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(54) **SOLID STATE BLOWER.**

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(73) Proprietor: **PIEZO ELECTRIC PRODUCTS, INC.**
186 Massachusetts Avenue
Cambridge, Massachusetts 02139 (US)

(72) Inventor: **KOLM, Eric A.**
36 Salisbury Road
Brookline, MA 02146 (US)
Inventor: **KOLM, Henry H.**
Weir Meadow
Wayland, MA 01778 (US)

(74) Representative: **Jennings, Guy Kenneth et al,**
GILL JENNINGS & EVERY 53-64 Chancery Lane
London WC2A 1HN (GB)

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Solid state blower

Technical Field

The invention relates to pumping devices for air or liquids and specifically to a blower utilizing an undulating blade.

Background Art

Electronic equipment is customarily cooled using rotary fans or blowers, which circulate air through the entire housing to maintain a constant operating temperature. Steady state temperature maintenance of the electronic components is important not only to prevent overheating, but also to assure reliable operation.

Most electronic equipment now contains only solid state electronic components, such as miniaturized transistors and integrated circuits, and no longer utilizes vacuum tubes and other generally large heat producing components. The amount of cooling required to maintain stable operating temperatures has therefore been substantially reduced. Also, the cooling requirements have been localized, since only several very small components, typically mounted on printed circuit boards, actually require cooling. Thus, cooling of the entire cabinet is not required. Nevertheless, even though wasteful, electronic equipment has continued to be cooled in this manner, since neither rotary fans nor other cooling devices have successfully been miniaturized, and rotary fans, which have been substantially improved over the years, continue to offer the most reliable and efficient method of cooling. Comparatively, however, when used in solid state electronic equipment, rotary fans or blowers stand out as the largest, noisiest and most short-lived part of the assembly, the only moving component, and the component which most severely limits environmental tolerance specifications.

Another form of blower, using the principle of a vibrating blade, has been proposed in the past. AT—B—167,983 and US—A—4,063,826 are typical of such designs. In US—A—4,063,826 a flexible blade is driven magnetically to deflect from side to side. The blade bends back and forth about a node point. The flapping end of the blade to the outside of the node point is disposed in a pumping duct to pump liquid through the duct. In AT—B—167,983, a flexible blade is fixedly mounted at the inlet end of a blower duct and driven magnetically from side to side. Theoretically, due to the few moving parts, blowers of these types are susceptible of miniaturization; as a practical matter however, they are generally so inefficient that they are better suited for producing heat than for generating cooling air movement, with the result that none has found any significant commercial acceptance.

According to the present invention, a blower or pump device of this same general type, that is to say comprising a housing, a generally planar resilient impeller and means for oscillating the impeller perpendicularly to its plane to propagate a travelling wave along the impeller to pump fluid is characterised in that the oscillating means comprises an elongate piezoelectric element mounted in the region of one end to the housing and connected at its other end to the impeller and means applying voltage to cause the end of the piezoelectric element remote from the housing to oscillate. Such a device is extremely efficient, inexpensive to manufacture and designed for a long service life.

The piezoelectric element, or so-called "bilaminate" is a strip consisting of two layers of piezo-electric ceramic, polarized in opposite directions, which on their facing sides are separated by a conducting layer and which on their outside faces are surrounded by conducting layers. The two outside conducting layers are connected as electrodes to a controlled alternating current supply. Since the piezo-electric layers have opposite polarity, voltage applied across the bilaminate strip induces bending of the element. Accordingly, alternating voltage across the piezo-electric element will drive the impeller back and forth at the point of attachment.

The impeller is preferably disposed in a duct in the housing and its characteristics are such that its resonant frequency approximates to that of the piezo-electric element so that it is driven in quadrature.

The device operates without any substantial mechanical friction to permit high operating speed, a consequently high throughput relative to size, a virtually unlimited service life, and may be miniaturized and still produce a significant flow of air to cool miniature components. In its miniaturized form, the device may be mounted directly on printed circuit boards, alongside the individual components which require cooling, and due to its high efficiency will provide sufficient cooling air.

The device preferably is constructed with a pair of counter-oscillating blades in parallel pumping channels so that it is dynamically balanced and vibration free. Pumping efficiency of the device may be improved by providing venturi intake ports along the output half of the duct to increase the air flow through the ducts.

Brief Description of the Drawings

For a better understanding of the invention, reference may be had to the following detailed description of the preferred embodiments, taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a pictorial view of a solid state blower having a pair of blades driven by piezoelectric elements according to the invention;

Fig. 2 is a longitudinal-sectional view of a piezo-electric bilaminate driving element for use with the blower of Fig. 1;

Figs. 3a, 3b, 3c, 3d, 3e and 3f are schematic representations of first the blade at rest and then the pumping motion of the blade, phased in quadrature, at various points of the oscillation cycle; and

Fig. 4 is a pictorial view of a modified form of the solid blower shown in Fig. 1.

Best Mode For Carrying Out the Invention

Referring to Fig. 1, a solid state blower according to the present invention has a housing 10, outer walls 12 and an inner divider 14 forming a pair of air channels 16 between the bottom 17a and top 17b (lifted out of the way for clarity). A pair of resilient blades 18 are mounted in the channels 16 for driving air through the device. The blades 18 are generally tapered from their inlet ends 24 toward the outlet ends 22 and have whip portions 20 at their outlet ends 22 to improve the air throughput pumping capacity. The whip portions 20 are preferably made of Mylar®.

A piezo-electric bilaminate 28 is attached at one end 40, for example by a plastic holder and screws 41, to each of the housing walls 12 and at the other end 42, by cementing or any other suitable means to a point on each blade 18 to support the blade in the channel 10 in a manner such that open lateral movement of the bilaminates the blades 18 are free to undergo simultaneous lateral deflection. This mounting arrangement permits free lateral movement of the blade 18 along the entire length with corresponding lateral movement of the end 42 of the piezo-electric element 28.

A piezo-electric element suitable for use in the present invention is marketed by Gulton Industries, Inc., Piezo Products Division, Metuchen, N.J., under the name "Piezo Ceramic Bender Element", No. G1195. Each bilaminate strip 28 (Fig. 2) has two layers of piezo-electric ceramic 29 separated by a layer of conducting material 30, e.g. brass. The outside layers 32, 34 are silver, and connected to the leads 36, 38 of a controlled alternating current supply 39. The two ceramic layers 29 are polarized in opposite directions, so that voltage across the bilaminate induces a bending motion in the strip. Since the bilaminate strip 28 is fixed on the housing at 41, controlled alternating voltage, therefore, causes the free end 42 of the piezo-electric element 28 to move back and forth at the voltage frequency. The bending movement of the bilaminates 28, in turn, drives the blades 18 back and forth at the point of attachment 42 at a controlled rate.

Although not illustrated in Fig. 1, the connections from the piezeo-electric elements 28 to the power supply 39 are conveniently made at the end 40, beneath the holder 41.

When driven back and forth, the blade 18 represents a beam subjected to combined bending and shearing loads varying so rapidly that inertial effects dominate to propagate a traveling flexure wave along the impeller or blade from the inlet end of the duct toward the outlet end of the duct. Typically a voltage oscillating in the range of 60—400 hz is applied. The most efficient pumping action results when the driving force is applied in quadrature, that is, to produce a 90 degree (°) phase lag in the oscillation cycle between two points along the blade, for example near the inlet end of the duct and near the outlet end, as illustrated schematically in Figs. 3a—3f. The driving force (F) is applied at a single point, and with a selected frequency range depending, e.g., upon the blade material, taper, and resiliency and thus the blade resonant frequency, such that the blade undergoes both lateral displacement and bending at the point of applied force. The driving force F on the blade produces the successive blade shapes shown in Figs. 3a—3f and directions of air motion (A) indicated by arrows, as described below.

Referring to Fig. 3a, with the blade 18 at rest, an initial lateral force F is applied (by the piezo-electric element) to the blade at point 42. Thereafter, the rear portion of the blade 18 moves toward the duct wall 16a, with the forward end of the blade lagging (Fig. 3b) due to inertia. Lateral movement of the blade 18 at 42 not only pushes air in the duct toward the outlet end, but draws air in from the inlet end.

When the rear portion (at 42) of the blade 18 reaches the duct wall 16a (Fig. 3b), the force F applied by the bilaminate is reversed (Fig. 3c) to move the rear portion of the blade toward the other wall 16b (Fig. 3d). The forward end of the blade, however, continues to lag behind by 90° of the oscillation cycle. When the driven point 42 of the blade reaches the other wall 16b, the force F is again reversed (Fig. 3e) to move the blade back, again the forward end of the blade reaching the duct wall 16b 90° later in the oscillation cycle (Fig. 3f). The motion of the blade continues to draw in air into the blower and expel air once in the duct. Optimum pumping efficiency results when the blade resonance frequency is at or near the driving frequency of the piezo-electric bilaminate assembly 28, since this maintains a quadrature relation between the leading (rear) and lagging (forward end) portions of the blade 18, and provides inlet and outlet valving as illustrated in Figs. 3b—3f.

The blade may be operated either in a free medium or in a duct, e.g. 16. In the latter embodiment, the duct 16 has a width such that the ends 24, 22 of the blades 18 contact, or almost contact, the duct walls, during the back and forth lateral movement, the downstream contact lagging the upstream point of contact by 90° of the oscillation cycle. Thus, the two contact points will have a quadrature relation with respect to each other so that the blade tips perform the functions of intake and outlet valves. See Figs. 3b—3f. Air throughput is also improved if venturi air louvers 56 are provided in the duct walls in the output half of the blower.

In the Fig. 1 embodiment, the blower contains two counter-oscillating blades 18 to operate 180° out of phase with each other. The complementary back and forth motion of the two blades 18 provides dynamic balancing and prevents vibration of the device.

As an example of the efficient operation of the present invention, a miniaturized form of blower constructed in accordance with Fig. 1, having an overall length of about 44,5 mm (1.075 inches) a width of 19,0 mm (0.75 inches) and a height of 12,7 mm (0.5 inches), and operated at a frequency of 60 hz by the piezo-electric bilaminates, produces a sufficient throughput of air and a sufficient output pressure to be capable of blowing out a windproof lighter. Thus the device is very efficient, and in tests, operation has been very stable, with efficiency so high that rises in temperature of the bilaminates have been virtually undetectable.

A modified embodiment of the solid state blower illustrated in Fig. 1 is shown in Fig. 4, where in place of the side mounted piezo-electric element 28, a pair of end-mounted bilaminate piezo-electric elements 128 drive respective ones of a pair of flat resilient blades 118. The free ends of the blades are terminated in whip portions 122, preferably made of Mylar, (Reg.TM).

The blower assembly includes a housing 110, side walls 112 and a bottom plate 117a. A top cover may be added if desired, similar to cover 17b shown in Fig. 1. In this embodiment, the blades 118 are not disposed in separate pumping ducts, yet efficient pumping action is achieved without the enhanced valving action produced by the ducts due to the quadrature travelling wave induced in the blades 118.

The piezo-electric bilaminates 128 are mounted at one end 140 to a cross member 141 bridging the walls 112 of the housing 110. The member 141 is provided with a pair of vertical slots 142, each of which is sized to snugly receive the end of the bilaminate 128 and a pair of electrically conductive contact leaves 144, one on either side of the bilaminate. Conductors, not shown, are connected to the leaves for coupling to the alternating voltage supply.

The free ends of the bilaminates 128 are attached to coupler weights 150, which in turn support the resilient blades 118. The weights 150 have vertical slots along their narrow edges for snugly engaging the bilaminates and blades, respectively. As shown in Fig. 4, the blades preferably are substantially wider than the bilaminates, to maximize air flow.

In this mounting arrangement, as in the Fig. 1 embodiment, the blade 118 is not fixed at any point relative to the housing and is free to move laterally (i.e., perpendicular to the flat surface of the blade 118) back and forth along its entire length when driven by the free end of the piezo-electric element 128.

As in the case of the blade in Fig. 1, when alternating voltage is applied across the bilaminates 128, a cyclical back and forth movement occurs in the free ends of the bilaminates 128 which in turn drives the weights 150 and the ends of the blade 118 fixed to the weights 150 back and forth in the housing. Since the entire length of the blade 118 is free to move back and forth relative to the housing, a traveling flexure wave is propagated when the blade is driven at an appropriate frequency, i.e. to produce quadrature similar to that illustrated in Figures 3a—3f, from the inlet end 124 toward the outlet end whip portion 122. Since, however, the propagated wave travels along the blade from one end 124 to the other 122, the blower works every efficiently in pumping fluids, especially air, without the need for blade valving action. To effect dynamic balancing of the system, the two bilaminates are driven to opposing phase relationship, as in the Figure 1 embodiment.

Although for dynamic balancing purposes it is preferable to employ a pair of counter-oscillating blades, the embodiments of both Figures 1 and 4 can provide effective air movement with a single oscillating blade.

Claims

1. A pumping device comprising a housing (10), a generally planar resilient impeller (18) disposed in said housing and means (28) for oscillating the impeller perpendicularly to its plane to propagate a travelling wave along the impeller to pump fluid through said housing, characterised in that the oscillating means comprises an elongate piezo-electric element (28) connected in the region of one end (41) to the housing (10) and connected at its other end (42) to the impeller (18) and means (36, 38) applying voltage to cause the end of the piezo-electric element remote from its connecting point to the housing to oscillate.

2. A pumping device according to claim 1 characterised in that the impeller (18) is disposed in a duct (16) in the housing.

3. A pumping device according to claim 1 or claim 2 characterised in that the characteristics of the impeller (18) are such that its resonant frequency approximates to that of the piezo-electric element (28) so that it is driven in quadrature.

4. A pumping device according to any one of the preceding claims characterised in that the impeller (18) and the oscillating means (28) are duplicated.

5. A pumping device according to claim 4 characterised in that the two impellers (18) are driven in anti-phase with each other.

6. A pumping device according to claim 4 or

claim 5 characterised in that each impeller (18) is disposed in a separate duct (16) in the housing (10).

7. A pumping device according to claim 2 or claim 6 characterised in that the or each duct (16) includes an inlet port, an outlet port and venturi intake ports (56) in the output half of the duct.

8. A pumping device according to any one of the preceding claims characterised in that the or each impeller (18) is tapered so as to have decreasing thickness with increasing distance from its point of connection to the respective piezoelectric element (28).

9. A pumping device according to any one of the preceding claims characterised in that the or each piezo-electric element (28) is a bilaminate.

10. A pumping device according to any one of the preceding claims characterised in that the combined weight of the or each impeller (18) and the inter-connection of the respective piezoelectric element (28) provides resonance at the frequency of oscillation of the applied voltage.

11. A pumping device according to any one of the preceding claims characterised in that the or each impeller (18) is mounted inside the housing and parallel to the respective piezoelectric element (28).

12. A pumping device according to any one of claims 1 to 10 characterised in that the or each impeller (18) is mounted inside the housing and coplanar with the respective piezoelectric element 28.

Patentansprüche

1. Pumpvorrichtung mit einem Gehäuse (10), einem im Gehäuse angeordneten, im allgemeinen ebenen, nachgiebigen Flügelrad (18) und einem Mittel (28) zum Oszillieren des Flügelrades senkrecht zu seiner Ebene, um eine sich entlang des Flügelrades zur Pumpströmung durch das Gehäuse fortbewegende Welle fortzupflanzen, dadurch gekennzeichnet, daß das Oszillierungsmittel ein längliches piezoelektrisches Element (28) umfaßt, das im Bereich seines einen Endes (41) mit dem Gehäuse (10) und mit seinem anderen Ende (42) am Flügelrad (18) verbunden ist, und daß Mittel (36, 38) Spannung anbringen, damit das eine Ende des piezo-elektrischen Elementes entfernt von seinem Verbindungspunkt am Gehäuse oszilliert.

2. Pumpvorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß das Flügelrad (18), in einem Leitungskanal (16) im Gehäuse angeordnet ist.

3. Pumpvorrichtung nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Eigenschaften des Flügelrades (18) derart sind, daß seine Resonanzfrequenz der des piezo-elektrischen Elementes (28) angenähert ist, so daß er um 90° phasenverschoben angetrieben wird.

4. Pumpvorrichtung nach irgendeinem der vorstehenden Ansprüche 1 bis 3, dadurch gekennzeichnet, daß das Flügelrad (18) und das Oszillierungsmittel (28) doppelt vorliegen.

5. Pumpvorrichtung nach Anspruch 4, dadurch gekennzeichnet, daß die beiden Flügelräder (18) gegenphasig zueinander angetrieben werden.

6. Pumpvorrichtung nach Anspruch 4 oder 5, dadurch gekennzeichnet, daß jedes Flügelrad (18) in einem getrennten Leitungskanal (16) im Gehäuse (10) angeordnet ist.

7. Pumpvorrichtung nach Anspruch 2 oder 6, dadurch gekennzeichnet, daß der oder jeder Leitungskanal (16) eine Einlaßöffnung, eine Auslaßöffnung und Venturieinlaßöffnungen (56) in der Auslaßhälfte des Leitungskanals umfaßt.

8. Pumpvorrichtung nach irgendeinem der vorstehenden Ansprüche, dadurch gekennzeichnet, daß das oder jedes Flügelrad (18) derart gestaltet ist bzw. sich verjüngt, daß es eine abnehmende Dicke mit zunehmender Entfernung von seinem Verbindungspunkt mit dem entsprechenden piezo-elektrischen Element (28) besitzt.

9. Pumpvorrichtung nach irgendeinem der vorstehenden Ansprüche, dadurch gekennzeichnet, daß das oder jedes piezo-elektrische Element (28) ein Bilaminat ist.

10. Pumpvorrichtung nach einem der vorstehenden Ansprüche, dadurch gekennzeichnet, daß das kombinierte Gewicht des oder jedes Flügelrades (18) und der Zwischenverbindung zum entsprechenden elektrischen Element (28) eine Resonanz liefert mit der Oszillationsfrequenz der angelegten Spannung.

11. Pumpvorrichtung nach irgendeinem der vorstehenden Ansprüche, dadurch gekennzeichnet, daß das oder jedes Flügelrad (18) im Inneren des Gehäuses und parallel zum entsprechenden piezo-elektrischen Element (28) befestigt ist.

12. Pumpvorrichtung nach irgendeinem der vorstehenden Ansprüche 1 bis 10, dadurch gekennzeichnet, daß das oder jedes Flügelrad (18) im Inneren des Gehäuses und koplanar zum entsprechenden piezo-elektrischen Element befestigt ist.

Revendications

1. Dispositif de pompage comprenant un corps (10), un organe d'impulsion élastique généralement plan (18) disposé dans ledit corps et des moyens (28) destinés à faire osciller l'organe d'impulsion perpendiculairement à son plan pour propager une onde progressive le long de l'organe d'impulsion afin de pomper un fluide à travers ledit corps, caractérisé en ce que les moyens oscillants comprennent un élément piezo-électrique allongé (28) connecté, dans la région d'une première extrémité (41), au corps (10) et connecté, par son autre extrémité (42), à l'organe d'impulsion (18) et des moyens (36, 38) appliquant une tension pour faire osciller

l'extrémité de l'élément piézo-électrique éloigné de son point de connexion au corps.

2. Dispositif de pompage selon la revendication 1, caractérisé en ce que l'organe d'impulsion (18) est disposé dans une gaine (16) à l'intérieur du corps.

3. Dispositif de pompage selon la revendication 1 ou la revendication 2, caractérisé en ce que les caractéristiques de l'organe d'impulsion (18) son telles que sa fréquence de résonance est à peu près la même que celle de l'élément piézo-électrique (28) afin qu'il soit commandé en quadrature.

4. Dispositif de pompage selon l'une quelconque des revendications précédentes, caractérisé en ce que l'organe d'impulsion (18) et les moyens oscillants (28) sont en double.

5. Dispositif de pompage selon la revendication 4, caractérisé en ce que les deux organes d'impulsion (18) sont commandés mutuellement en opposition de phase.

6. Dispositif de pompage selon la revendication 4 ou la revendication 5, caractérisé en ce que chaque organe d'impulsion (18) est disposé dans une gaine séparée (16) à l'intérieur du corps (10).

7. Dispositif de pompage selon la revendication 2 ou la revendication 6, caractérisé en ce que la ou chaque gaine (16) comprend un orifice d'entrée, un orifice de sortie et des orifices (56) d'admission de Venturi dans la moitié de sortie de la gaine.

8. Dispositif de pompage selon l'une quelconque des revendications précédentes, caractérisé en ce que le ou chaque organe d'impulsion (18) est effilé afin d'avoir une épaisseur qui décroît avec l'accroissement de la distance à partir de son point de connexion à l'élément piézo-électrique respectif (28).

9. Dispositif de pompage selon l'une quelconque des revendications précédentes, caractérisé en ce que le ou chaque élément piézo-électrique (28) est une bilame.

10. Dispositif de pompage selon l'une quelconque des revendications précédentes, caractérisé en ce que le poids combiné du ou de chaque organe d'impulsion (18) et de l'interconnexion avec l'élément piézo-électrique respectif (28) donne une résonance à la fréquence d'oscillation de la tension appliquée.

11. Dispositif de pompage selon l'une quelconque des revendications prédédentes, caractérisé en ce que le ou chaque organe d'impulsion (18) est monté à l'intérieur du corps et parallèlement à l'élément piézo-électrique respectif (28).

12. Dispositif de pompage selon l'une quelconque des revendications 1 à 10, caractérisé en ce que le ou chaque organe d'impulsion (18) est monté à l'intérieur du corps et est coplanaire à l'élément piézo-électrique respectif (28).

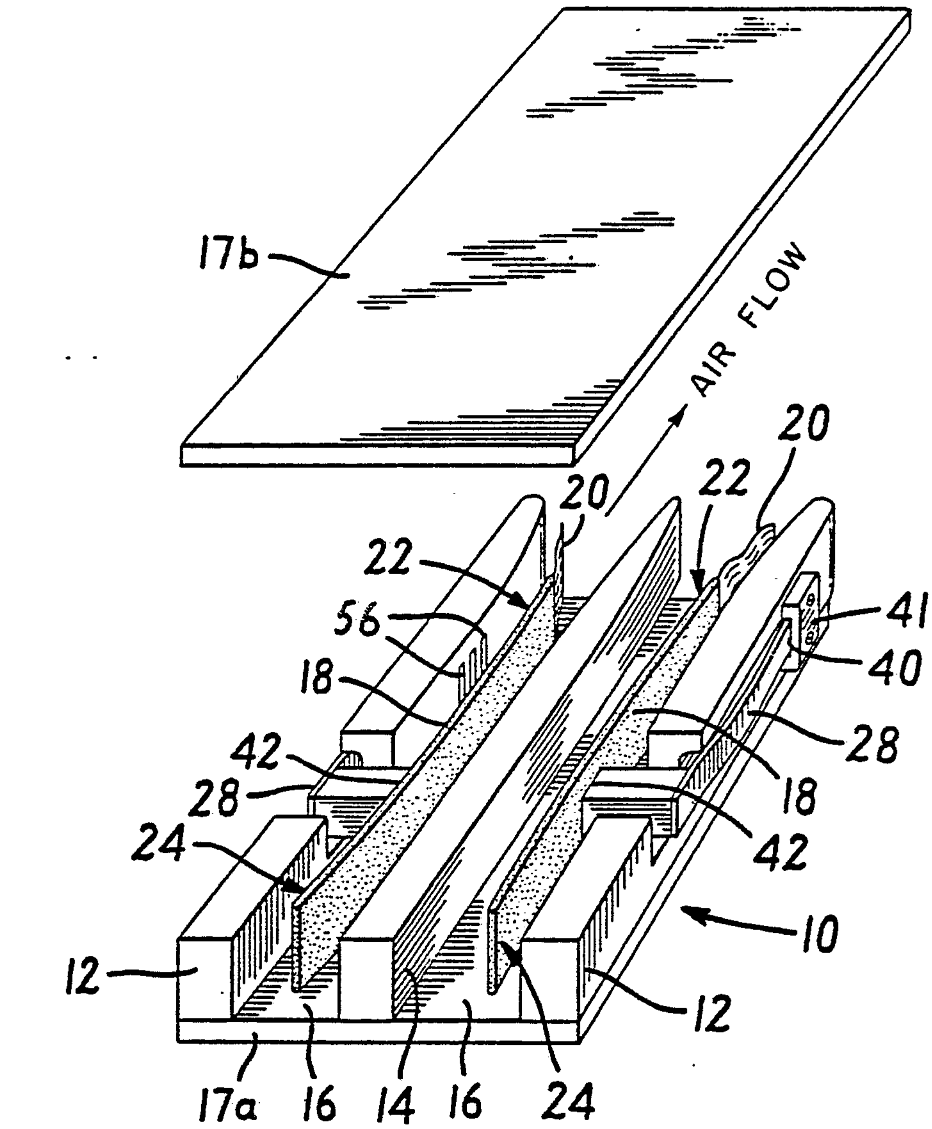
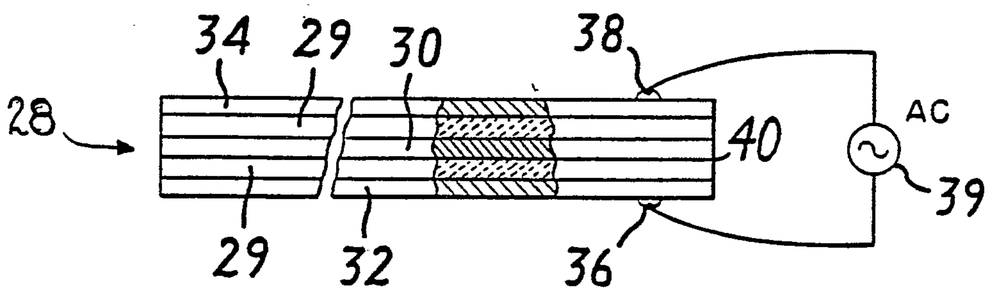

17b
AIR FLOW
20
22
20
22
56
41
40
18
28
42
18
28
42
24
10
12
12
17a
16
14
16
24

FIG. 1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30
38
28
AC
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39
29
32
36

FIG. 2

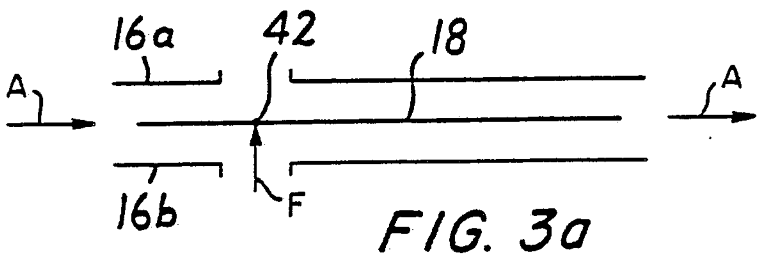


FIG. 3a

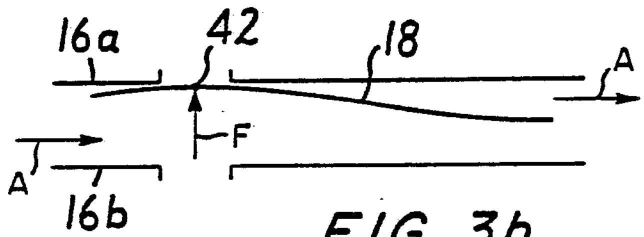


FIG. 3b

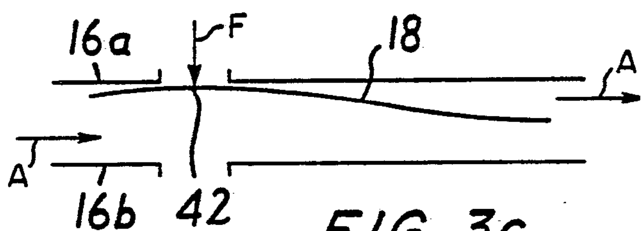


FIG. 3c

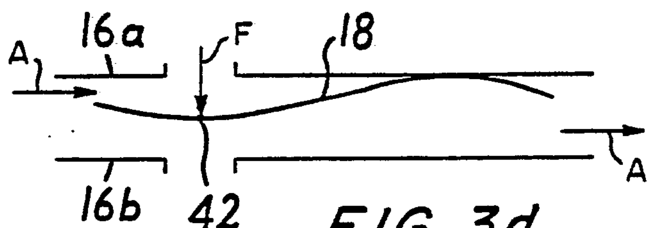


FIG. 3d

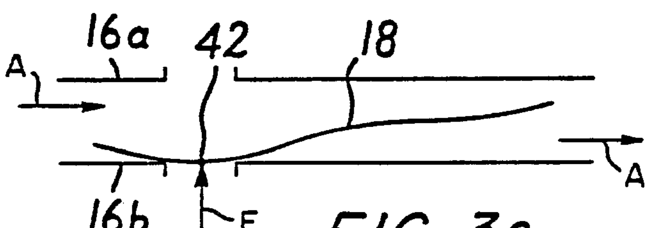


FIG. 3e

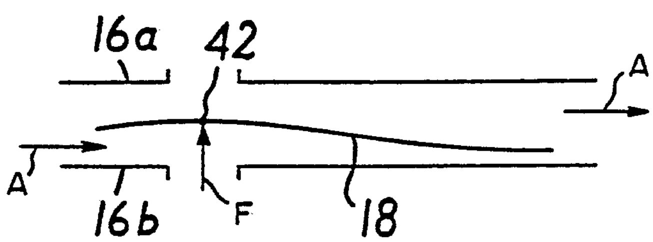
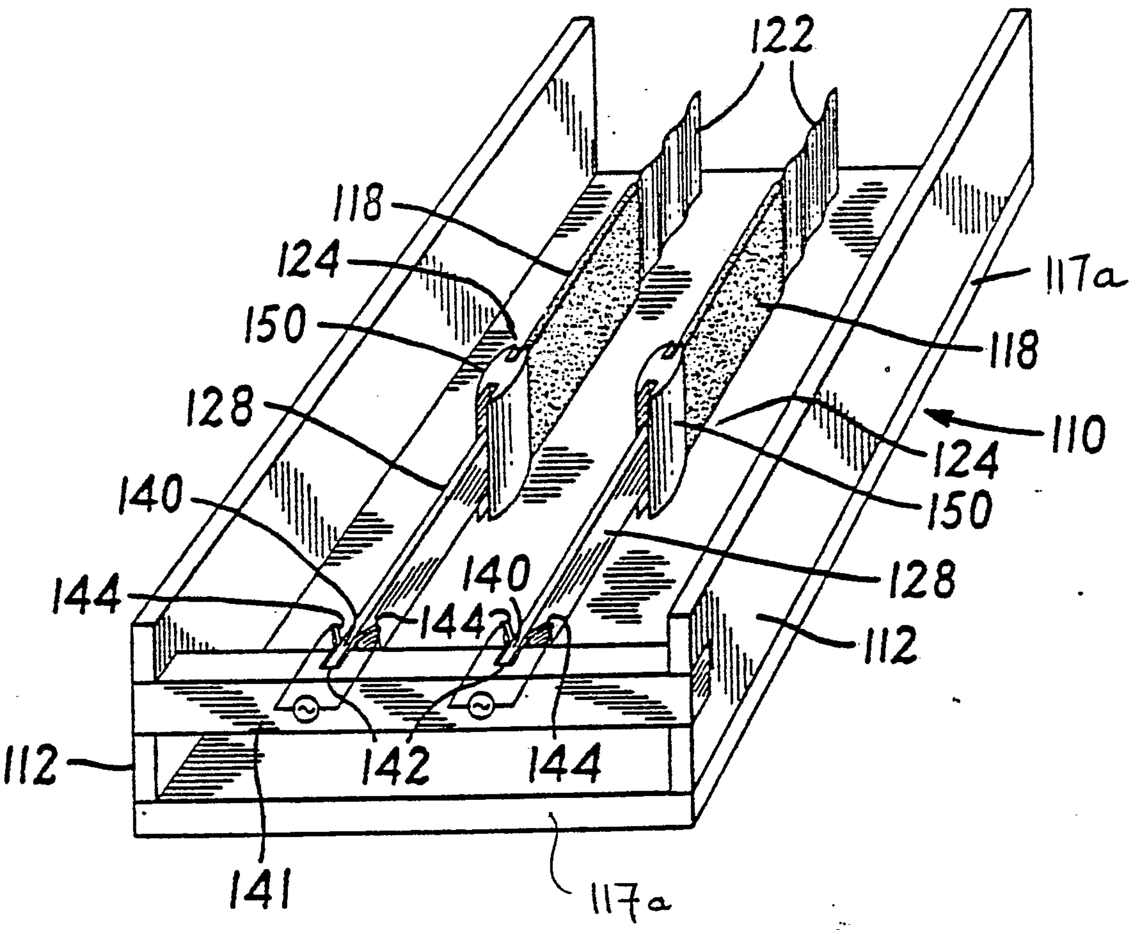


FIG. 3f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118
124
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141
117a

FIG. 4