

[54] **COMPOSITE METAL STRUCTURE
USEFUL IN SOUND ABSORPTION**

[72] Inventor: **Philip D. Takkunen**, Woodbury
Township, County of Washington,
Minn.

[73] Assignee: **Minnesota Mining and Manufactur-
ing Company**, St. Paul, Minn.

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[52] U.S. Cl. **181/33 G**, 181/33 GA, 29/182.3,
210/496, 210/510

[51] Int. Cl. **E04b 1/86**, B22f 7/04

[58] Field of Search 181/33 G, 33 GA, 42, 50, 36 A,
181/71, 33 HB; 29/182, 182.1, 182.2, 182.3,
182.5, 182.7, 182.8; 210/496, 510

- [56] **References Cited**
- UNITED STATES PATENTS**
- | | | | |
|-----------|---------|--------------------|-----------|
| 2,159,488 | 5/1939 | Parkinson | 181/33 G |
| 2,826,309 | 3/1958 | Forman et al. | 210/510 |
| 3,087,572 | 4/1963 | Baruch et al. | 181/33 G |
| 3,087,574 | 4/1963 | Watters | 181/33 G |
| 3,113,634 | 12/1963 | Watters | 181/33 HB |
| 3,113,635 | 12/1963 | Allen et al. | 181/42 |
| 3,177,972 | 4/1965 | Wirt | 181/33 HB |
| 3,253,675 | 5/1966 | Baruch | 181/33 R |

3,433,322	3/1969	Olsson	181/33 R
3,482,703	12/1969	Roberts et al.	210/510 X
3,507,355	4/1970	Lawson	181/33 R

FOREIGN PATENTS OR APPLICATIONS

935,119	8/1963	Great Britain	181/33 HA
829,012	2/1960	Great Britain	181/33 HB

OTHER PUBLICATIONS

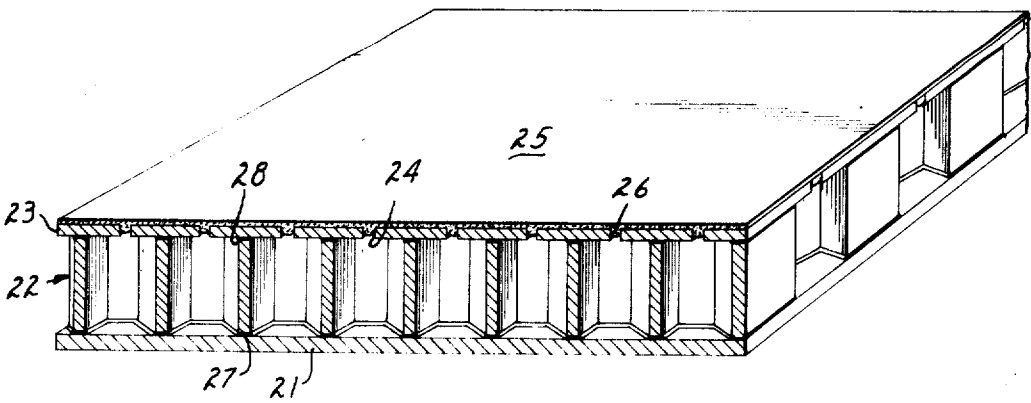
"Acoustical-Impedance Characteristics of Sintered Stainless Steel," The Journal of the Acoustical Society of America, Volume 36, No. 5, May 1964, pp. 811-815

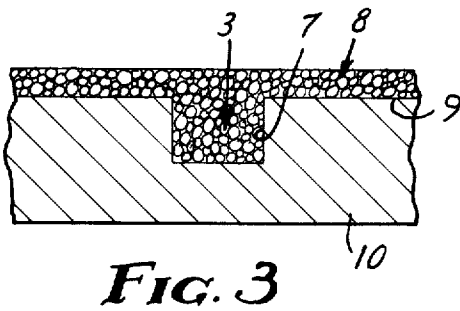
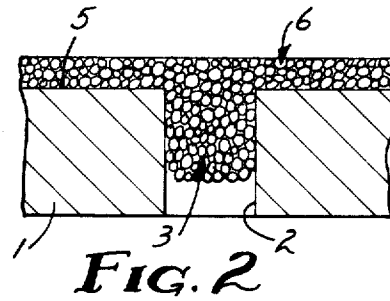
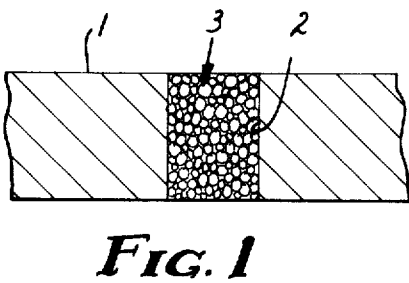
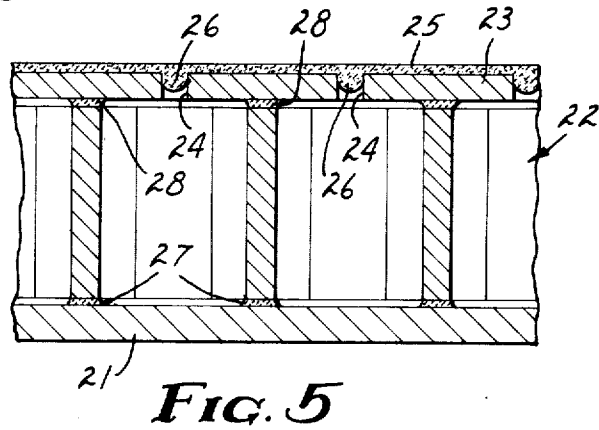
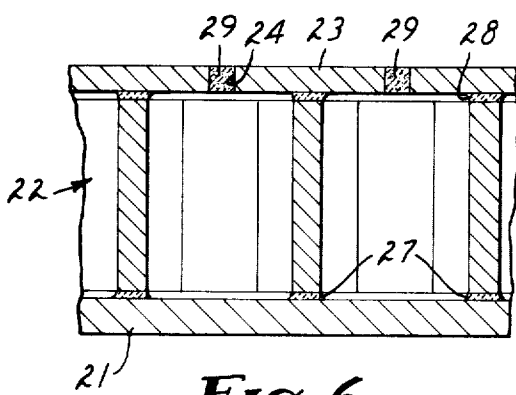
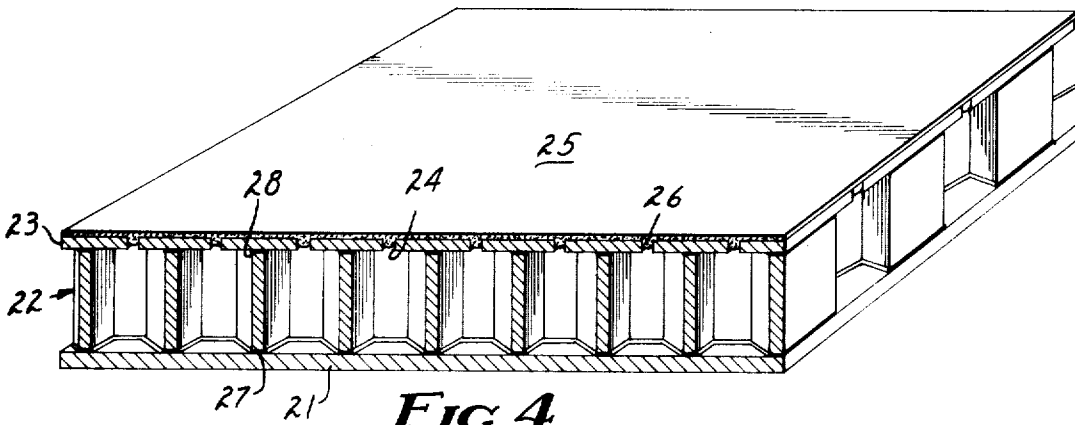
Primary Examiner—Robert S. Ward, Jr.
Attorney—Kinney, Alexander, Sell, Steldt & Delahunt

[57] **ABSTRACT**

A composite metal structure, useful in sound absorption applications, comprising a metal part having perforations or recesses containing sintered porous powdered metal is made by pressing said metal part with a mixture of powdered metal and heat-fugitive binder to force said mixture into said perforations or recesses, and then heating the assembly to volatilize the burn-off said binder and sinter said powdered metal, the powdered metal in the resulting structure being held in said perforations or recesses by a metallurgically integral bond as well as mechanical bond.

7 Claims, 6 Drawing Figures





INVENTOR.
PHILIP D. TAKKUNEN
 BY *Kinney, Alexander,*
Sell, Steddt & De La Hunt
 ATTORNEYS

COMPOSITE METAL STRUCTURE USEFUL IN SOUND ABSORPTION

This invention relates to powder metallurgy. In another aspect, it relates to the metalworking field in which metal parts are joined together. In another aspect, it relates to a composite metal structure useful as an acoustic or sound suppression structure. In a further aspect it relates to a metal sound absorption structure having a laminated configuration. And in a further aspect it relates to a reinforced fluid permeable structure useful as a filter, air bearing, air diffuser, and the like.

For a number of years now, increasing attention has been focused on the abatement or suppression of sound or noise, such as that emanating from aircraft engines. A variety of assemblies have been proposed, evaluated, or used for that purpose. One such assembly is a damped-resonator acoustical panel (see U.S. Pat. No. 3,166,149) comprising a honeycomb or cellular core sandwiched or interposed between a solid sound reflecting sheet and a perforated, sound admitting layer or acoustic face sheet. Similar assemblies are known where the acoustic face sheet is a perforated metal sheet, a sintered woven metal screen, or is made of sintered metal fibers. Though these prior art assemblies have a number of useful applications, they do have some limitations, particularly a balance of sound suppression and structural integrity when subjected to severe stress and corrosive environments.

In the accompanying drawing, FIGS. 1, 2, and 3 are cross-sectional views illustrating various embodiments of the composite metal structures of this invention; FIG. 4 is a view in perspective and partial section of a honeycomb sandwich panel made in accordance with this invention; FIG. 5 is a cross-section of a portion of FIG. 4 showing details thereof; and FIG. 6 is a view like FIG. 5 illustrating a modification thereof.

Briefly, according to one aspect of this invention, a composite metal structure useful for sound suppression applications is provided, said structure comprising a metal part, such as a stainless steel, having perforations or recesses containing a porous body of sintered powdered metal. Such a structure can be made by pressing the metal part with a mixture, preferably in the form of a plastic mass, comprising powdered metal and heat-fugitive binder, to force the mixture into said perforations or recesses, and then heating the assembly to volatilize, burn-off, or otherwise remove said binder and sinter said powdered metal. Such a structure can be used as an acoustic face sheet to suppress or attenuate the sound or noise emanating from the operation of the aircraft engines or other noise generators. Such a structure has improved structural integrity, particularly at the severe stress and corrosive conditions encountered in or by aircraft.

The body of sintered powdered metal is held within said perforations or recesses by a combination of metallurgically integral bond and a mechanical bond, the assembly of the metal sheet and sintered powdered metal within the perforations or recesses being in effect a single or integral piece of metal. Such a bond and structure is distinguishable over that disclosed in U.S. Pat. No. 3,264,720 which discloses a porous powdered metal layer bonded to a permeable metal sheet or screen.

The term "metallurgically integral" in this context means that there is a solid state or interatomic diffusion between the contiguous sintered powdered metal particles and between the surface of the metal parts and powdered metal particles contiguous therewith. At the juncture between the sintered powdered metal and the metal part contiguous therewith, there will be a solid state diffusion zone of the powdered metal and said metal part with the balance of the sintered powdered metal between the adjoining metal parts having a density less than that of the theoretical density of the powdered metal, a uniform microporosity, and a grain structure free of dendritic grains. The portion of the metal parts between the perforations or recesses are free of dissimilar heat-affected zones. The walls of the perforations or recesses, apart from their metallurgical or sintered bonding to the body of sintered powdered metal, constrain the latter body, such constraint being enhanced by irregularities in the surfaces of said walls which generally are inherent in the fabrication of the metal part. Such constraint, in effect, is a mechanical bond. When the above described structure is subjected to sound, the intensity of the sound is attenuated by absorption in the structure.

The perforated or recessed metal part can be made of a variety of metals commonly used in construction, such metals including iron, nickel, cobalt, copper, chromium, and alloys thereof such as steels (e.g., stainless steel), inconel, nichrome, and monel. Any metal or alloy which can be sinter-bonded to powdered metal can be used to fabricate the perforated or recessed metal part. Of course, the metal part cannot have a melting point lower than the sintering temperatures necessary to effect the sinter bond relied on in this invention. Further, said metal part can be made wrought, cast, or sintered powdered metal. The perforations or recesses in the metal part can be obtained by punching or drilling operation or the like. The walls of the perforations or recesses can be relatively smooth or irregular.

The stainless steels used for the metal part can be AISI stainless steels, such as those of the 300 series, e.g., types 301, 302, 304, 305, 316, and 347, and precipitation hardening stainless steel, e.g., PH 15-7 Mo, and nickel based alloy, e.g., Inconel-625.

The powdered metals used in the practice of this invention, in addition to the stainless steels mentioned above, representatively include known sinterable metals used in conventional powder metallurgy such as iron, copper, nickel, beryllium, chromium, cobalt, molybdenum, tantalum, titanium, tungsten, and alloys thereof. The stainless steel metal powders disclosed in copending application, Ser. No. 743,588, now U.S. Pat. 3,620,690 will be particularly useful because of the enhanced bond strength and corrosion resistance which can be obtained. Precipitation hardening stainless steel, e.g., PH-15-7 Mo, and nickel based alloys, e.g., Inconel-625 can also be used. The non-refractory metals and alloys are preferred as powdered metals because of the lower sintering temperatures which can be used. The powdered metal to be used will depend upon the particular composition of the perforated or recessed metal part, the desired sintering temperature, and the degree of porosity desired for the sintered body of powdered metal. Although the compositions of the

metal part and powdered metal may differ, it will be desirable if they are the same where differential thermal expansion or galvanic corrosion is to be avoided.

The mesh size of the powdered metal used in the practice of this invention can vary and generally the particular powdered metal used will have a range of particle size. Generally, the smaller the mesh size, the greater the density of the sintered body of powdered metal in the perforations or recesses, and hence the greater the acoustical resistance. It may be desirable to use blends of two or more powdered metal products to obtain a desirable balance of acoustical and strength characteristics. For example, powdered metal with mesh sizes in the range of -20+325 can be used, such as -200+325, -100+200, -50+100, -20+50 or blends thereof (The term "mesh" referred to herein means mesh size according to the U.S. Standard Sieve system).

In preparing the green mixture of powdered metal and binder, the powdered metal of desired mesh is blended with an organic heat-fugitive binder, such as those disclosed in U.S. Pat. Nos. 2,593,943, 2,709,651, 2,851,354, and 3,158,532; the preferred binder is methyl cellulose (e.g. Methocel 60-HG, 4,000 cps). Various volatilizable vehicles can be used in conjunction with these binders, such as water, as well as various plasticizers, such as glycerin. The blending can be carried out in a conventional manner in various types of commercially available mixers, blenders, tumblers, and the like, care being taken to ensure that the blend is homogeneous and the components well dispersed. The resulting blend will be in the nature of a plastic mass or dough and will be similar in consistency to that of modeling clay. The plastic mass can be shaped in a rubber mill, calendered, or knife-coated to the desired thickness to form a green sheet having a rubbery, pliable nature. The green sheet can be pressed into the perforated or recessed metal part so that the green material is in effect extruded into the perforations or recesses to a desired degree. This can be accomplished by roll pressing, ram pressing, isostatic pressing or the like, depending on the shape of the metal part. Alternatively, where the metal part is in the form of a sheet, the plastic mass can be directly rolled into the perforations or recesses, for example, by simultaneously feeding the plastic means and metal part sheet into the nip of oppositely rotating rolls. Another method is to spread powdered metal particles coated with binder (as disclosed in U.S. Pat. Nos. 2,851,354 and 2,845,346) over the perforated or recessed metal part, and then pass the coated metal part through rollers to cause the perforations or recesses to become filled with the green mixture. All of these various modes of filling the perforations or recesses can be carried out under heat, e.g., to facilitate release of the resulting pressed article from the equipment used to carry out the operation.

The assembly of the perforated or recessed metal part and green material is heated to remove binder and volatilizable component, such as water and plasticizer. The structure is then sintered under vacuum or a suitable atmosphere, such as a reducing atmosphere like hydrogen or dissociated ammonia. Sintering atmosphere, temperature, and duration of sintering will depend upon the particular powdered metals used, the selection of these conditions being within the skill the

art. In the case of where stainless steel is used as the powdered metal, a hydrogen or dissociated ammonia atmosphere with a dew point of -40° F. or lower and sintering temperatures in the range of 1,200° to 1,400° C., preferably 1,250° to 1,350° C. will be suitable, and the duration of sintering will usually be from 10 minutes to 2 or 3 hours.

Referring now to the drawing and initially to FIG. 1, a metal part 1 is shown having a perforation defined by walls 2 (the part will have a plurality of such perforations but only one is shown in the drawing for purposes of brevity). Said metal part can be made of wrought metal, cast metal or relatively dense sintered powdered metal. Disposed within perforation 2 is a porous body 3 of sintered powdered metal, the individual contiguous particles being sintered together and the surface of the particles contiguous with the walls 2 of the perforation also sintered thereto. The density of the sintered particles within perforation 2 and the extent to which the body of sintered particles fills the perforations can vary, depending upon the degree of acoustical resistance desired. FIG. 2 shows a modification where the upper surface 5 of the metal part 1 is sinter bonded to a porous layer 6 of sintered powdered metal, this layer of course being integral with the body 3 of sintered powdered metal within perforation 2. FIG. 3 shows another modification where the body 3 of sintered powdered metal is disposed within recess or cavity 7 and is integral with a layer 8 of porous sintered powdered metal which is sinter-bonded to the top surface 9 of metal part 10. Other embodiments, not shown in the interest of brevity include a structure, like FIG. 2, except that a porous layer of sintered powder metal is also sinter-bonded to the lower surface of the metal part, the body of sintered powdered metal within the perforations being integral with the top and bottom layers of sintered powdered metal. As mentioned hereinbefore, the porous body of sintered powdered metal within the perforations or recesses, is sinter-bonded to the walls defined by said perforations or recesses and are further held therein by reason of an inherent mechanical bond.

Referring now to FIGS. 4 and 5, the acoustical panel illustrated there comprises a hard surfaced, substantially air impervious sound reflecting layer 21, made for example of stainless steel, and a honeycomb or cellular core 22, which are like that disclosed in said U.S. Pat. No. 3,166,149. Bonded to the top of said honeycomb is a sheet 23, made of stainless steel for example, having a plurality of perforations defined by walls 24. Each honeycomb cell will have generally a plurality of perforations 24 adjacent its upper end, though only one such perforation is shown for purposes of brevity. Surmounting perforated sheet 23 is a porous sintered powdered metal sheet 25, made of stainless steel powder for example, which is sintered to or metallurgically integral with sheet 23, the underside of the powdered metal sheet having a plurality of integral depending projections 26 which depend within the perforations and are bonded to the walls 24 thereof by metallurgically integral sinter bond. These projections are like the porous body 3 of sintered powdered metal shown in FIG. 2. The bonding of the sound reflecting sheet 21 and the perforated sheet 23 to the bottom and top of the honeycomb as indicated by reference Nos. 27 and 28 can be conventional or can be accomplished as dis-

closed in copending application FN 27,109, filed on even date herewith, such a bond being made of sintered powdered metal.

FIG. 6 illustrates a modification of the honeycomb embodiment shown in FIGS. 4 and 5, these embodiments being essentially the same except that in FIG. 6 the honeycomb structure lacks a surface layer of powdered metal, and though the porous bodies 29 of sintered powdered metal in FIG. 6 are shown as substantially fitting the perforations, they can fill only a portion thereof, e.g., as low as 10 percent.

As an example of this invention, a mixture of 95 parts by weight of AISI type 347L stainless steel powder (-50+100 mesh), 5 parts by weight of powdered molybdenum (3-4 microns), and 5 parts by weight of methyl cellulose (Methocel 60 HG) is mixed with a sufficient amount of a 15 weight percent aqueous solution of glycerin to provide 180 cc of said solution per kilogram of the powdered metals. The resulting green mixture is of a plastic consistency and it is rolled on a heated rubber mill, one roll running at 40 surface ft./min. at 140° F. and the other roll running at 30 surface ft./min. at 150° F., to produce a green sheet of 0.015 inch thickness.

A perforated stainless steel sheet (AISI 347L, 0.018 inch thick, having 0.050 inch holes on 0.093 inch centers) is degreased and grit-blasted. If desired, the sheet can be coated with powdered metal, e.g., stainless steel or molybdenum with a particle size of 3 to 10 microns, for example by spraying the sheet with an aerosol spray adhesive and then spreading the powdered metal over the sprayed surface. Alternatively, the stainless steel sheet can be vapor coated with tin. The layer of powdered metal or vapor coated metal will enhance the subsequently formed sinter bond, due to increased surface area and/or chemical activity.

The green sheet and the perforated stainless steel sheet are pressed together, for example with a hydraulic ram at 15TSI with a platen temperature of 200° F. or by means of simultaneously rolling the two sheets with heated rollers, as discussed above, such that the perforations are filled with the green material. The extent of filling the perforation can vary, e.g., 10 to 100 volume percent, depending upon the consistency of the green material, pressing conditions, and the degree of acoustical resistance desired. The overall thickness of the perforated sheet-green sheet can vary, and may be, for example, 0.025 inch to 0.030 inch.

The assembly is then heated in air to volatilize the water component in the green material and then heated to burn-off the binder (e.g., at 600° F. for 1 hour). The assembly is then heated in hydrogen at 1,350° C. (dew point -60° F.) for 1 hour.

For acoustic face sheets made as described above, as well as those made from perforated stainless steel with 0.077 inch holes and 45 percent open area, are shown below:

45% open area acoustic sheet with 0.077" perforations	26% open area acoustic sheet 0.050" perforations
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Acoustic properties:
Rayl no. (at 20 cm/sec)

30-70

30-70 65

NFL*	2.5-2.9	3.2-3.9
Mechanical properties:		
Tensile strength (KSPI)**	18-21	30-32
Young's modulus (10 ⁶ PSI)**	4.8-8.0	9.8-12.0
Elongation (%)	18-21	15-23
Density (lb/ft ³)*	0.84	0.81

*NFL = nonlinearity factor = (Rayl no. at 500 cm/sec)/(Rayl no. at 20 cm/sec).

**Based on cross-sectional area of perforated sheet.

***The perforated sheet density is 0.6 lb/ft³.

The strength of the sinter bond between the bodies of sintered powder metal within the perforation will vary and depend on the size of the perforations, the extent of penetration of the green material into the perforations, the extent of diffusion (which, in turn, depends on particle size, sintering conditions, and metal compositions used). A suitable test for strength is to insert a rod into the perforations and determine the amount of force necessary to dislodge the sintered bodies from the perforations. For the particular examples given in the above table, a force in excess of 2,000 psi, and in some cases in excess of 6,000 psi, was necessary to dislodge the bodies.

As a modification of the acoustic panel described above and illustrated in FIGS. 4 and 5, the top of the webs of honeycomb can be bonded to a sheet of sintered powdered metal which in turn is sinter-bonded at its upper surface to a sheet of perforated metal, the perforations of which contain the porous bodies of sintered powdered metal integral to the sheet of sintered powdered metal bonded to the honeycomb.

Various modifications and alterations of this invention will become apparent to those skilled in the art without departing from the scope and spirit of this invention.

What is claimed is:

1. A metal acoustical panel comprising a metal part having a plurality of spaced apart perforations filled with porous bodies of sintered powdered metal in the range of -20 to +325 mesh metallurgically integral with the walls defining said perforations.

2. The panel of claim 1, wherein said part is a sheet of wrought, cast, or sintered powdered metal.

3. The panel of claim 2 wherein said bodies of sintered powdered metal are integral with a sheet of porous sintered powdered metal metallurgically integral by a sinter bond between the two sheets.

4. The panel of claim 2 wherein said metal part is a wrought sheet of stainless steel.

5. The panel of claim 2 wherein said powdered metal is powdered stainless steel.

6. A metal acoustical panel comprising a solid metal base sheet, a perforated metal sheet, a metal honeycomb structure interposed between and bonded to said sheets, a face sheet of sintered powdered metal sinter bonded to the top of said perforated metal sheet, and porous bodies of sintered powder metal in the range of -20 to +325 mesh integral with said face sheet and depending within said perforations of said perforated sheet, said bodies being metallurgically integral with the walls defining said perforations.

7. The article of claim 1 wherein said sheet and bodies are made of stainless steel.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,693,750 Dated September 26, 1972

Inventor(s) Philip D. Takkunen

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Line 7 of the ABSTRACT, delete "the" (2nd occurrence), and substitute therefor -- or --.

Column 4, line 33, after "brevity" insert a comma.

Column 5, line 1, delete "FN 27,109" and substitute therefor -- SN 73,891 --;

line 40, delete "15TSI" and substitute therefor -- 15 TSI --;

line 55, after "For" insert -- properties of --;

line 60, delete "46% open area" and "26% open area";

line 63, after "perforations" (1st occurrence), insert -- and 46% open area --;

line 63, after "perforations" (2nd occurrence), insert -- and 26% open area --.

Column 6, line 3 of the Table, delete "(KSPI)" and substitute therefor -- 10^3 psi --;

line 6 of the Table, delete "Density" and substitute therefor -- Weight --;

line 10, delete "density" and substitute therefor -- weight --;

line 40, after "metal" insert -- comprising powdered metal --;

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,693,750 Dated September 26, 1972

Inventor(s) Philip D. Takkunen - 2 -

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 6, line 58, after "metal", insert -- comprising powdered metal --;

line 63, delete "article" and substitute therefor
-- panel --.

Signed and sealed this 3rd day of April 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents