

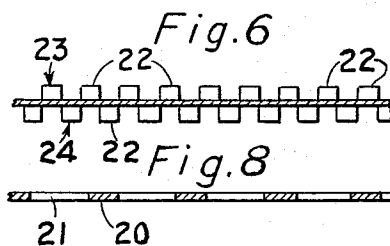
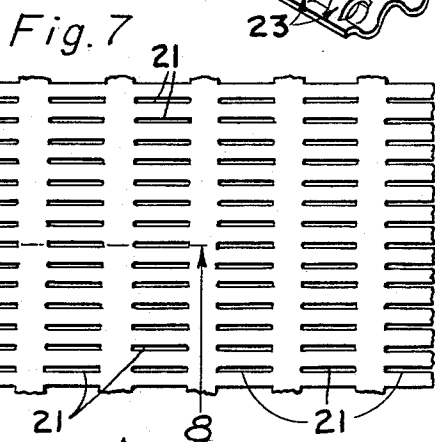
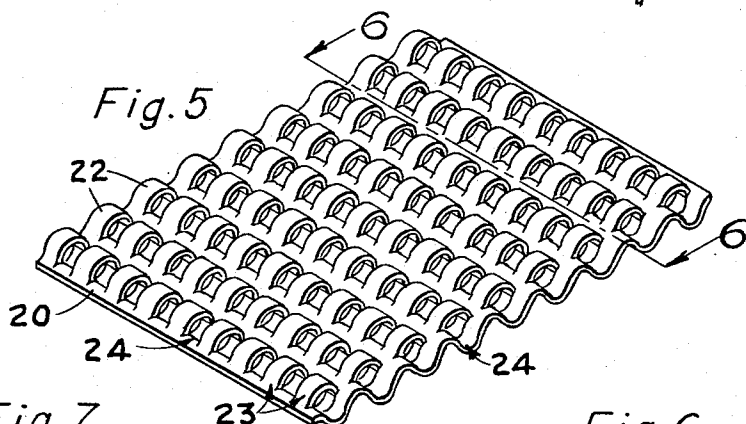
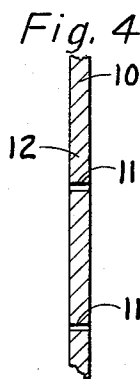
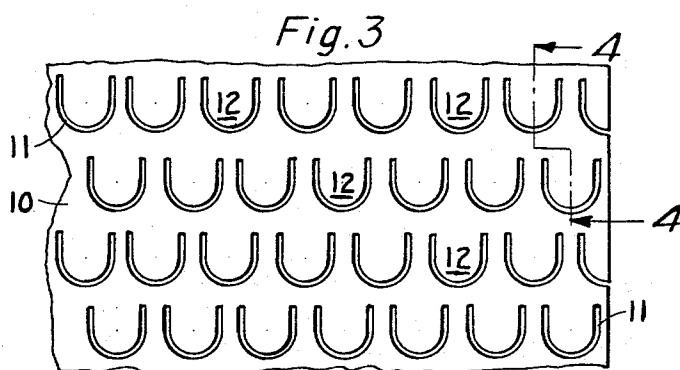
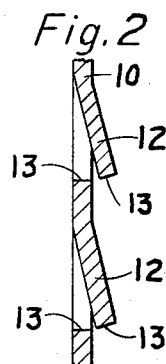
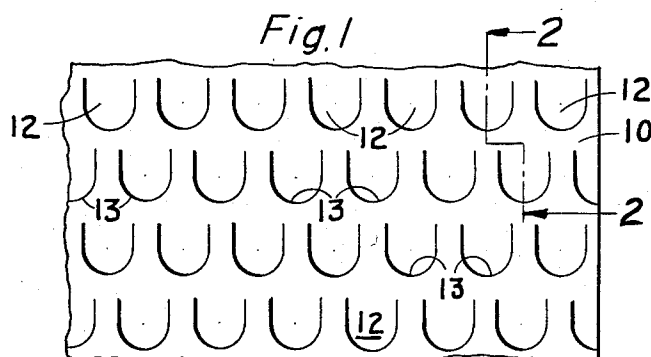
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3,279,043

PERMEABLE SHEET METAL AND METHOD OF MAKING SAME

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## 3,279,043 PERMEABLE SHEET METAL AND METHOD OF MAKING SAME

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Divided and this application June 15, 1964, Ser. No. 381,280

8 Claims. (Cl. 29—163.5)

This invention relates to permeable sheet metal having a predetermined flow resistance so that it will be useful for acoustical and other special purposes. The invention also contemplates a method of producing such a permeable sheet material. This is a divisional application of patent application Serial No. 178,117, filed March 7, 1962, now abandoned.

Increasing usage of gas turbine machinery for various industrial and other uses has resulted in greater emphasis being given to the development of suitable means for maintaining the noise encountered in the operation of such machinery at an unobjectionable level. Because of the possible fire hazards that may be created when the usual sound absorbing materials are used with gas turbine machinery, different types of porous or permeable sheet metals have been suggested for these applications. Those most suitable and readily available are the porous sheet stainless steels produced either by powder metallurgy or by the sintering of steel fibers or wires.

Such porous or permeable stainless steel sheets have also been suggested for use in boundary layer control and in transpiration cooling in addition to the acoustical applications. In all of these uses, however, operating difficulties have been encountered because of the tendency of the random circuitous and restricted pores or openings to become clogged with fine particles of various foreign materials always present in the air or turbine gases. Moreover, the permeable sheet metals produced by powder metallurgy and sintering often lack strength because of their nonunitary structure and are considered to be overly expensive for many of these presently known and contemplated uses and applications of such materials.

It has now been discovered that the aforementioned limitations and objections can be overcome by making the pores or openings in the sheet metal of controlled and predetermined size, configuration, arrangement, and distribution, and having the diameter or width of each opening less than the thickness of the sheet; and it has been found possible to produce such a permeable sheet metal in the form of a unitary structure by a novel method and on an economically practical basis. In accordance with this invention, the desired controlled openings are produced in the sheet metal by a method which includes the steps of perforating the sheet by shearing and bending the metal in the desired locations, removing predetermined amounts of metal from the exposed edges of the perforations, and then flattening and returning the remaining bent metal to the original plane surface. It has been considered that acid or chemical etching will provide an effective way of removing metal from the exposed edges of the perforations. If such etching is used, the sheet metal may, if desired, be coated on both sides before perforation with a layer of any suitable chemically resistant coating, thus limiting the metal removal to the exposed edge areas.

One of the principal objects of the invention, therefore, is to provide a permeable sheet metal in which the pores are of predetermined size, configuration, arrangement, and distribution so as to produce a predetermined permeability useful for special applications of the sheet metal.

Another object of the invention is to provide a novel method of producing permeable sheet metal having open-

ings of predetermined size, configuration, arrangement, and distribution.

It is also an object of the invention to provide a permeable sheet metal in which the pores are of predetermined size and configuration and the arrangement and distribution are such as to render the flow resistance of such permeable sheet metal suitable for acoustical purposes.

A further object of the invention is to provide a permeable sheet metal in which the pores are of predetermined size and configuration, having a width or diameter less than the thickness of the sheet, and the arrangement and distribution are such as to render the flow resistance of such permeable sheet metal suitable for acoustical purposes.

It is another object of the invention to provide a method of producing permeable sheet metal having a predetermined flow resistance, which method comprises the steps of perforating the sheet by shearing and bending the metal in selected locations, removing predetermined amounts of metal from the exposed edges of such perforations, and then flattening and returning the remaining bent metal to the original plane surface.

Still another object of the invention is to provide a method of producing permeable sheet metal according to the last preceding paragraph in which the sheet metal is coated on both sides with a chemically resistant coating before perforation and the metal is removed from the exposed edges of the perforations by means of a chemical etching process.

The above and other features and objects of the invention will be apparent from the following more detailed description and the accompanying drawing, in which:

FIG. 1 is a plan view of one form of metal sheet which has been perforated with openings of predetermined size, shape, arrangement, and distribution as an early step in the method of making permeable sheet metal in accordance with this invention;

FIG. 2 is an enlarged sectional view of the perforated sheet taken along the line 2—2 of FIG. 1;

FIG. 3 is a plan view of the finished perforated sheet having the initial shape of perforations shown in FIG. 1;

FIG. 4 is an enlarged sectional view taken along the line 4—4 of FIG. 3;

FIG. 5 is an isometric view of a portion of a metal sheeting having perforations of another shape that is suitable for the practice of this invention;

FIG. 6 is a sectional view taken along the line 6—6 of FIG. 5; and

FIGS. 7 and 8 are views corresponding respectively with FIGS. 3 and 4 showing the finished permeable sheet made with the form of perforations illustrated in FIG. 5.

Referring now to the form of permeable sheet metal illustrated in FIGS. 1—4, it will be observed that said sheet, which embodies the important features of and is made in accordance with the novel method of the present invention, comprises a relatively thin gage metal plate or sheet 10 of any desired size having a multiplicity of openings 11 therein. Depending upon the particular application or use of the finished permeable sheet, the metal employed may be any desired stainless steel, aluminum or other suitable alloy and the gage may be in the range of about 12 to 30 (or 0.10 to 0.012 inch thick). For most uses, the thickness or gage of the metal should be sufficient to provide adequate structural strength or rigidity so that when the permeable sheet is used as the wall of a duct, for example, it will not have to be reinforced or abnormally supported throughout its area. There is an upper limit on thickness, however, in that it should not be so thick as to prevent it from being cleanly sheared and bent in a normal perforating operation, as will hereinafter appear. For all of the uses now under consideration,

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the width of the openings 11 is less than the thickness of the metal.

In FIG. 3, the openings 11 are arcuate or U-shaped and of substantially uniform predetermined width throughout their length, the width in any instance being less than the thickness of the metal and depending on the ultimate permeability desired in the final product. Permeability depends upon and is measured by the flow resistance ( $r$ ) of the sheet and also the mass reactance (inertia) of the air or other fluid in the pores; and the ratio of ( $r$ ) to mass reactance of the air or gas in the pores is very important acoustically. Flow resistance ( $r$ ), as used herein, means the measure of the volume of flow ( $U$ ) through a unit area of the permeable sheet per unit of time (cubic centimeters per second per square centimeter, for example) for any particular difference in pressure ( $p$ ) between the two surfaces of the material. This definition and relationship may be expressed by the formula

$$r = \frac{p}{U}$$

It will be understood that the permeability depends not only on the size and configuration or shape of the openings 11, but also on the number or total amount of openings per unit of area. For acoustical purposes, the size of the openings or pores should be very closely controlled in order to control the flow resistance and mass reactance of the air or gas in the pores, and the arrangement and distribution should be such as to provide the greatest number or total accumulated length of openings per unit of area consistent with the desired final strength of the sheet. In addition, the placing and number of openings should allow sufficient metal between openings that the metal will not crack or break through between openings in the perforating operation. It has been found that, for most shapes of openings, arranging the openings in relatively uniformly spaced rows, both longitudinally and transversely of the sheet, as illustrated, permits the greatest number of openings per unit of area, though other arrangements will obviously fall within the purview of this invention.

As shown in FIGS. 3 and 4, the width of the openings is somewhat exaggerated. For most of the uses contemplated by this invention, the openings could not be formed by the usual or normal cutting of punching techniques and still be of accurately controlled size and maintain smooth plane surfaces on both sides of the sheet. The method of making the permeable sheet 10 is therefore an important part of the present invention and will now be described, it being borne in mind that economy of cost in the final product is also an important consideration.

It has been found that the thin gage metal sheet 10 may first be perforated in a conventional perforating press (flat bed or rotary) having dies which will shear the metal in a relatively clean, sharp cut and produce bent-out or offset tabs 12 of the desired shape and arrangement. The tabs should also be sheared and bent in a fashion or manner so that they can be bent back to the original plane of the metal, and the sheared and bent metal should not flow or be coined or upset during the perforating process. Such tabs 12 protrude from the surface of the sheet 10 and leave exposed sheared edges 13. To provide openings of controlled size useful for the purposes discussed above, a predetermined amount of metal is next removed from the exposed edges 13 of the tabs. This is important since the desired permeability and flow properties cannot be obtained without the removal of some metal. If this is done by a mechanical technique, such as grinding or filing, the metal removal would probably be limited to the bent-out portion of the edge 13 of the tab. Greater uniformity of metal removal over the entire exposed edge 13 can be obtained, however, by acid or other suitable chemical etching of the entire sheet under controlled conditions. Thus, if it is desired to have the final opening 11 only 0.004 inch in width, the etching opera-

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tion would be controlled to remove 0.002 inch around the entire periphery of the cut. The next step is to bend or otherwise move the tabs 12 back into their original positions in the plane of the sheet to provide the finished flat sheet shown in FIGS. 3 and 4. This then produces an opening 11 which is 0.004 inch wide.

Chemical etching will, of course, act on the entire metal surface immersed in the etching solution. Where the amount of metal to be removed from the edges is small, as is usually the case, any metal removal from the main plane surfaces of the sheet will be negligible. Should it be desired to prevent such removal, however, the two surfaces of the sheet 10 may, prior to perforation, be suitably chemically treated or coated with a layer of a resistant varnish or other coating so that only the cut and exposed edges will be attacked during the etching operation. It will also be apparent that by an etching technique it would readily be possible to vary or regulate uniformly the amount of metal removed across the sheet by regulating the length of time each unit of area is in the etching solution, and in this way a control of the distribution of mass reactance and flow resistance over an area may be achieved for certain acoustic applications.

Flattening of the bent perforated metal back to its original plane may be accomplished in any desired manner. It may be done by hand hammer and anvil if the total area of the finished sheet is sufficiently small for ease in handling; or the bent perforated sheet, after metal removal from the edges of the perforations, may be passed between smooth surfaced rollers. It has also been found that a properly applied stretching operation, depending somewhat on the shape of the perforations, may be employed to return the sheared and bent metal to the original plane surface.

From the foregoing description of the permeable sheet 10 having arc-shaped slots 11, it is believed that the form and arrangement of the modification illustrated in FIGS. 5-8 will be readily understood. As shown in FIGS. 7 and 8, a permeable sheet embodying the features of this invention comprises a thin gage metal plate or sheet 20 of any desired size having therein a plurality of somewhat elongated, substantially parallel openings 21 which may be arranged in rows that run both longitudinally and transversely of the sheet. In this instance, the openings 21 constitute straight slots which, as in the form shown in FIGS. 3 and 4, are formed by first shearing and bending the metal in the form and shape shown in FIG. 5. Instead of arcuate tabs, however, the perforations are made in the sheet 20 by shearing and bending by means of conventional metal perforating techniques to form a multiplicity of curved ribs 22. In this instance, the ribs 22 are arranged in alternate horizontal rows 23 and 24 (indicated by arrows in FIGS. 5 and 6), rows 23 being bent upwardly from the plane of the sheet and rows 24 being bent downwardly from the plane of the sheet.

To produce openings of controlled size, predetermined amounts of metal may be removed from the exposed edges of curved ribs 22 in any convenient manner, such as by grinding, filing or by the chemical or acid etching procedure described above. In the event that chemical etching is used, the sheet 20 may be chemically treated or precoated on each side with a layer of a suitable chemical resistant coating which is sufficiently strong and flexible to withstand the perforating operation. Following the metal removal step, the curved ribs 22 are flattened back to their original positions in any desired manner, thus providing the finished permeable sheet with its openings 21 of controlled size, configuration, distribution, and arrangement.

It is to be understood that in any form of the openings in the metal sheet, including the two forms shown in the drawing and described above, the tabs should be only sheared and bent so that the bent metal may be bent or moved back to its original plane. The metal

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should not flow or be coined or upset during the perforating process. Moreover, perforating processes which remove metal are not suitable for the practice of the present invention because for presently contemplated uses the width of the openings is invariably less than a metal thickness, whereas the die design for perforations in which metal is removed requires removal of more than a metal thickness. The use of slots or other elongated openings as described is also important because such openings make poor filters so that the finished sheet will not clog up so readily when used for acoustics, boundary layer control and transpiration cooling.

I claim:

1. A method of producing a porous metal sheet having a predetermined permeability per unit of area of said sheet, which method comprises:

- (a) perforating said sheet by smoothly shearing and bending predetermined portions of the metal in a multiplicity of locations in uniform and closely spaced relation to one another thereby forming exposed edges in the sheet and such bent portions;
- (b) removing uniform amounts of metal substantially equal to one-half the width of the desired pore size from each of said exposed edges; and
- (c) returning said bent portions to their original positions in said sheet.

2. A method of producing a porous metal sheet having a predetermined permeability per unit of area of said sheet, which method comprises:

- (a) pressing said sheet between a pair of cooperating perforating dies to smoothly shear and bend predetermined portions of the metal in a multiplicity of locations in closely spaced relation to one another thereby forming smooth exposed edges in such sheared and bent portions;
- (b) etching said exposed edges to remove predetermined amounts of metal therefrom; and
- (c) returning said bent portions to their original positions in said sheet.

3. A method of producing a porous metal sheet having a predetermined permeability per unit of area of said sheet, which method comprises:

- (a) pressing said sheet between a pair of cooperating perforating dies to smoothly shear and bend predetermined portion of the metal in a multiplicity of locations in closely spaced relation to one another thereby forming smooth exposed edges in such sheared and bent portions;
- (b) etching said exposed edges to remove predetermined amounts of metal therefrom; and
- (c) returning said bent portions to their original positions in said sheet, the amount of metal removed from the exposed edges by the etching step being sufficient to form openings whose width is less than the thickness of the sheet after said bent portions have been returned to their original positions.

4. A method of producing a porous metal sheet having a predetermined permeability per unit of area of said sheet, which method comprises:

- (a) coating at least one side of said sheet with a layer of a chemically resistant coating which will withstand the action of a subsequently applied etching solution;
- (b) pressing said sheet between a pair of cooperating perforating dies to smoothly shear and bend predetermined portions of the metal in a multiplicity of locations in closely spaced relation to one another thereby forming smooth exposed edges in such sheared and bent portions;
- (c) etching said exposed edges to remove predetermined amounts of metal therefrom; and
- (d) returning said bent portions to their original positions in said sheet.

5. A method of producing a porous metal sheet having a predetermined and uniformly varying permeability

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per unit of area of said sheet, which method comprises:

- (a) perforating said sheet by smoothly shearing and bending predetermined portions of the metal in a multiplicity of locations in uniform and closely spaced relation to one another thereby forming exposed edges in such bent portions;
- (b) passing said sheet through an etching solution for a sufficient length of time to remove predetermined amounts of metal from said exposed edges, the length of time varying for different predetermined portions of said sheet; and
- (c) returning said bent portions to their original positions in said sheet.

6. A method of producing a porous metal sheet having a predetermined and uniformly varying permeability per unit of area of said sheet, which method comprises:

- (a) coating at least one side of said sheet with a layer of a chemically resistant coating which will withstand the action of a subsequently applied etching solution;
- (b) pressing said sheet between a pair of cooperating perforating dies to smoothly shear and bend predetermined portions of the metal in a multiplicity of locations in closely spaced relation to one another thereby forming smooth exposed edges in such sheared and bent portions;
- (c) passing sheet through an etching solution for a sufficient length of time to remove predetermined amounts of metal from said exposed edges, the length of time varying for different predetermined portions of said sheet; and
- (d) returning said bent portions to their original positions in said sheet.

7. A method of producing a porous sound attenuating sheet having a predetermined permeability per unit of area, comprising the steps of:

- (a) subjecting said sheet to opposed forces to produce a multiplicity of cut exposed edges on opposite sides of said sheet; and
- (b) removing substantially equal and uniform amounts of metal from each of said exposed edges on opposite sides of said sheet to produce openings of predetermined width.

8. A method of producing a porous sound attenuating sheet of material having a predetermined permeability per unit of area, comprising the steps of:

- (a) coating said sheet with a material which will withstand the action of an etching solution;
- (b) subjecting said sheet of proposed forces to produce a multiplicity of cut exposed edges on opposite sides of said sheet;
- (c) etching the sheet at such exposed edges to remove substantially equal and uniform amounts of the material therefrom and produce openings in the sheet having a width substantially equal to one-third the thickness of said sheet; and
- (d) returning the cut exposed edges to their original positions in said sheet.

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