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(54) **HOUSING WITH RECIRCULATION CONTROL FOR USE WITH BANDED AXIAL-FLOW FANS**
GEHÄUSE MIT REZIRKULATIONSREGELUNG ZUR ANWENDUNG IN AXIALLÜFTER MIT ZARGE
BOITIER A RECIRCULATION CONTROLEE POUR UTILISATION AVEC UN VENTILATEUR AXIAL
A PALES ENTOUREES PAR UN ANNEAU CYLINDRIQUE

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Description

Background of the Invention

[0001] This application relates primarily to banded, axial-flow fans that are used in combination with a housing. We use the term banded axial-flow fan to describe a fan having a hub that rotates on an axis and has blades extending in an outwardly direction (for example, generally radially) from the hub to a circular band that connects the blade tips. Blade rotation tends to force air in the general direction of the fan axis.

[0002] We use the term fan and housing combination to describe such axial flow fans in combination with a housing (e.g., a shroud or a duct) that guides airflow entering and/or leaving the fan. By shroud, we mean an airflow guide shaped and positioned to guide airflow moving between the fan and a heat exchanger. An example of a banded shrouded fan that moves air through a heat exchanger is disclosed in Gray U.S. Patent, 4,548,548, which is hereby incorporated by reference. By duct, we mean an elongated flow path such as those used in heat, ventilation, and air conditioning systems.

[0003] In order to compare the invention to the prior art, a figure from the '548 patent is reproduced here as Fig. 1B.

[0004] US-A-4685513 discloses a compact fan and shroud package for radiators with fan blades curved rearwardly supporting a rotating shroud at an optimised distance from the radiator for improved airflow through the radiator. The package comprises a fan having a hub that rotates on an axis and blades extending outwardly from the hub to a circular band that connects the blade tips, the package further comprising a housing to control airflow entering the fan, leaving the fan or both, a portion of the housing being positioned outward of the fan band so that there are running clearances between the fan band and housing such that recirculating airflow moves in the pathway between the fan and housing. The housing may be a single injection moulded unit.

[0005] There have been efforts to reduce the effects of undesired airflow recirculation experienced with fan and housing combinations. Airflow recirculation can be explained as follows. The fan generates a pressure difference between the upstream side of the fan (the side from which air is drawn) and the downstream side of the fan (the side of the fan which exhausts the airflow) -- i. e., pressure is higher on the downstream side than on the upstream side. Airflow recirculation is the undesired flow of air from the downstream to the upstream side of the fan, resulting from this pressure difference. For banded fans in a housing, the recirculating airflow passes through the running clearance between the housing and the band.

[0006] One way to reduce recirculation is to reduce the fan-to-housing clearance. Another way to reduce recirculation is to incorporate labyrinth seals between the fan and the housing. In some cases these methods may

present difficulties in economic manufacture.

[0007] Hauser U. S. Pat. 4,357,914 discloses a cooling fan for use with an annular radiator having baffle rings to reduce recirculation.

[0008] In accordance with one aspect of the invention there is provided a fan and housing combination comprising a fan having a hub that rotates on an axis and blades extending outwardly from the hub to a circular band that connects the blade tips, the combination further comprising a housing to control airflow entering the fan, leaving the fan, or both; a portion of the housing being positioned outward of the fan band so that there are running clearances between the band and the housing such that recirculating airflow moves in a pathway between the band and the housing; in which the stationary flow control vanes are connected to the housing in a position to encounter and redirect recirculating airflow, said housing and said vanes being a single injection molded plastic unit.

[0009] In accordance with a second aspect of the invention there is provided a fan and housing combination comprising a fan having a hub that rotates on an axis and blades extending outwardly from the hub to a circular band that connects the blade tips, the combination also comprising a housing to control air flow entering the fan, leaving the fan, or both; a portion of the housing being positioned outward of the fan band so that there are running clearances between the band and the housing such that recirculating airflow moves in a pathway between the band and the housing; the housing further comprising a rearward housing segment having a reduction in radius at a location rearward of the trailing edge of the fan band, and elongated motor supports which extend from the rearward housing segment to a centrally positioned motor mount; in which the stationary flow control vanes are connected to the housing in a position to encounter and redirect recirculating airflow, an airflow recirculation pathway being formed between the fan band and the housing, and at least a portion of the vanes being positioned in the pathway.

[0010] The invention features certain configurations for banded, axial-flow fan and housing combinations that provide a surprising combination of efficiency, low noise, and manufacturability.

[0011] The invention generally features fan and housing combinations which include stationary flow control vanes (e.g. thin members) positioned to encounter and redirect recirculating airflow. A portion of the housing is positioned outward of the fan band, and there are running clearances between the band and the housing such that recirculating airflow moves in a pathway between the fan and the housing. According to the invention, the stationary flow control vanes are attached to the housing.

[0012] The invention provides a combination of efficiency, manufacturability and low noise. Without wishing to bind ourselves to a particular theory, such benefits may be explained at least in part as follows. Recirculat-

ing airflow generally has a swirling (rotational) component of velocity imparted either by the fan blading or by vicious effects in the recirculation passage. When reingested by the fan, this swirl causes the fan blades to operate locally at an angle of attack different from that of the main flow. Swirl also may increase inflow turbulence, which causes broadband noise, and it may lead to flow non-uniformities causing undesirable tones.

[0013] The invention is particularly suited for shrouded fans that draw airflow through an upstream heat exchanger, but the invention also can be applied to fans that blow air through a downstream heat exchanger. It is also particularly suited for ducted fans.

[0014] We have found that the invention can be practiced in two general configurations described below. While both configurations are included in a single invention, we have found that specific optimum vane geometry may be different for the two configurations, as detailed below.

[0015] The first configuration features placement of the vanes generally within the space between the fan band and the housing, although embodiments in which the vanes continue downstream of the fan band are also included within the first configuration. This configuration is best suited for applications in which there are axial packaging constraints, such as automotive applications in which a shrouded fan draws air through a heat exchanger immediately adjacent (usually upstream of) the fan.

[0016] The second configuration features placement of the vanes such that they are at least partially (or even entirely) upstream of the fan band from the perspective of the primary airflow. Such configurations are particularly suited for ducted fans, such as those in airhandlers for heating, ventilating and/or cooling buildings, where axial space is less constrained.

[0017] In preferred embodiments of the first configuration of the invention, the housing and vanes are a single injection molded plastic unit. For the second configuration, the vanes may be injection molded as part of an array that is assembled with the housing.

[0018] Preferred embodiments (particularly for automotive applications with fan/shroud/radiator combinations) are also characterized by a fan-to-housing (usually a shroud) running clearance of at least 0.25% of the fan diameter. We use the term running clearance to designate the spacing between the fan band and portions of the housing that extend around the fan band.

I. Vanes In The Band-To-Housing Gap

[0019] In preferred embodiments of the first configuration of the invention, the housing (shroud) is characterized by a reduction in radius at a location rearward of the trailing edge of the fan band. The pathway of recirculating airflow can include an inlet formed between the trailing edge of the fan band and the portion of the housing at the reduced radius. The trailing edge of the fan

band is the rearward-most portion of the band. In some embodiments, the band includes a lip that extends rearward of the blade trailing edge. Preferably, at least a portion of the vanes is positioned radially outward of the inlet to the recirculation pathway.

[0020] The above-described housing radius reduction can reduce the housing radius R_r (see Fig. 2A) to a value approximately equal to, or even less than, the outer radius of the trailing edge of the fan band (R_b , see Fig. 2A, described below). "Approximately equal" in this context means a radius that would risk interference if the portion of the housing with the reduced radius were not offset axially from the fan band. For example, for automotive and similar applications, the two radii may differ by less than standard or nominal radial running clearance "C" (see Fig. 2A).

[0021] Also in preferred embodiments, the housing comprises a rearward housing segment extending from the radius reduction rearwardly to the rearward housing (shroud) terminus. Elongated motor supports may be attached to that rearward housing segment, extending from the housing to a centrally positioned motor mount. As the housing extends rearwardly from the location of the radius reduction, the inside diameter of the housing may increase, producing a flare to improve performance.

[0022] In yet other preferred embodiments, an inlet to the recirculation pathway is formed between the housing and the trailing edge of the band; the housing comprises a rearward portion which extends first rearwardly and then inwardly and forwardly, forming a pocket axially rearward of the inlet of the recirculation flow path. Such pockets may have a rounded back or a straight back. A portion of the vanes may extend into the pocket, and at least a portion of the vanes is axially rearward of the trailing edge of the band. Also, the vanes may be characterized by a reduction in radius at a position axially rearward of the trailing edge of the fan band.

[0023] Also in some embodiments, the recirculating airflow pathway includes an outlet formed between the housing and an outwardly flaring segment of the leading edge of the fan band. Advantages may be achieved according to the invention with other geometries that do not include this detail, however.

[0024] The vanes may be straight (radial or non-radial) taken in a section in a plane normal to the fan axis. Alternatively, the vanes may be curved taken in a section in a plane normal to the fan axis.

II. Vanes Upstream Of The Fan Band

[0025] We turn now to a second configuration of the invention in which the vanes are at least partially upstream of the fan band.

[0026] In some embodiments of the second configuration of the invention, the space through which airflow recirculates comprises a restriction upstream (from the perspective of recirculating airflow) of the vanes. With-

out wishing to be bound to or limited by a specific theory, we believe improved performance from this configuration may result, at least in part, because the restriction causes the airflow to jet into the spaces between the vanes, rather than to be deflected radially or tangentially. Also preferably, the band comprises a lip flaring outwardly to establish the above described restriction. (This embodiment of the invention also has application in some embodiments of the first configuration of the invention, e.g. in the embodiment of Fig. 5B where the inlet to the recirculation path is the restriction.)

[0027] The vanes may be part of a single injection molded plastic piece. For example, the vanes may be arranged in an array whose inward tips are connected by an inner ring. The inner ring gives structural rigidity to the vane assembly, which allows the housing to be formed around the vane assembly.

[0028] The vanes may be molded in various configurations that better match the direction of incoming recirculating airflow. These configurations may be particularly beneficial in fans producing a relatively low pressure rise at some segment of the duty cycle. For example, the vanes may be molded so that the end faces of the vanes are beveled (preferably at least 20° and most preferably at least 30°) so that the high pressure side surfaces extend slightly further upstream (from the perspective of recirculation airflow) than the low pressure side surfaces. The sides of the vanes can also be hooked so that the high pressure side surfaces are concave near the upstream end of the vanes (e.g. so that the radius of the concave portion is between 0.1S and 1.0S, where S is the spacing between adjacent vanes). The vanes may be angled slightly from purely radial, with the radially inward tip being inclined towards recirculation flow impinging on the vanes. The vanes (or at least the high pressure side of the vanes, with the low pressure side being straight) may be curved in a planar section normal to the fan axis (e.g., the section may be cylindrical with a radius of curvature of between 0.15D and 0.3D).

[0029] Other features and advantages of the invention will be apparent from the following description of preferred embodiments and from the claims.

Brief Description of the Drawings

I. Vanes In The Band-To-Housing Gap

[0030] Fig. 1A is a side view in section of a fan and shroud according to the invention, including an upstream heat exchanger.

[0031] Fig. 1B shows a prior art fan.

[0032] Figs. 2A-2D are views in section of portions of fan and shroud combinations according to the invention, showing alternative configurations of the shroud radius reduction.

[0033] Figs. 3A and 3B are sections of fan and shroud combinations showing variations in shroud design up-

stream of the vanes.

[0034] Figs. 4A-4C are diagrammatic representations of arrays of vanes according to the invention in circumferential view.

[0035] Figs. 5A and 5B are side views, in section, of other fan/shroud combinations according to the invention, in which a heat exchanger is downstream of the fan.

[0036] Fig. 6 is a diagrammatic representation of a fan and duct combination according to the invention.

[0037] Figs. 7-9 are side views in section of other fan and housing combinations.

II. Vanes Upstream Of The Fan Band

[0038] Fig. 10 is a side view in section of a fan and duct showing vanes upstream of the fan band.

[0039] Figs. 11 is a side view in section of a ducted, banded fan being used with a dual-ring vane assembly.

[0040] Fig. 12 is an end view of the vanes taken along 12-12 of Fig. 11, showing only a portion of the vanes.

[0041] Fig. 13A is a close-up of the circled portion of Fig. 12. Figs. 13B and 13C are similar views of alternative configurations.

[0042] Fig. 14A is a sectional view taken along 14A-14A of Fig. 12 showing square leading edge details for a pair of vanes. Fig. 14B is a section of an alternative vane configuration.

[0043] Fig. 15 is perspective view of one particular vane embodiment according to the invention.

Description of the Preferred Embodiments

[0044] We will describe embodiments of the two configurations of the invention separately.

I. Vanes in Gap Between Housing and Fan Band

[0045] In Fig. 1A, fan 20 is positioned in shroud 26 to pull air through heat exchanger 21. Axis A is the fan's rotational axis. Fan 20 has a band 24 connecting the outer tips of blades 22. Band 24 terminates at its upstream edge in a lip 30. Vanes 28 are attached to shroud 26. Figs. 4A-4C are sectional views (perpendicular to the fan axis) of arrays of vanes 28, showing the alternative configurations of the vanes. The sections are taken looking rearwardly along the fan axis, and the direction of fan rotation is clockwise. In Fig. 4A, vanes 28E are radial. In Fig. 4B, vanes 28F are straight, and they are angled from the radial direction. In Fig. 4C, vanes 28G are curved to receive airflow having a rotational component in the direction of fan rotation. Advantageously, the design of vanes 28 and shroud 26 permits the entire shroud and the vanes to be injection molded as a single unit. The spacing between vanes 28 is selected to remove swirl without excessively blocking airflow. In typical applications there will be more than 10 and less than 1000 (e.g., 30-200) of these vanes, although there may be fewer or more in specific applications.

[0046] Fan 20 and shroud 26 are designed with running clearances to avoid interference between band 24 and shroud 26. Shroud 26 has a radius reduction rearward of band 24 (formed by shroud segments 27 and 29), which reduces the shroud radius (R_r) to less than the outer radius (R_b) of band 24 at its trailing edge, plus clearance "C". Fig. 2A illustrates R_r , R_b and R_c on a fan and housing similar to that shown in Fig. 1A.

[0047] Motor supports (one shown as 37 in Fig. 1A) are attached to shroud segment 29. Shroud 26 is mounted to radiator 21 by mounts 23.

[0048] For comparative purposes, we include Fig. 1B which is a figure reproduced from Gray, U.S. 4,548,548. Note that the recirculation flow path between the shroud and the band does not include vanes. Moreover, the radius of the shroud is relatively constant rearward of the lip of the band, at a value that must provide clearance between the band and the shroud. The radius of the fan band R_b , the radius of the shroud after the reduction R_r , and clearance "C" are shown in Fig. 2A, discussed below.

[0049] The operation of the invention can be described as follows. Recirculating airflow enters the inlet between band 24 and the shroud radius reduction formed by segments 27 and 29. The airflow turns to travel in space 32 and encounters vanes 28 whereby rotational velocity is reduced. The airflow exits the recirculation path through outlet 36, which is formed between the upstream edge of lip 30 and shroud 26.

[0050] Preferably, the widths of inlet 34 and outlet 36 are as narrow as manufacturing processes permit to minimize leakage and resulting lost energy. In practice, for typical automotive applications, the width of inlet 34 may be about 0.04D (where D = the fan diameter) or less, and the width of outlet 36 may be 0.02D or less.

[0051] Figs. 2A-2D are diagrammatic representations of details of fan/shroud combinations that are similar to the one shown in Fig. 1A, with differing inlets to the recirculation flow path space. In each of those figures, fan blades terminate in a similar band. Vanes are included in the space between the fan band and the shroud. The shroud includes a radius reduction rearward of the trailing edge of the fan band. The specific designs of the shrouds differ in these radius reductions, thus providing different inlets to the recirculation flow path. In view of those similarities, the embodiments of Figs. 2A-2D will only be described to highlight the differences among those embodiments. Features in Figs. 2A-2D are numbered with numbers corresponding to those used in Figs. 1A.

[0052] In Fig. 2A, the shroud radius reduction segments 27A and 29A are rearward of the trailing edge of band 24A. The inner radius of segment 29A is less than the outer radius of the trailing edge of band 24A.

[0053] In Fig. 2B, shroud segment 29B has an inner radius slightly larger than the outer radius of the trailing edge of band 24B.

[0054] In Fig. 2C, segment 29C has a radius approx-

imately equal to that of the fan band. Segment 26C flares outwardly, to optimize performance in some applications. The thickness of the shroud may decrease with rearward extent, so that the outer shroud diameter in this segment flares less or is generally cylindrical.

[0055] In Fig. 2D, segment 29D is rounded to form a pocket 48D. This geometry allows a large amount of flare to be used on an injection moldable part. Vanes 28D extend into the pocket.

[0056] Figs 3A and 3B are sections of fan and housing combinations that are similar to the fan of Fig 1A, except in the configuration of shroud 26' and 26" upstream of the fan. In both figures, fan blade 22 terminates in a band 24. Vanes 28 are positioned in the recirculation flow path. Motor supports 37 extend from a downstream extension of the shroud. Unlike the fan and housing depicted in Fig. 1A, in Fig. 3A, a restriction is not formed between the band 24' and shroud 26'. In Fig. 3B, the radius of shroud segment 26" is essentially constant, and a restriction is formed between band 24 and shroud 26". Both configurations are within the spirit of the invention.

[0057] Figs. 5A and 5B show two alternative fan and housing configurations in which the fan is upstream of the heat exchanger, and the shroud guides airflow (shown generally with an arrow) from the fan into the heat exchanger. In Fig. 5A, fan blade 54 has a band 55 with a lip 56 that forms an inlet to the fan. Airflow recirculation takes place through inlet 67 into space 57 between the shroud 58 and the band 55, and exits outlet 68. Vanes 59 are positioned in space 57 to encounter recirculating airflow and reduce swirl in the recirculating airflow. Fan motor 65 is positioned between the fan and the heat exchanger 62. Shroud 58 includes a segment 60 to which motor supports 61 are attached.

[0058] In Fig. 5B, fan 70 blows air into downstream heat exchanger 82. Unlike the assembly of Fig. 5A, motor 71 of the assembly of Fig. 5B is upstream of the fan. The fan band 75 has a lip 76 on the downstream side, and the inlet to the fan is formed by a shroud segment 80 which curves inwardly and back toward heat exchanger 82. The motor 71 is attached to support 81. Recirculating airflow moves through inlet 83 to space 77 between band 75 and shroud 78, and exits outlet 84. Vanes 79 are positioned in space 77 to encounter that recirculating airflow and to reduce swirl in it. In this configuration, the inlet restriction upstream of the vanes and the vane shaping referenced below may be beneficial.

[0059] Fig. 6 is a section showing a variation of the invention useful in ducted fans. The vanes 44 are provided as a separately molded part having a flared rear face 49 which terminates in an edge 50 that forms the inlet 52 for the recirculation flow path. In other respects, the blades 48, the band 46 and the duct 51 are similar to those described below.

[0060] Fig. 7 shows a fan 640 housed in a shroud 642 which guides airflow through a radiator (not shown) upstream of the fan. Vanes 644 are L-shaped in this view

and radial in a plane perpendicular to the fan axis. Lip 646 forms a restriction inlet 648 with lip 647. The vanes are spaced from 3.2 to 12.7mm (1/8 to 1/2 of an inch) apart around the circumference, with the smaller spacing being used in very small fans.

[0061] The fan and housing combination of Fig. 7 can also be used (with some modification) as a ducted fan. In some applications, the width of the recirculation outlet is at least twice the width of the recirculation inlet. Increasing the width of outlet reduces the velocity of the leakage flow thus reducing flow disruption as the recirculation flow enters the main flow.

[0062] In Fig. 8, fan 780 has a band 782 with an upstream edge that turns back axially to form lip 784. Shroud 786 includes vanes 788. A lip 790 on shroud 786 forms a restriction 792 in the recirculation path, which feeds the airflow to vanes 788 and from there to outlet 794. In this particular embodiment, the outlet to the recirculation path is at least twice as wide as the restriction.

[0063] In Fig. 9, band 800 of fan 801 has a trailing lip 802 which forms restriction 803 with shroud 804. Leakage vanes 805 extend from shroud 804. Bell mouth 807 together with the axially forward edge of band 800 form outlet 806 to the recirculation path.

II. Vanes Upstream of the Fan Band

[0064] Fig. 10 depicts a fan 90 in which the housing 92 is a duct or shroud having vanes 94 upstream of band 96. Inlet 91 is formed between the upstream edge of band 96 and duct 92. This inlet ("X") is on the order of 0.005D-0.02D. Recirculation airflow is entrained into vanes 94 and leaves through the open sides 98 of the slots between vanes 94.

[0065] With reference to Figs. 11-15, in preferred embodiments the array of vanes is provided by a dual ring structure 217 which fits within the duct 212 just upstream of the fan 214. The vane assembly may be made from molded plastic, hard plastic foam, or any suitable material which may be fashioned into the requisite geometry. As shown in Fig. 11, the assembly consists of an outer ring 216, an inner ring 218, and a plurality of vanes 220 disposed generally radially between the two rings 216, 218.

[0066] Although use of an inner ring 218 is not absolutely necessary, it is preferred. The ring 218 gives structural rigidity to the assembly. This is beneficial if it is desired to form the housing by wrapping sheet metal, or some other flexible material, around the perimeter of the outer ring 216 to form the duct.

[0067] The inner ring 218 also divides the duct into separate flow passageways, an inner primary passageway 222 through which the primary flow passes, and an outer, annular recirculation passageway 224 through which the recirculation flow passes. The inner ring 218 helps to inhibit radial flow, where it exists, from reentering the fan.

[0068] As disclosed above, it is advantageous to use a banded fan 214 in which the band 226 terminates in a curved lip 228. The curved lip 228 forms a restriction 230 in the recirculation passageway 224.

[0069] As shown in Fig. 13A and 14A, the vanes 220 may be substantially flat, non-shaped vanes. Such vanes generally may provide adequate performance. As explained below, however, for other applications (e.g., low pressure rise fans or fans that are designed both for high and low pressure rise) additional vane shaping can improve performance.

[0070] Without wishing to bind ourselves to a single, specific theory as to the operation of such shaping improvements, it appears that the tangential velocity of the recirculation flow is induced mainly by viscous effects, and is therefore approximately a fixed percentage of tip speed. The axial velocity, however, is caused by the pressure difference across the fan. As a result, a fan which generates a relatively low pressure (for its diameter and rotation speed) will have a recirculation flow which approaches the vane at an angle closer to tangential than will be the case for a relatively high pressure fan. When air approaches a vane with a square end face (Figure 14A) at an angle close to tangential, there is a tendency for some of this flow to be deflected in the tangential and inward radial directions, rather than to pass through the space between the vanes. In this case, it is beneficial to provide some additional shaping to the vanes.

[0071] Tangential deflection of airflow is reduced by bevelling the end face 234 of each of the vanes 220, as shown in Fig. 14B. The end face 234 is beveled such that the high pressure side surface 236 of the vane projects further upstream (taken from the perspective of the recirculation flow) than the low pressure side surface 238. The bevel angle, β , can be at least 20°, and is preferably 30° or more.

[0072] Deflection of flow in the inward radial direction is reduced by incorporating additional detailed vane shaping in two respects. First, as shown in Fig. 14B, the high pressure side surface 236 is made concave by the addition of a cylindrical region 242 at the leading edge 250, i.e., the juncture of the high pressure side surface 236 and end face 234. The radius of curvature r of the cylindrical region 242 can be on the same order as 1/2 of the spacing between vanes.

[0073] Secondly, the vanes can be non-radial in a section **perpendicular to a plane normal to the fan axis**. In Fig. 13B, the innermost tips 250 of the vanes 220 are inclined into the impinging recirculation flow. The lean angle, λ , should preferably be between 3° and 10° from radial. Alternatively, as shown in Fig. 13C, vanes (or at least the high pressure side of the vanes) of some embodiments are slightly cylindrical in a plane normal to the fan axis. The center of curvature is parallel with the fan centerline and is placed on a tangent to the outside periphery of the vane. The radius of curvature is approximately 20% of the fan diameter. The vanes are radial

at the outer periphery of the device, and are more inclined toward the flow as radius decreases.

[0074] Fig. 15 is a perspective view of a portion of a dual ring structure 217 looking axially toward the rear face 232 of vanes 240. As described above, the leading edge 242 of vanes 220 is beveled, and the high pressure side face 236 is shaped. The vanes are slightly cylindrical in a plane normal to the fan axis.

[0075] Other embodiments are within the following claims. For example, the above described vanes can be used with fan/shroud combinations that blow air through a downstream heat exchanger. Specifically, they can be used with the fan/shroud combinations as generally described in a commonly owned U.S. Patent Application titled Fan Inlet With Curved Lip And Cylindrical Member Forming Labyrinth Seal, filed on June 17, 1993, by Michael Sortor, and given serial number 08/079,317.

Claims

1. A fan (20) and housing combination comprising a fan having a hub that rotates on an axis and blades (22) extending outwardly from the hub to a circular band (24) that connects the blade tips, the combination further comprising a housing to control airflow entering the fan, leaving the fan, or both; a portion (26) of the housing being positioned outward of the fan band so that there are running clearances between the band and the housing such that recirculating airflow moves in a pathway between the band and the housing; **characterised in that** stationary flow control vanes (28) are connected to the housing in a position to encounter and redirect recirculating airflow, said housing and said vanes being a single injection molded plastic unit.
2. The fan and housing combination as claimed in Claim 1 in combination with a heat exchanger in which the housing is positioned upstream from a heat exchanger, whereby the fan pushes air through the heat exchanger.
3. A fan (20) and housing combination comprising a fan having a hub that rotates on an axis and blades extending outwardly from the hub to a circular band that connects the blade tips, the combination also comprising a housing to control airflow entering the fan, leaving the fan, or both; a portion of the housing being positioned outward of the fan band so that there are running clearances between the band and the housing such that recirculating airflow moves in a pathway between the band and the housing; the housing further comprising a rearward housing segment (27, 29) having a reduction in radius at a location rearward of the trailing edge of the fan band, and elongated motor supports (37) which extend from the rearward housing segment to a centrally

positioned motor mount; **characterised in that** stationary flow control vanes (28) are connected to the housing in a position to encounter and redirect recirculating airflow, an airflow recirculation pathway being formed between the fan band and the housing, and at least a portion of the vanes being positioned in the pathway.

4. The fan and housing combination as claimed in Claim 3 in which the pathway has an inlet formed between the fan band (24) and the housing (26), and at least a portion of the vanes (28) is positioned radially outward of the pathway inlet (34) and the radially innermost face of the vanes is rounded or beveled.
5. The fan and housing combination of Claim 3 in which, as the housing extends rearwardly from the location of the radius reduction, the inside diameter of the housing (29C, 29D) increases.
6. The fan and housing assembly of Claim 5 in which, as the housing extends rearwardly from the location of the radius reduction, the thickness of the housing (29C) decreases.
7. The fan and housing combination of Claim 1 or Claim 3 in which the vanes (28F) are non-radial taken in a section in a plane normal to the fan axis.
8. The fan and housing combination of Claim 1 or Claim 3 in which the vanes (28G) are curved taken in a section in a plane normal to the fan axis.
9. The fan and housing combination of Claim 1 or Claim 3 **characterised in that** the vanes (79, 94, 220) are positioned at least in part upstream of the fan band (75, 96, 226).
10. The fan and housing combination of Claim 3 in which said vanes are all part of a single injection moulded plastic assembly.
11. The fan and housing combination of Claim 1 or Claim 3 wherein said vanes (220) have a beveled end face (234).
12. The fan and housing combination of Claim 11 wherein the end faces (234) of said vanes (220) are beveled by at least 20°.
13. The fan and housing combination of Claim 12 wherein said vanes are arranged in an array whose inward tips are connected by an inner ring.
14. The fan and housing combination of Claim 11 in which the high pressure side (236) of the vanes has a concave portion (242) adjacent to the end face of

the vanes.

15. The fan and housing combination of Claim 14 in which the radius of said concave portion is between 0.1S and 1.0S, where S is the spacing between adjacent vanes.

16. The fan and housing combination of Claim 15 in which the high pressure side (236) of said vanes is curved in a plane normal to the fan axis.

17. The fan and housing combination of Claim 16 in which the high pressure side (236) of said vanes is substantially cylindrical in a plane normal to the fan axis, having a radius of curvature between 0.15D and 0.3D, where D is the fan diameter.

18. The fan and housing combination of Claim 11 in which:

- a) the end faces (234) of said vanes (220) are beveled by at least 20°;
- b) the high pressure side (236) of the vanes (220) has a concave portion (242) adjacent to the end face of the vanes, having a radius of curvature of between 0.1S and 1.0S, where S is the spacing between adjacent vanes; and
- c) the high pressure side (236) of the vanes is substantially cylindrical in section in a plane normal to the fan axis, having a radius of curvature of between 0.15D and 0.3D, where D is the fan diameter.

Patentansprüche

1. Aus Lüfter (20) und Gehäuse bestehende Baugruppe, zu der ein Lüfter mit einer auf einer Achse umlaufenden Nabe und Flügeln (22), die sich von der Nabe nach außen bis zu einem die Flügelspitzen verbindenden Abschlußring (24) erstrecken, sowie des weiteren ein Gehäuse zur Führung des in den Lüfter einströmenden, des aus dem Lüfter ausströmenden Luftstroms oder für beides gehören; wobei ein Abschnitt (26) des Gehäuses so vom Abschlußring des Lüfters nach außen hin angeordnet ist, daß Spalte zwischen dem Abschlußring und dem Gehäuse entstehen, so daß die rückströmende Luft einen zwischen dem Abschlußring und dem Gehäuse vorhandenen Strömungsweg passiert; **dadurch gekennzeichnet, daß** unbewegliche Leitbleche (28) am Gehäuse so befestigt sind, daß sie dem Rückluftstrom ausgesetzt sind und diesen umlenken, wobei das Gehäuse und die Leitbleche in einem Stück spritzgossen sind.
2. Aus Lüfter und Gehäuse bestehende Baugruppe nach Anspruch 1, ergänzt durch einen Wärmetau-

scher, wobei das Gehäuse dem Wärmetauscher gegenüber vorgeschaltet ist, wodurch der Lüfter die Luft durch den Wärmetauscher fördert.

3. Aus Lüfter (20) und Gehäuse bestehende Baugruppe, zu der ein Lüfter mit einer auf einer Achse umlaufenden Nabe und Flügeln, die sich von der Nabe nach außen bis zu einem die Flügelspitzen verbindenden Abschlußring erstrecken, sowie des weiteren ein Gehäuse zur Führung des in den Lüfter einströmenden, des aus dem Lüfter ausströmenden - Luftstroms oder für beides gehören; wobei ein Abschnitt des Gehäuses so vom Abschlußring des Lüfters nach außen hin angeordnet ist, daß Spalte zwischen dem Abschlußring und dem Gehäuse entstehen, so daß die rückströmende Luft einen zwischen dem Abschlußring und dem Gehäuse vorhandenen Strömungsweg passiert; wobei zum Gehäuse des weiteren ein rückseitiges Gehäusesegment (27, 29) mit einer Radiusverringern an einer Stelle, die sich gegenüber der rückwärts hervorstehenden Kante des Lüfterabschlußringes weiter in Rückwärtsrichtung befindet, und eine sich längs vom rückseitigen Gehäusesegment zu einem in der Mitte befindlichen Motorlager erstreckende Motorlagerung (37) gehören, **dadurch gekennzeichnet, daß** unbewegliche Leitbleche (28) am Gehäuse so befestigt sind, daß sie dem Rückwärtsluftstrom ausgesetzt sind und diesen umlenken, wobei zwischen dem Lüfterabschlußring und dem Gehäuse ein Strömungsweg für die rückströmende Luft gebildet ist und mindestens ein Abschnitt der Leitbleche in diesen Strömungsweg hineinreicht.

4. Aus Lüfter und Gehäuse bestehende Baugruppe nach Anspruch 3, bei der der Strömungsweg eine Eintrittsöffnung zwischen dem Abschlußring (24) des Lüfters und dem Gehäuse (26) aufweist und mindestens ein Abschnitt der Leitbleche (28) radial außerhalb der Eintrittsöffnung (34) des Strömungsweges angeordnet und die in radialer Richtung am weitesten innen befindliche Fläche der Leitbleche abgerundet oder abgefast ist.
5. Aus Lüfter und Gehäuse bestehende Baugruppe nach Anspruch 3, bei der der Innendurchmesser (29C, 29D) des Gehäuses mit zunehmender Entfernung von der Stelle der Radiusverkleinerung am Gehäuse in Richtung Rückseite größer wird.
6. Aus Lüfter und Gehäuse bestehende Baugruppe nach Anspruch 5, bei der die Dicke des Gehäuses (29C) mit zunehmender Entfernung von der Stelle der Radiusverkleinerung am Gehäuse in Richtung Rückseite abnimmt.
7. Aus Lüfter und Gehäuse bestehende Baugruppe nach Anspruch 1 oder 3, bei der die Leitbleche

(28F) in einem Schnitt in einer Ebene senkrecht zur Lüfterachse nicht radial angeordnet sind.

8. Aus Lüfter und Gehäuse bestehende Baugruppe nach Anspruch 1 oder 3, bei der die Leitbleche (28G) in einem Schnitt in einer Ebene senkrecht zur Lüfterachse gekrümmt sind. 5
9. Aus Lüfter und Gehäuse bestehende Baugruppe nach Anspruch 1 oder 3, **dadurch gekennzeichnet, daß** die Leitbleche (79, 94, 220) zumindest teilweise entgegen der Strömungsrichtung vor dem Lüfterabschlußring (75, 96, 226) angeordnet sind. 10
10. Aus Lüfter und Gehäuse bestehende Baugruppe nach Anspruch 3, bei der sämtliche Leitbleche ein Teil einer aus einem Stück spritzgegossenen Kunststoffanordnung sind. 15
11. Aus Lüfter und Gehäuse bestehende Baugruppe nach Anspruch 1 oder 3, bei der die Leitbleche (220) eine abgefaste Stirnfläche (234) aufweisen. 20
12. Aus Lüfter und Gehäuse bestehende Baugruppe nach Anspruch 11, bei der die Stirnflächen (234) der Leitbleche (220) eine Fase von mindestens 20° aufweisen. 25
13. Aus Lüfter und Gehäuse bestehende Baugruppe nach Anspruch 12, bei der die Leitbleche zu einer Baugruppe zusammenfaßt sind, wobei die inneren Leitblechspitzen durch einen inneren Ring verbunden sind. 30
14. Aus Lüfter und Gehäuse bestehende Baugruppe nach Anspruch 11, bei der die Hochdruckseite (236) der Leitbleche in der Nähe der Stirnfläche der Leitbleche einen konkaven Abschnitt (242) aufweist. 35
15. Aus Lüfter und Gehäuse bestehende Baugruppe nach Anspruch 14, bei der der Radius des konkaven Abschnitts zwischen 0,1 S und 1,0 S liegt, wobei S der Abstand zwischen den benachbarten Leitblechen ist. 40
16. Aus Lüfter und Gehäuse bestehende Baugruppe nach Anspruch 15, bei der die Hochdruckseite (236) der Leitbleche in einer Ebene senkrecht zur Lüfterachse gekrümmt ist. 45
17. Aus Lüfter und Gehäuse bestehende Baugruppe nach Anspruch 16, bei der die Hochdruckseite (236) der Leitbleche im großen und ganzen in einer Ebene senkrecht zur Lüfterachse zylindrisch ist und einen Krümmungsradius zwischen 0,15 D und 0,3 D hat, wobei D der Lüfterdurchmesser ist. 50
18. Aus Lüfter und Gehäuse bestehende Baugruppe 55

nach Anspruch 11, bei der:

- a) die Stirnflächen (234) der Leitbleche (220) eine Fase von mindestens 20° aufweisen;
- b) die Hochdruckseite (236) der Leitbleche (220) angrenzend an die Stirnfläche der Leitbleche einen konkaven Abschnitt (242) einen Krümmungsradius von 0,1 S bis 1,0 S aufweist, wobei S der Abstand zwischen den benachbarten Leitblechen ist; und
- c) die Hochdruckseite (236) der Leitbleche im Schnitt in einer Ebene senkrecht zur Lüfterachse im großen und ganzen zylindrisch ist und einen Radius von 0,15 D bis 0,3 D aufweist, wobei D der Lüfterdurchmesser ist.

Revendications

1. Combinaison d'un ventilateur (20) et d'un boîtier, comprenant un ventilateur ayant un moyeu qui tourne sur un axe et des pales (22) qui s'étendent vers l'extérieur du moyeu vers une bande circulaire (24) qui raccorde les bouts des pales, la combinaison comprenant en outre un boîtier destiné au réglage de la circulation de l'air entrant dans le ventilateur, de l'air quittant le ventilateur ou des deux, une partie (26) du boîtier étant disposée vers l'extérieur de la bande du ventilateur afin qu'il existe des espaces de passage entre la bande et le boîtier si bien qu'un courant d'air qui recircule se déplace dans un trajet formé entre la bande et le boîtier, **caractérisée en ce que** des ailettes fixes (28) de réglage de circulation sont raccordées au boîtier en position telle qu'elles rencontrent et redirigent le courant d'air qui recircule, le boîtier et les ailettes étant formés par une seule unité de matière plastique moulée par injection. 45
2. Combinaison d'un ventilateur et d'un boîtier selon la revendication 1, combinée à un échangeur de chaleur, dans laquelle le boîtier est disposé en amont d'un échangeur de chaleur, si bien que le ventilateur pousse l'air à travers l'échangeur de chaleur. 50
3. Combinaison d'un ventilateur (20) et d'un boîtier comprenant un ventilateur ayant un moyeu qui tourne sur un axe et des pales qui s'étendent à l'extérieur du moyeu vers une bande circulaire qui raccorde les bouts des pales, la combinaison comprenant aussi un boîtier destiné au réglage de la circulation de l'air entrant dans le ventilateur, de l'air quittant le ventilateur ou des deux, une partie du boîtier étant disposée à l'extérieur de la bande du ventilateur afin qu'il existe des espaces de passage entre la bande et le boîtier et que le courant d'air qui recircule se déplace suivant un trajet compris entre la 55

- bande et le boîtier, le boîtier comprenant en outre un segment de boîtier (27, 29) tourné vers l'arrière et ayant une réduction de rayon à un emplacement qui se trouve en arrière du bord de fuite de la bande de ventilateur, et des supports allongés (37) de moteur qui s'étendent depuis le segment de boîtier tourné vers l'arrière vers une monture de moteur placée au centre, **caractérisée en ce que** des ailettes fixes (28) de réglage de circulation sont raccordées au boîtier en position telle qu'elles rencontrent et redirigent le courant d'air qui recircule, un trajet de recirculation du courant d'air étant formé entre la bande de ventilateur et le boîtier, et une partie au moins des ailettes étant disposée dans ce trajet.
4. Combinaison d'un ventilateur et d'un boîtier selon la revendication 3, dans laquelle le trajet a une entrée formée entre la bande (24) de ventilateur et le boîtier (26), une partie au moins des ailettes (28) est disposée radialement à l'extérieur de l'entrée (34) du trajet et la face radialement la plus interne des ailettes est arrondie ou chanfreinée.
 5. Combinaison d'un ventilateur et d'un boîtier selon la revendication 3, dans laquelle, lorsque le boîtier s'étend vers l'arrière depuis l'emplacement de réduction de rayon, le diamètre interne du boîtier (29C, 29D) augmente.
 6. Ensemble d'un ventilateur et d'un boîtier selon la revendication 5, dans lequel lorsque le boîtier s'étend vers l'arrière depuis l'emplacement de réduction de rayon, l'épaisseur du boîtier (29C) diminue.
 7. Combinaison d'un ventilateur et d'un boîtier selon la revendication 1 ou 3, dans laquelle les ailettes (28F) considérées en coupe dans un plan perpendiculaire à l'axe du ventilateur ne sont pas radiales.
 8. Combinaison d'un ventilateur et d'un boîtier selon la revendication 1 ou 3, dans laquelle les ailettes (28G) sont courbées, lorsqu'elles sont considérées en coupe par un plan perpendiculaire à l'axe du ventilateur.
 9. Combinaison d'un ventilateur et d'un boîtier selon la revendication 1 ou 3, **caractérisée en ce que** les ailettes (79, 94, 220) sont positionnées au moins en partie en amont de la bande de ventilateur (75, 96, 226).
 10. Combinaison d'un ventilateur et d'un boîtier selon la revendication 3, dans laquelle les ailettes font toutes partie d'un seul ensemble de matière plastique moulée par injection.
 11. Combinaison d'un ventilateur et d'un boîtier selon la revendication 1 ou 3, dans laquelle les ailettes (220) ont une face chanfreinée d'extrémité (234).
 12. Combinaison d'un ventilateur et d'un boîtier selon la revendication 11, dans laquelle les faces d'extrémité (234) des ailettes (220) sont chanfreinées avec un angle d'au moins 20°.
 13. Combinaison d'un ventilateur et d'un boîtier selon la revendication 12, dans laquelle les ailettes sont disposées suivant un arrangement dont les bouts tournés vers l'intérieur sont raccordés par une bague interne.
 14. Combinaison d'un ventilateur et d'un boîtier selon la revendication 11, dans laquelle le côté à haute pression (236) des ailettes a une partie concave (242) adjacente à la face d'extrémité des ailettes.
 15. Combinaison d'un ventilateur et d'un boîtier selon la revendication 14, dans laquelle le rayon de la partie concave est compris entre 0,1 S et 1,0 S, S étant l'espacement des ailettes adjacentes.
 16. Combinaison d'un ventilateur et d'un boîtier selon la revendication 15, dans laquelle le côté à haute pression (236) des ailettes est courbé dans un plan perpendiculaire à l'axe du ventilateur.
 17. Combinaison d'un ventilateur et d'un boîtier selon la revendication 16, dans laquelle le côté à haute pression (236) des ailettes est pratiquement cylindrique en coupe dans un plan perpendiculaire à l'axe du ventilateur, avec un rayon de courbure compris entre 0,15 D et 0,3 D, D étant le diamètre du ventilateur.
 18. Combinaison d'un ventilateur et d'un boîtier selon la revendication 11, dans laquelle :
 - a) les faces d'extrémité (234) des ailettes (220) sont chanfreinées suivant un angle au moins égal à 20°,
 - b) le côté à haute pression (236) des ailettes (220) a une partie concave (242) adjacente à la face d'extrémité des ailettes, ayant un rayon de courbure compris entre 0,1 S et 1,0 S, S étant l'espacement des ailettes adjacentes, et
 - c) le côté à haute pression (236) des ailettes est pratiquement cylindrique en coupe dans un plan perpendiculaire à l'axe du ventilateur, avec un rayon de courbure compris entre 0,15 D et 0,3 D, D étant le diamètre du ventilateur.

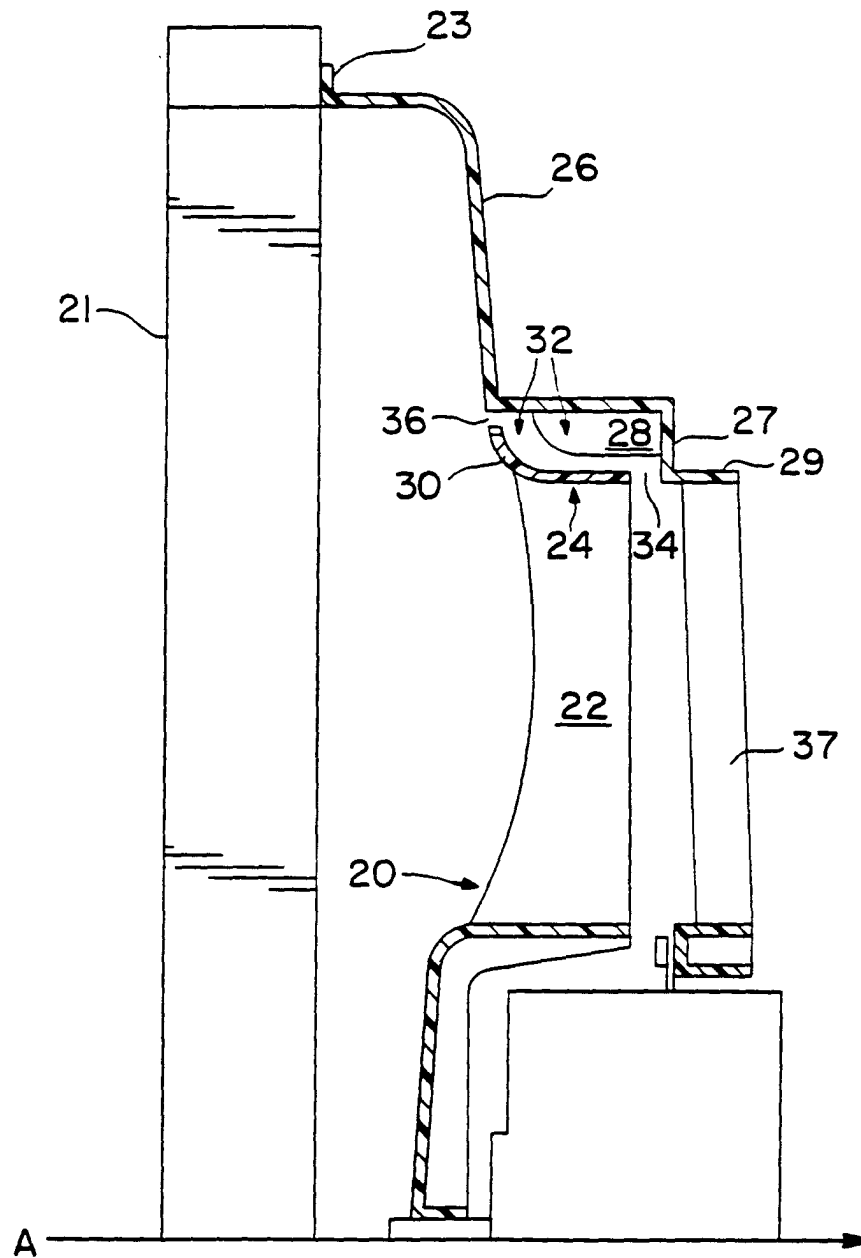


FIG. 1A

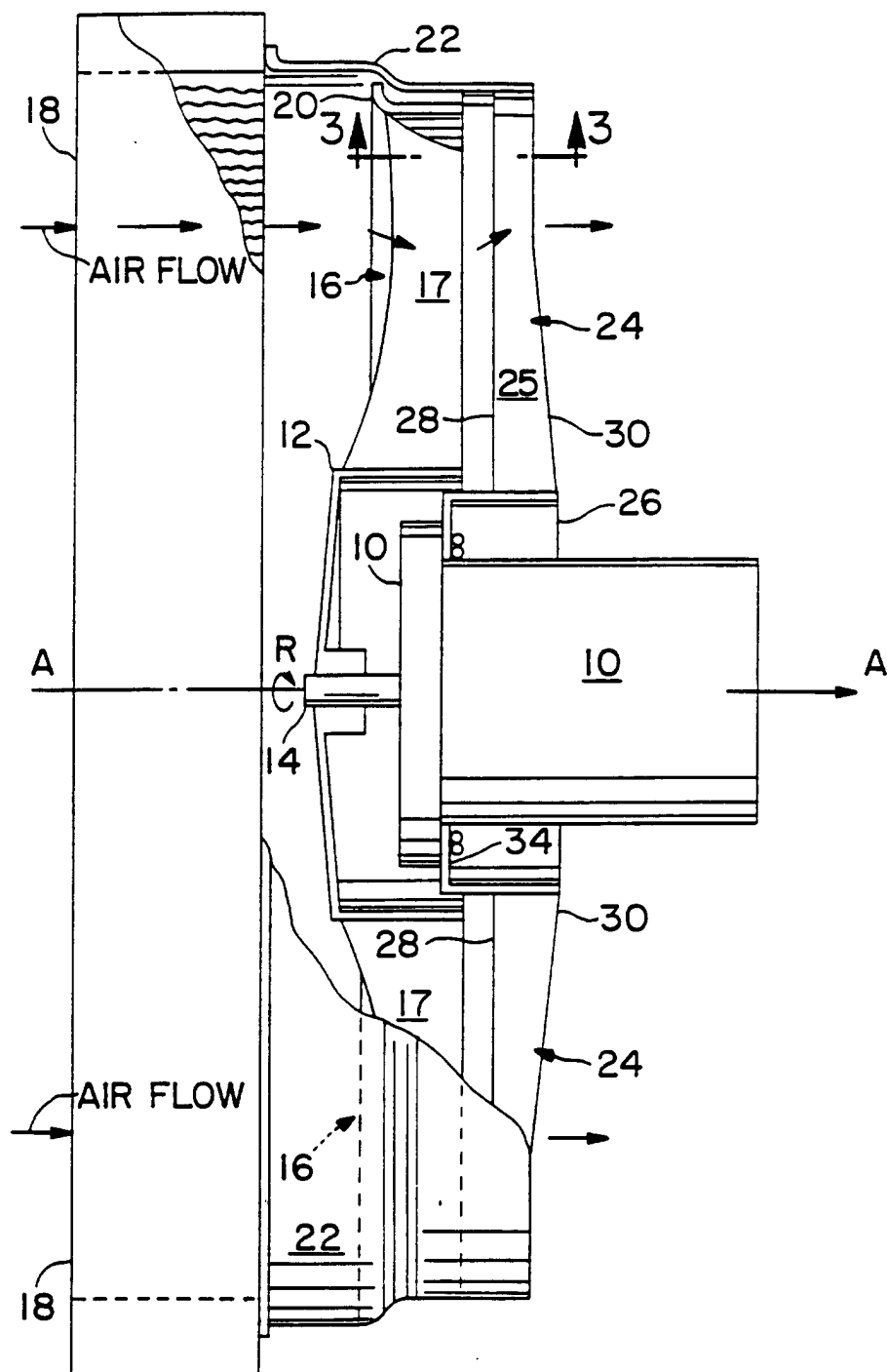


FIG. 1B
(PRIOR ART)

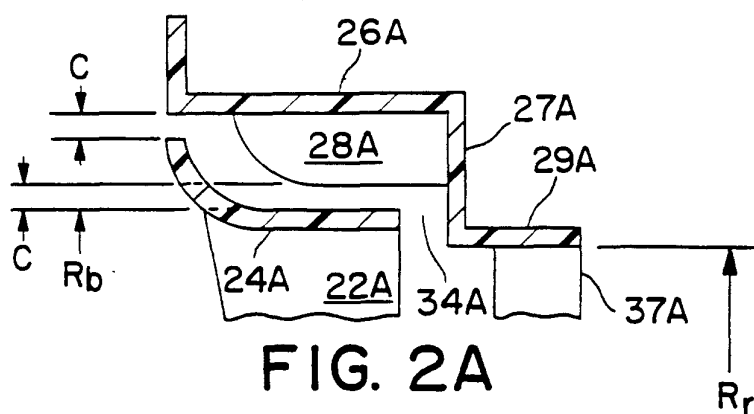


FIG. 2A

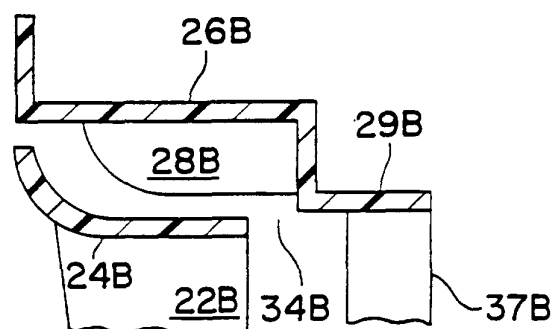


FIG. 2B

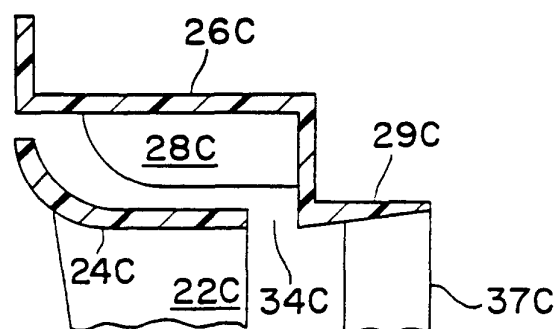


FIG. 2C

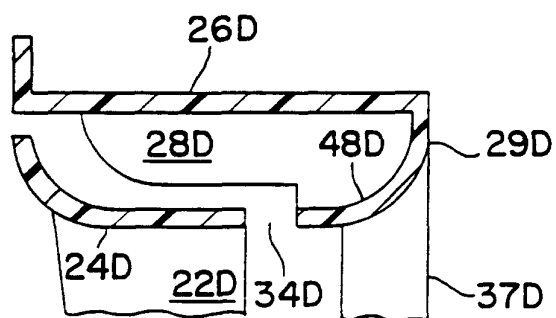


FIG. 2D

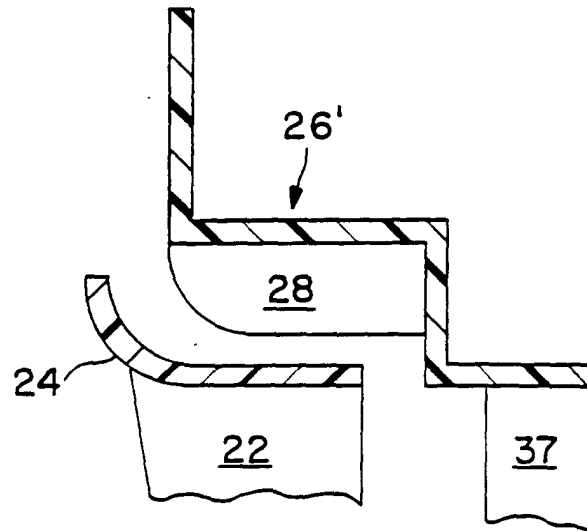


FIG. 3A

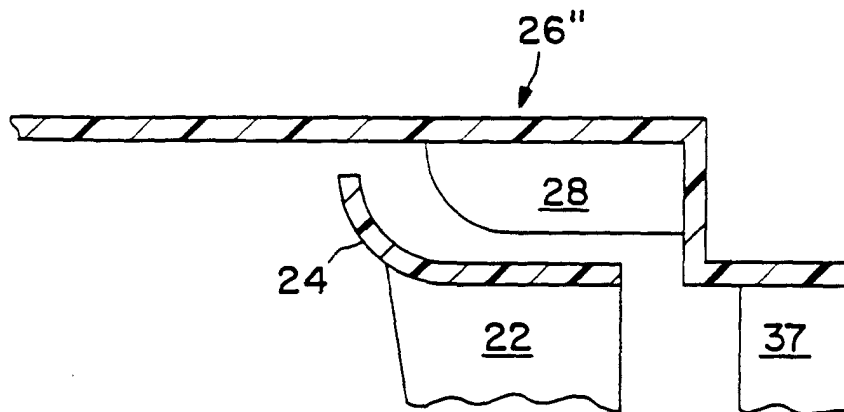


FIG. 3B

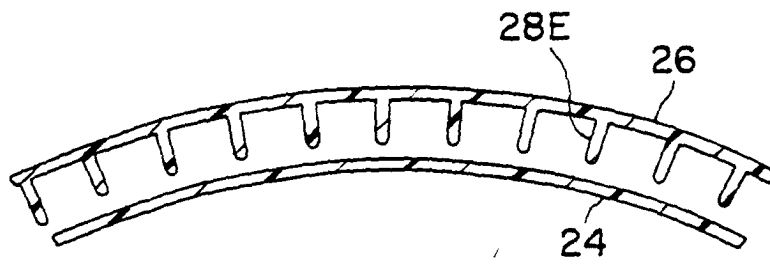


FIG. 4A

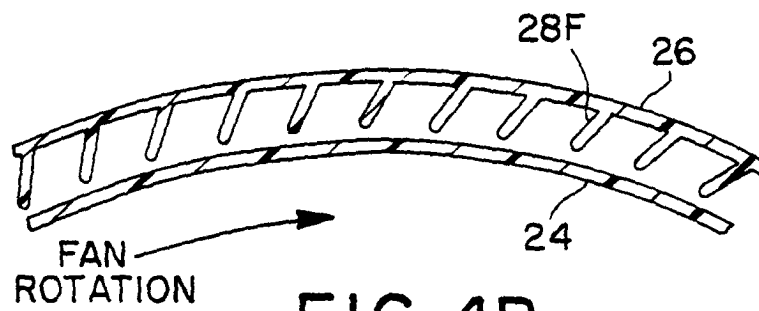


FIG. 4B

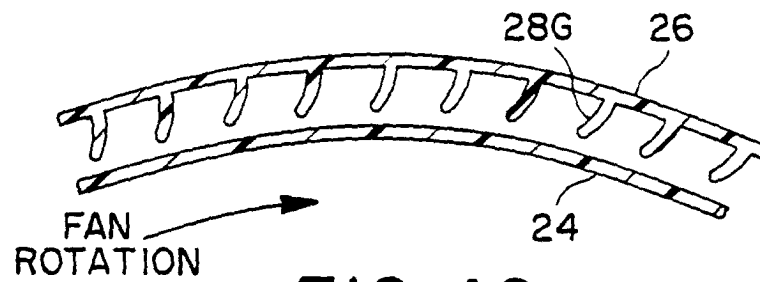


FIG. 4C

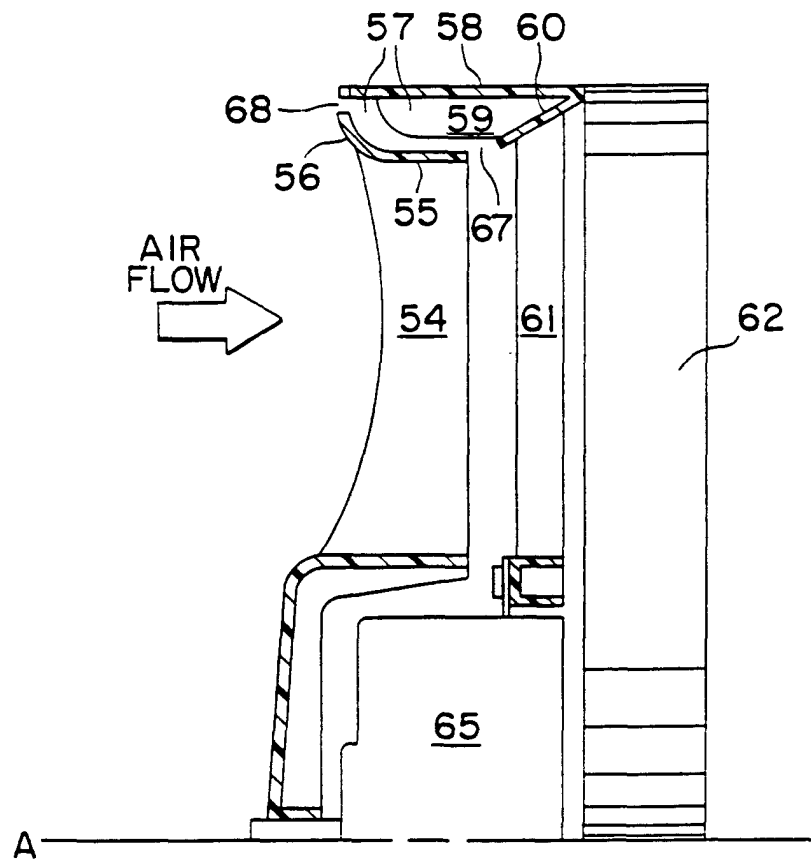


FIG. 5A

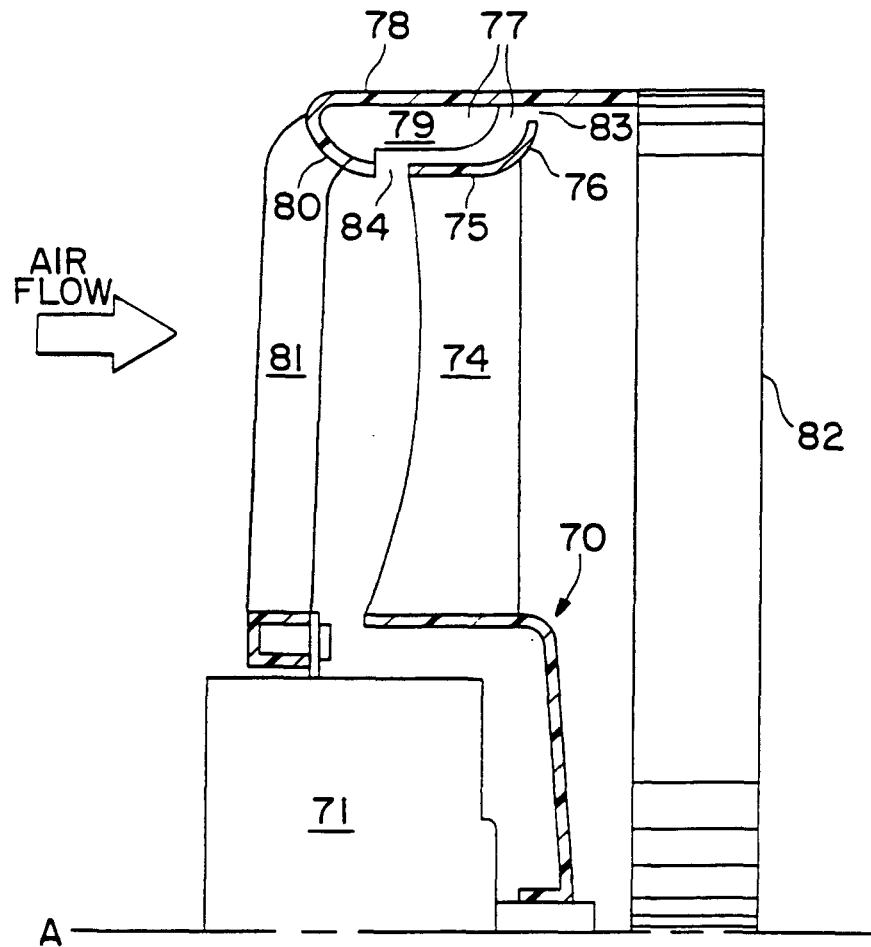


FIG. 5B

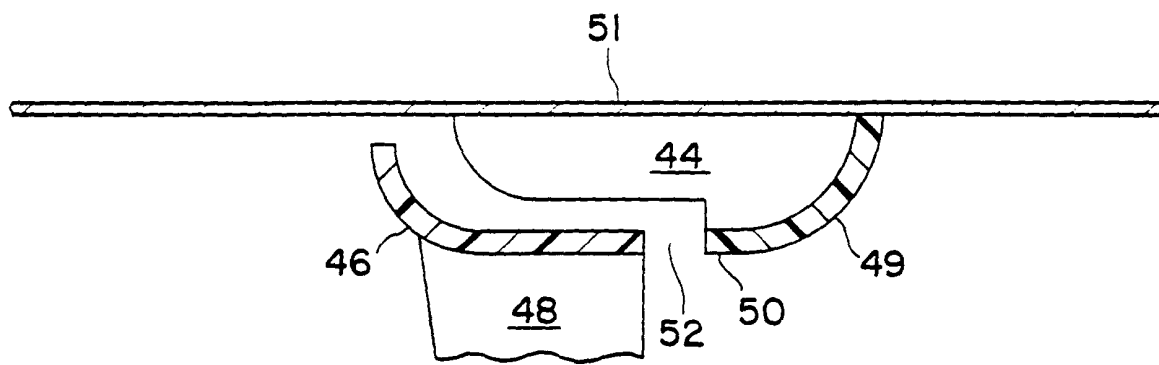


FIG. 6

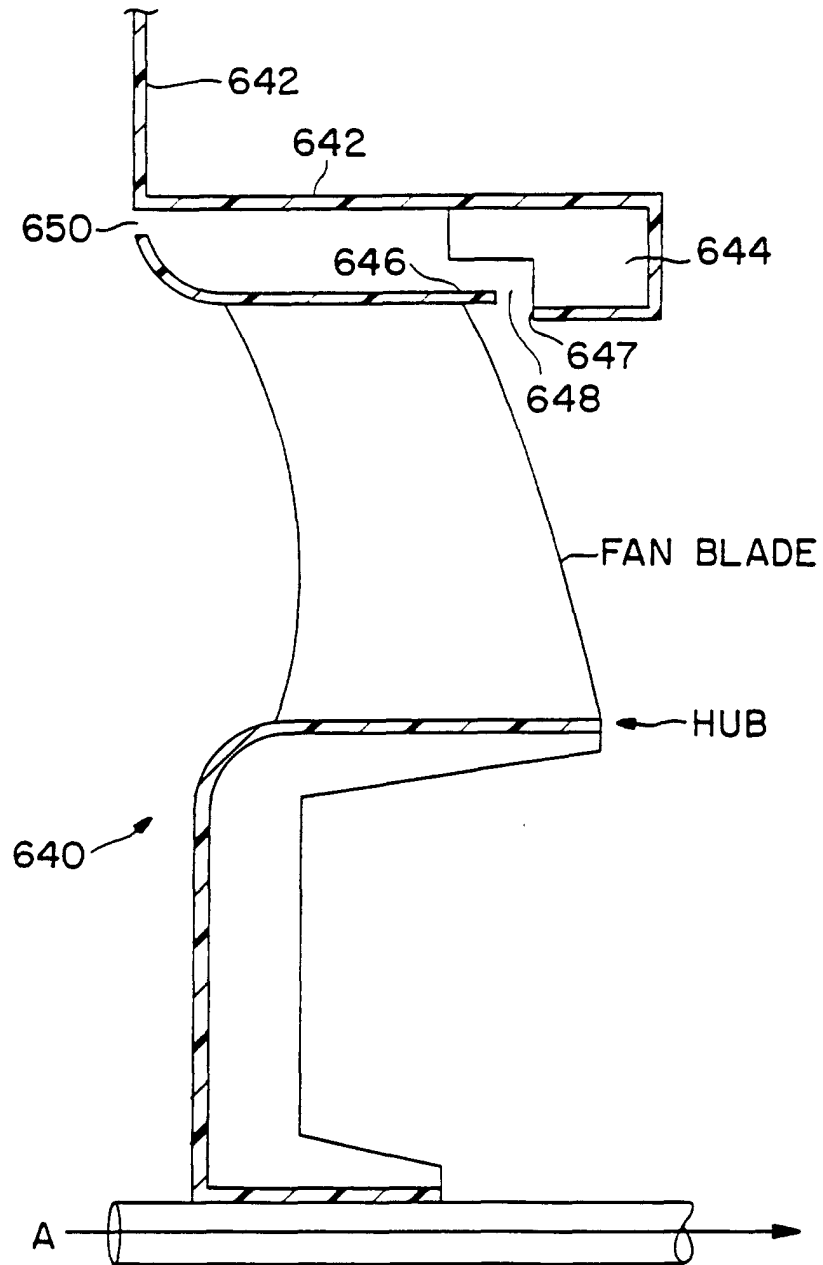


FIG. 7

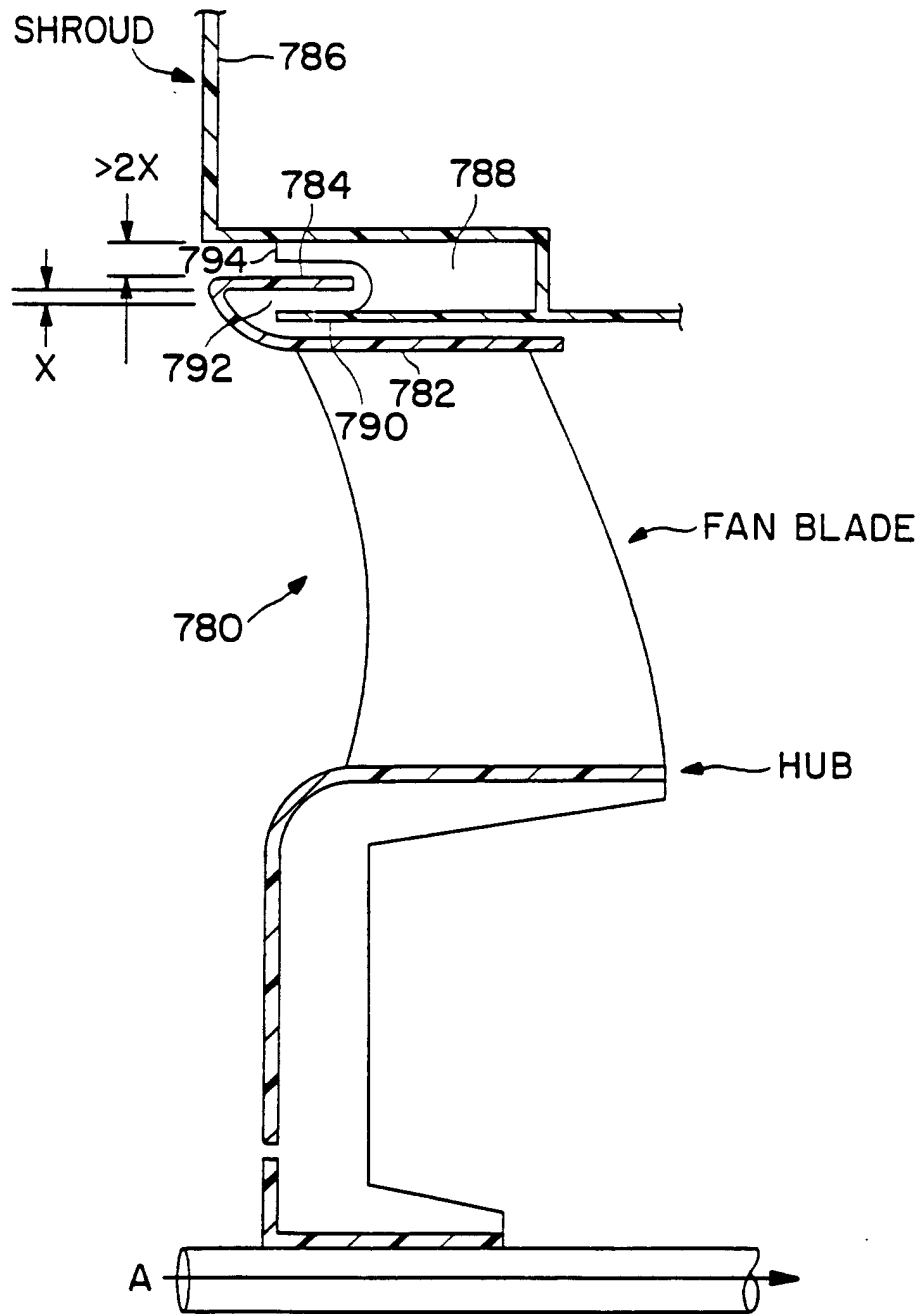


FIG. 8

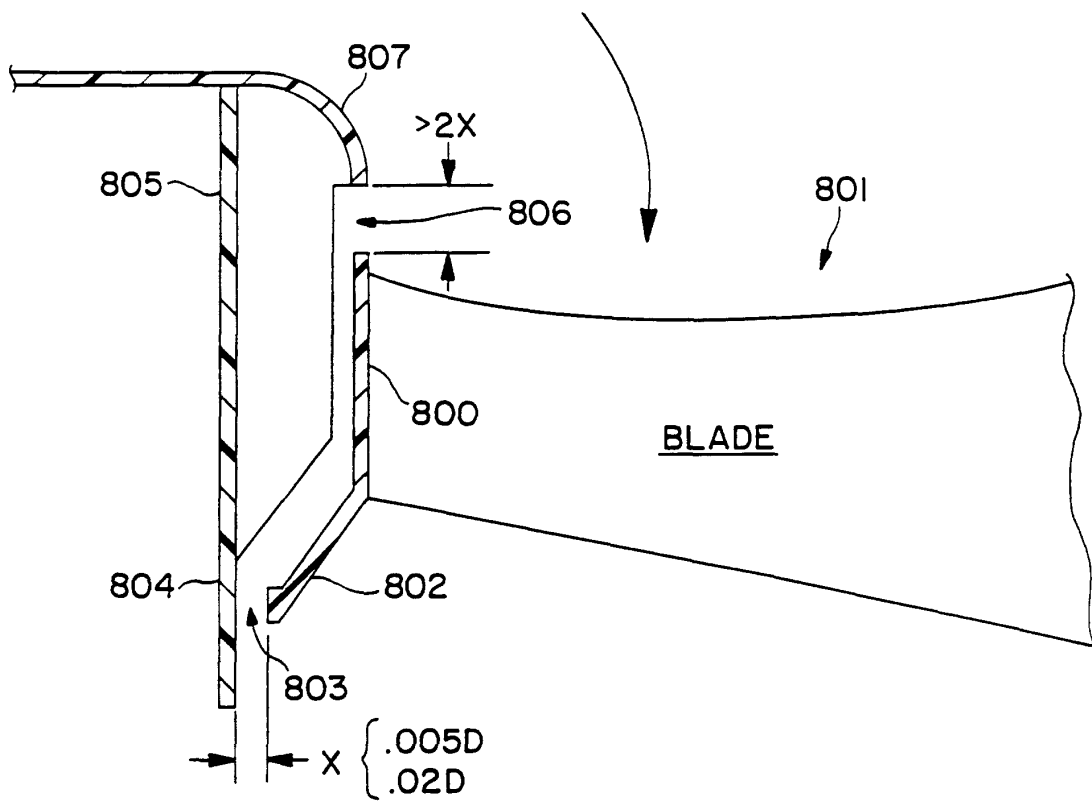


FIG. 9

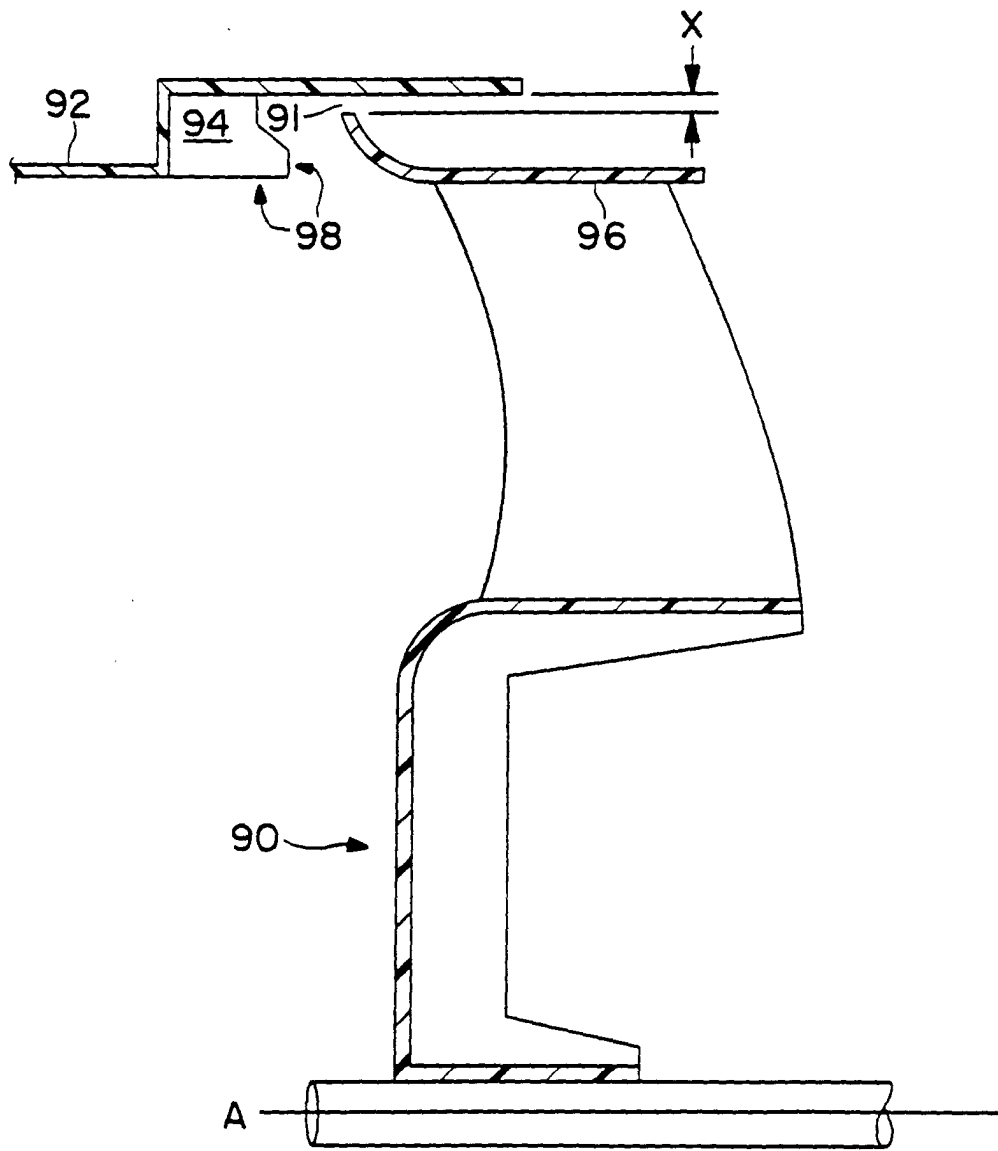


FIG. 10

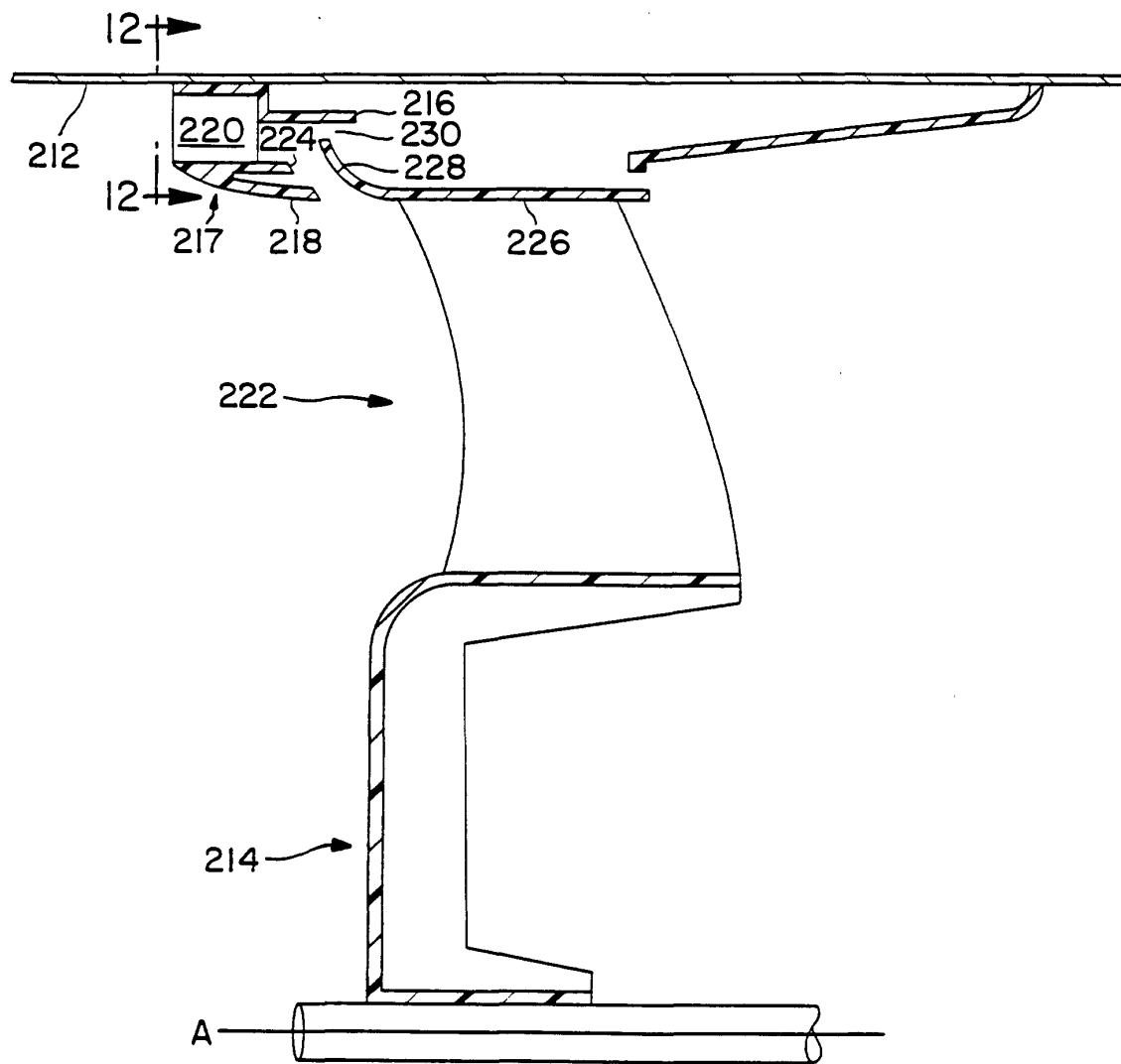


FIG. 11

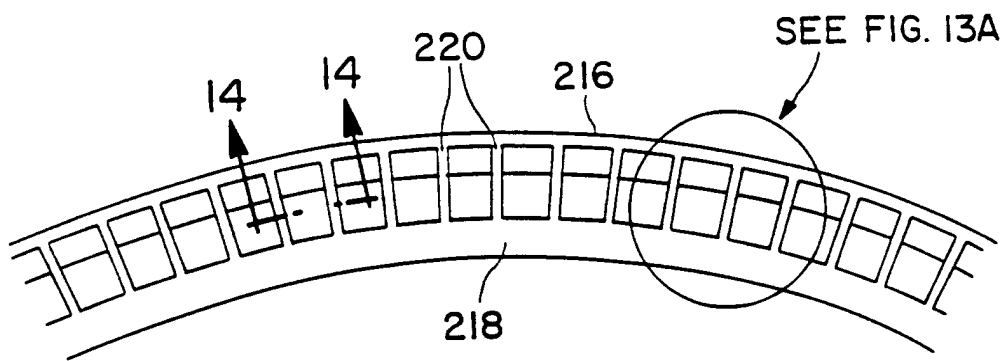


FIG. 12

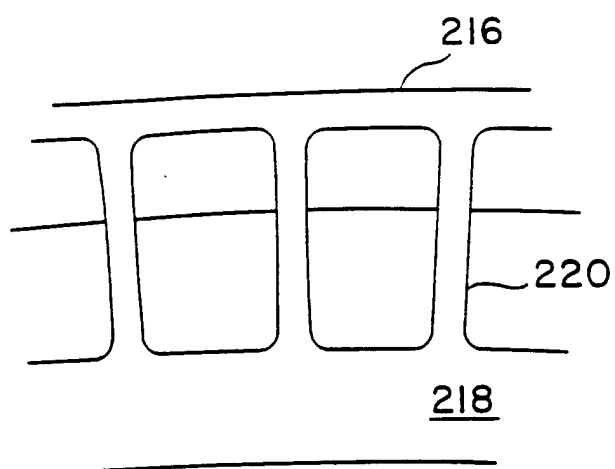


FIG. 13A

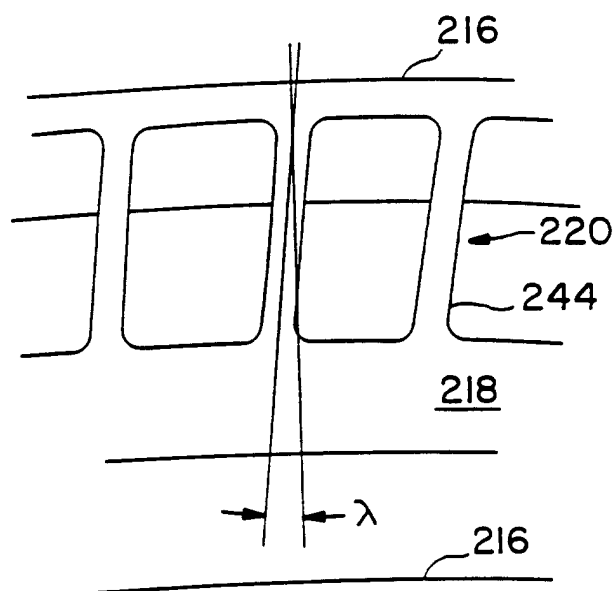


FIG. 13B

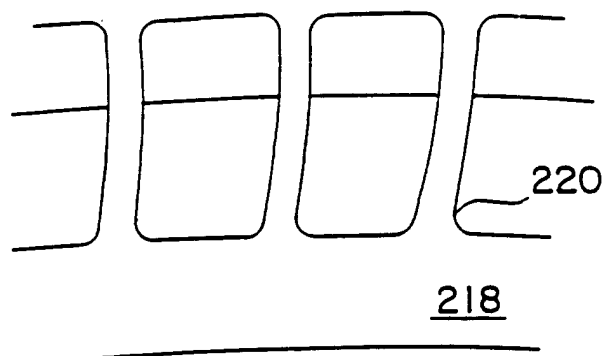


FIG. 13C

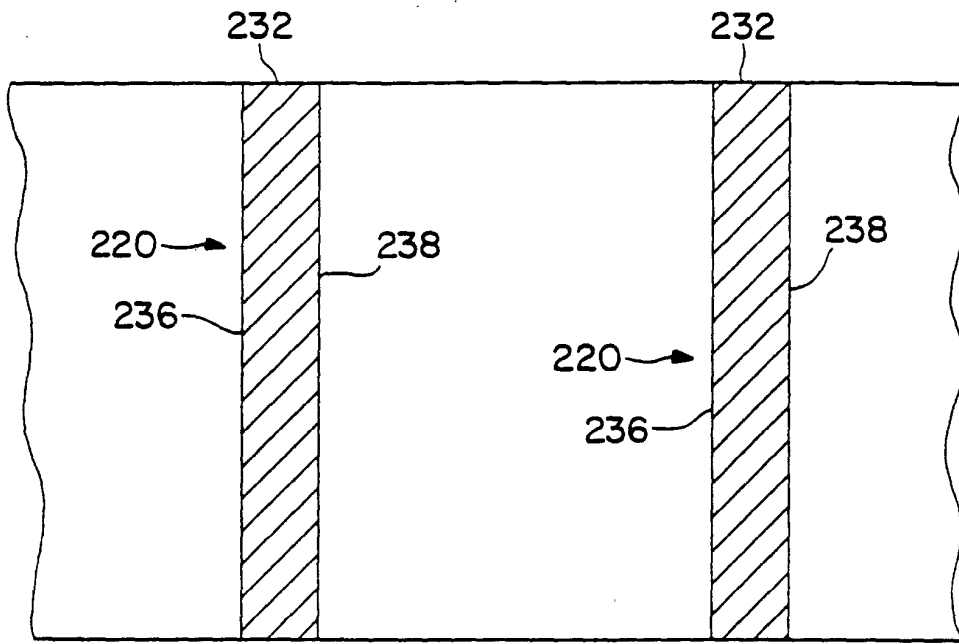
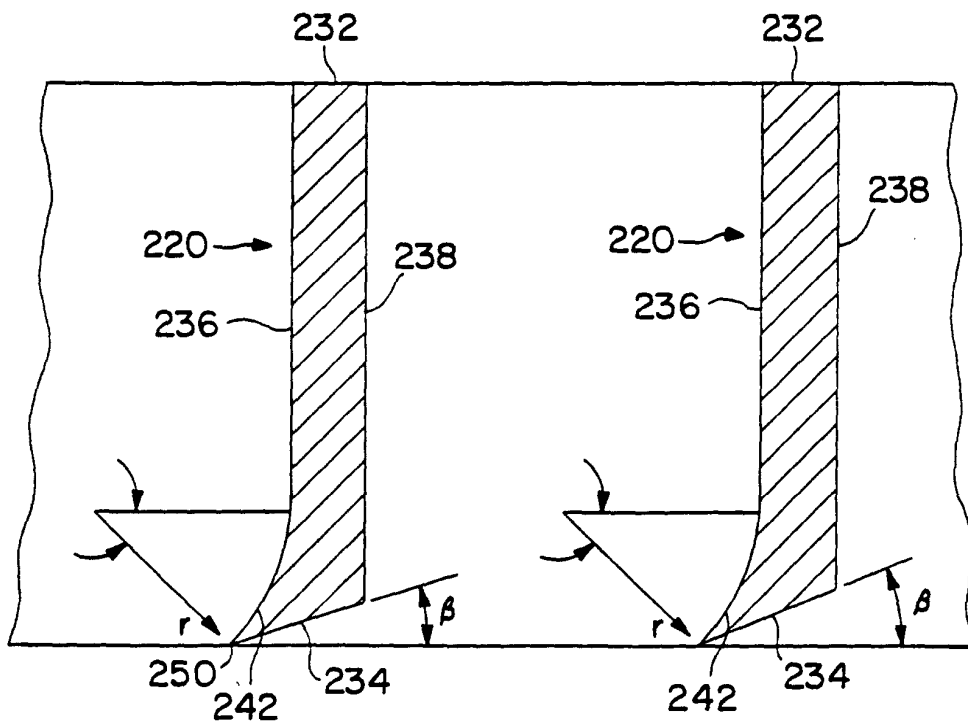


FIG. 14A



IMPINGING
RECIRCULATION
FLOW

FIG. 14B

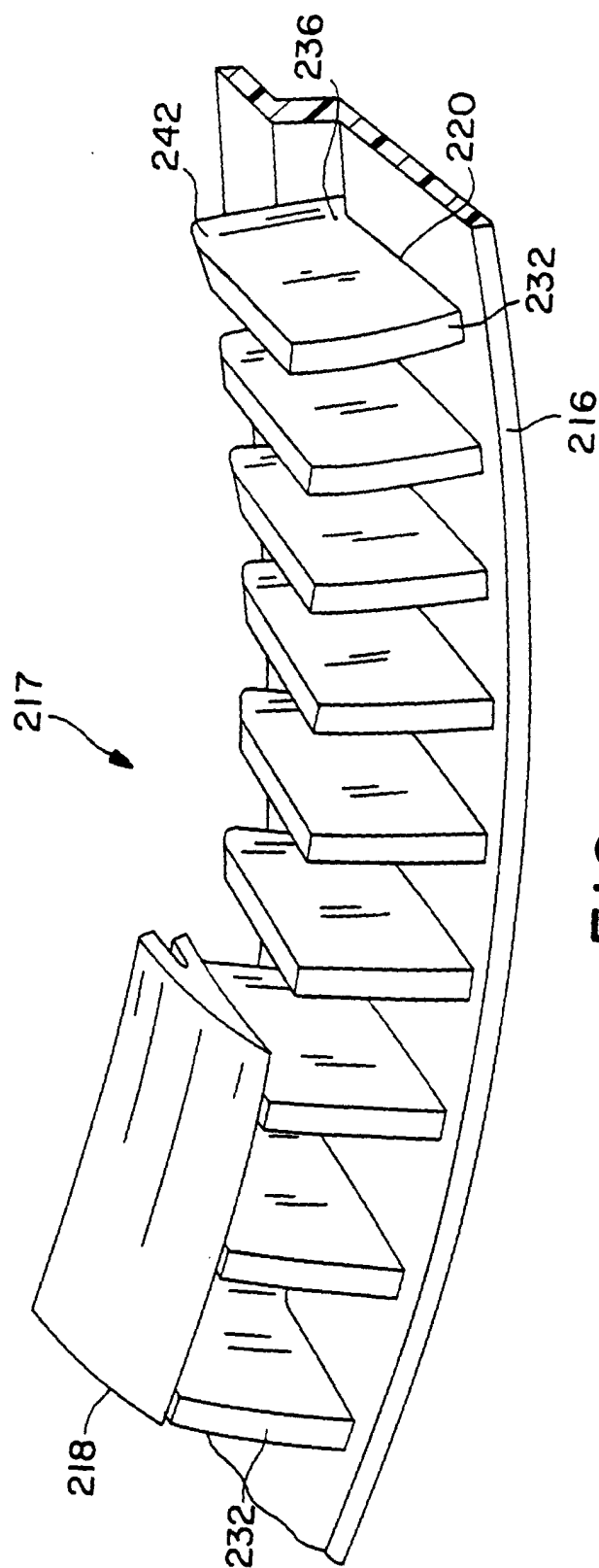


FIG. 15