20 and amounts to 10 mm. Consequently, the cross sectional area s of each channel is:

$$S=E.D.=11.9 \text{ sq. cm.}$$

the openings 19, 20 being associated with volumes of 3.97 and 5.95 sq. cm., respectively, of their respective channels.

The diagrams in FIGURES 4 and 5 show the results obtainable by the invention and clearly explain the behaviour of the low- and high-frequency resonators as a function of the various values of H. More particularly, the diagram in FIG. 4 refers to the panel 11 without a fibrous filling of the closed channels 16. The resonators of 2.97 c.b.c. formed by these channels jointly with the openings 19 respond to a frequency of about 2,800-3,000 c./sec., as will be seen from the location of the peak K on curve 30. From the same curve it will be further seen that if the open channels 17 were closed on the plane A, (i.e. $H=0$), the resonators formed thereby jointly with the openings 20 would respond to a frequency of about 1,100-1,200 c./s., as is apparent from the location of the peak M. The two peaks K and M are mutual-

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ly separated by an accentuated valley N. Comparison of the curves 30 ($H=0$) and 31 ($H=3$ cm.) shows that the peak M has moved towards lower frequencies (position M') the absorbing effect being improved throughout the band of 400-4,000 c./s., more particularly on the low frequency range. By bringing the value H to 6 cm., curve 32 a further improvement is obtained which is still quite marked in the low frequency range, the average value of the absorption factor within the said band having risen to about 0.6. The diagram in FIG. 5 which refers to the panel 11 provided with fibrous fillings 18 in the closed channels 16 will be easily understood in the light of the description of FIG. 4. The curves 30', 31' and 32' as compared with the corresponding curves 30, 31, 32 exhibit extraordinary wholly unexpected improvements of the absorption coefficient, which in the range 400-4,000 c./s. exceeds the value 0.9 in the case of the curve 32' ($H=6$ cm.). The curve 33 shows that a further increase of H is no longer advantageous, inasmuch as it gives rise to a peak M'', around 400 c./s., while reducing the absorption coefficient with all higher frequencies. The optimum value of H is consequently found to be about 6 cm., which is in practice highly advantageous, for the clearance then formed between the ceiling 10 and panel 11 (FIG. 1) is fully sufficient for location of the air conduits 22 and is at the same time narrow enough to avoid any excessive reduction in height of the room to be ventilated or conditioned.

Although the invention has been described with reference to a flat ceiling, it will be obvious that it can be employed in connection with vaults as well, when the panel 11 should be curved to suit the vault spaced therefrom by the selected width H. Further applications, modifications and improvements can obviously be carried out without departing from the scope of the specification and appended claims.

What I claim is:

1. In combination with the internal boundary of a room, a construction for sound absorbing, ventilating and air-conditioning said room comprising, a pair of sheets jointly defining in combination with said room boundary two families of acoustic resonators, a first one of said sheets being disposed having a surface facing the interior of said room, the second sheet being disposed between said first sheet and said boundary and spaced from said boundary and jointly defining with said boundary a space therebetween, said second sheet having undulations interposed between said boundary and said first sheet and cooperatively with said first sheet defining adjacent alternating channels of a same trapezoidal cross-sectional shape, said channels comprising a plurality of alternate channels inverted with respect to said first sheet and alternate channels non-inverted with respect to said first sheet, each non-inverted channel being disposed between two next successive inverted channels said sheets having spaced registering openings in the inverted channels, said first sheet having openings opening into each of said non-inverted channels, said openings providing communication between the interior of the room and the respective channels, said openings to the individual non-inverted channels being greater in number than the openings to the individual inverted channels, said inverted channels being in direct communication with said space along their full length and width and opening directly into said space, said space being free of obstructions precluding free communication between said inverted channels substantially along the length thereof, the first sheet being disposed substantially parallel to said boundary said second sheet undulations defining the non-inverted channels having crests spaced relative to said boundary a distance from about two to eight centimeters to cause said inverted channels to function as low frequency resonators, filling in said non-inverted channels cooperative therewith and the openings therein to cause the individual non-inverted channels to function as high frequency resona-

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tors, and means to provide conditioned or ventilating air under pressure in the space formed between said second sheet and room boundary, whereby the inverted channels form one of said families of acoustic resonators and the non-inverted channels form the other family of acoustic resonators and said inverted channels receive said condition air for delivery into said room through said openings therein.

2. The combination according to claim 1, in which all of said channels are of equal cross-section.

3. The combination according to claim 2, in which said

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undulations are dimensioned so that said channels have a depth substantially equal to the average width thereof.

4. The combination according to claim 1, in which the cross-section area of each channel is in the order of 8.5 to 13 square centimeters.

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