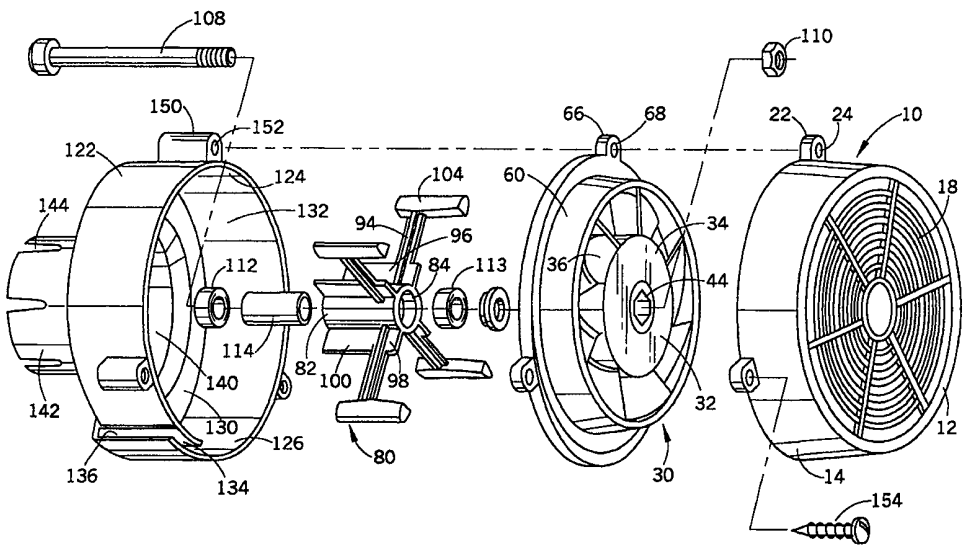




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(54) Title: AIR PRE-CLEANER



(57) Abstract

An air pre-cleaner for centrifugally ejecting heavier than air particulates from an air stream for use in an apparatus having an air intake includes a hood having an opening through which air enters the pre-cleaner. A vane assembly includes a centrally positioned dome, a collar encircling the dome, and a plurality of inlet vanes each being connected at an inner end to the dome and at an outer end to the collar. Each inlet vane is angled in relation to the horizontal plane. The vane assembly further includes a horizontal wall extending radially outward from the collar. An impeller assembly is rotatably mounted to the vane assembly. Also provided is a base on which the vane assembly is supported via the horizontal wall. The hood, the vane assembly and the base are secured to each other. Clean air exits the pre-cleaner through a central opening in the base and dirty air exits the pre-cleaner through peripheral openings in the base.

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## AIR PRE-CLEANER

BACKGROUND OF THE INVENTION

This invention pertains to air pre-cleaners. More particularly, this invention relates to an air pre-cleaner employing an inlet vane assembly and a rotating impeller assembly.

Air pre-cleaners are used for removing particulates from the air prior to introducing the air through an air cleaner or filter, which is connected to a carburetor or air intake structure, of an internal combustion engine. Pre-cleaners are generally located on the open inlet side of the air intake pipes or stacks of an internal combustion engine. The function of the pre-cleaner is to remove as many contaminants from the air as possible before the air flows into an air filter medium upstream from the internal combustion engine.

Air pre-cleaners operate on the principle of centrifugal separation. Outside air, with its entrained contaminants, enters the pre-cleaner from the vacuum created by the engine. The air and contaminants traverse a set of fixed, static vanes which cause the air to circulate at a great speed. Centrifugal force throws the contaminants and moisture towards the outer wall of the pre-cleaner. The contaminants follow the wall until they reach an opening where they are discharged back into the atmosphere or collected. Clean, dry air is then allowed to enter the filter and subsequently, the internal combustion engine.

As pre-cleaners work on centrifugal separation, greater air flow velocity will result in better separation between the air and the contaminants. The best contaminate separation happens when the engine is running at a high speed (in r.p.m.) thus causing a high velocity for the air which is flowing into the pre-cleaner. As the velocity of air flow decreases, the centrifugal force on the contaminants also decreases reducing the separation efficiency of the pre-cleaner.

Undesirable contaminants in the atmosphere include particulate matter such as dirt, dust, sand, snow and the like. While most engines include air filters which are meant to remove such contaminants from the air that feeds the engine, engine pre-cleaners are also beneficial in order to extend the life of the air filter and extend the engine's life while at the same time improving fuel economy.

Several different designs of air pre-cleaners are commercially available in the marketplace. In one design, an air pre-cleaner uses a rotatable impeller or spinner to separate particles from air, discharge the dirty air and particle mixture circumferentially from a housing and direct the clean air to the air intake structure of an engine. The clean air moves centrally through a stack to the engine in response to a vacuum pressure on the air moving towards the engine. This air pre-cleaner has an air inlet vane assembly located in the bottom of the housing. The air flows upwardly in a circular path into a centrifugal separation chamber and then turns downwardly into the centrally located clean air exit opening. This impeller is used to pump air and articulate matter out through side discharge openings. This type of air pre-cleaner, however, does not urge the air flowing over the vanes of the pre-cleaner toward the outer walls of the separation chamber in order to enhance particle separation from the air.

Known air pre-cleaners have also included a design in which air flows into the top of the air pre-cleaner and flows axially downwardly through the pre-cleaner and into the intake stack of the engine. Although such pre-cleaners may perform adequately with respect to particulate material, this is accomplished sometimes at the expense of reduced air flow. In other words, the pre-cleaner itself may become an air restriction. The known pre-cleaners of this type do not use static vanes which cause the air to circulate at as great a velocity

as such vanes could. Also, some pre-cleaners are only useable when positioned in one orientation, i.e., positioned on a vertical axis or positioned on a horizontal axis. Moreover, the known pre-cleaners do not have an optimized impeller construction. Also, they  
5 do not have stator vanes in the clean air exhaust passage of the pre-cleaner.

Accordingly, it has been considered desirable to develop a new and improved air-pre-cleaner which would overcome the foregoing difficulties and others while  
10 providing better and more advantageous overall results.

#### BRIEF SUMMARY OF THE INVENTION

An air pre-cleaner for centrifugally ejecting heavier than air particulates from an air stream for use  
15 in an apparatus having an air intake is provided.

More particularly, the air pre-cleaner comprises a hood having an opening in which air enters the pre-cleaner and a vane assembly including a centrally  
20 positioned dome, a collar encircling the dome and a plurality of vanes, each vane being connected at an inner end to the dome and at an outer end to the collar. Each vane is angled in relation to a horizontal plane. The vanes are inclined slightly away from the direction  
25 of air movement in the plane perpendicular to forward motion of the entering air. An impeller assembly is rotatably mounted to the vane assembly. Also provided is a base to which the vane assembly and the hood are secured. The base includes a clean air exit port. In  
30 one embodiment a rounded protrusion is provided on a first face of the base and encircling the clean air exit port to promote laminar air flow and to prevent direct access of liquid to the exit port.

One advantage of the present invention is the  
35 provision of a new and improved air pre-cleaner.

Another advantage of the present invention is the provision of an air pre-cleaner having a vane assembly

which includes a set of static vanes having a fully concave surface along which inlet air flows causing the air to rotate at a great centrifugal speed in relation to forward motion. In one embodiment, the vane pitch is twisted to keep the chord width relatively constant over the full vane length. This causes an essentially constant velocity over the entire vane surface. In another embodiment, the vane chord is slightly wider at the inner diameter than at the outer diameter.

Still another advantage of the present invention is the provision of an air pre-cleaner which includes a cover, a vane assembly, a rotating impeller assembly and a base that can be secured to each other, or disconnected from each other, in a simple manner. This enables ease of manufacture, assembly and repair of the air pre-cleaner.

Yet another advantage of the present invention is the provision of an air pre-cleaner which includes a pair of different covers that can be selectively secured to a vane assembly, a rotating impeller assembly and a base. Having two different covers enables the air pre-cleaner to be employed in a substantially vertical orientation using one of the covers and in a substantially horizontal orientation when using the other cover.

An additional advantage of the present invention is the provision of an air pre-cleaner having a base with a rounded wall encircling the clean air exit opening of the base. This construction allows for a substantially laminar flow of air from a dirt separation chamber into the clean air exit opening thereby increasing the efficiency of the air pre-cleaner.

A further advantage of the present invention is the provision of an air pre-cleaner having a vane assembly including a centrally positioned dome, a collar encircling the dome and a plurality of vanes which are each connected at a radially inner edge to the dome and

at a radially outer edge to the collar. There is an annular chamber defined in the dome. The dome annular chamber is open to a chamber defined between the vane assembly and a base of the air pre-cleaner to promote air flow.

5           Still another advantage of the present invention is the provision of an air pre-cleaner having a vane assembly in which the vanes are inclined slightly away from the direction of air movement in the plane perpendicular to forward motion of the entering air.  
10 For best particle separation, it has been found that air must be forced toward the outer walls of the separation chamber.

          Yet another advantage of the present invention is the provision of an air pre-cleaner having an impeller  
15 with a shape that will not unload with increasing static pressure. In one embodiment, the outer blade of the impeller has a compound shape. The shape is such that neither of the two impeller blade surfaces will unload or cavitate at increasing static pressures.

20           Still yet another advantage of the present invention is the provision of an air pre-cleaner having an impeller which makes less noise when spinning than do conventional impeller designs.

          Yet still another advantage of the present  
25 invention is the provision of an air pre-cleaner which includes an impeller with ejection blades that cooperate with stator vanes in the housing of the air pre-cleaner to provide much higher ejection pressures than can be obtained with the known designs. The design provides  
30 more air flow for a given size pre-cleaner than is true of the known air pre-cleaner designs.

          An additional advantage of the present invention is the provision of stator vanes positioned around the  
35 perimeter of an outlet tube of an air pre-cleaner. The stator vanes cooperate with inner blades of an impeller assembly to help keep the rotational energy of the air

in contact with the impeller blades.

A further advantage of the present invention is the provision of an air pre-cleaner which is made out of suitable conventional thermoplastic materials in a simple manner. To this end, the inlet cover is so shaped and sized that it can be readily injection molded using only two mold parts for reduced cost.

A still further advantage of the present invention is a provision of an air pre-cleaner having a hood with a grill surface which is resistant to clogging by debris and which resists the ingress of rain.

Still other benefits and advantages of the invention will become apparent to those skilled in the art upon a reading and understanding of the following detailed specification.

15

#### BRIEF DESCRIPTION OF THE DRAWINGS

The invention may take physical form in certain parts and arrangement of parts preferred embodiments of which will be described in detail in this specification and illustrated in the accompanying drawings which form a part hereof and wherein:

FIGURE 1 is an exploded perspective view of an air pre-cleaner according to a first preferred embodiment of the present invention;

FIGURE 2 is a side elevational view of the air pre-cleaner of FIGURE 1 in an assembled condition;

FIGURE 3 is a cross sectional view of the air pre-cleaner of FIGURE 2 along line 3-3;

FIGURE 4 is a cross-sectional view of the air pre-cleaner of FIGURE 2 along line 4-4;

FIGURE 5 is a perspective view of a vane assembly of the air pre-cleaner of FIGURE 3;

FIGURE 6 is a perspective view of a cover for an air pre-cleaner according to a second preferred embodiment of the present invention; and,

FIGURE 7 is a perspective view in cross-section of an air pre-cleaner employing the cover of FIGURE 5.

FIGURES 8A and 8B together are an exploded perspective view of an air pre-cleaner according a third preferred embodiment of the present invention;

FIGURE 9 is a perspective view of the air pre-cleaner of FIGURES 8A and 8B in an assembled condition;

5 FIGURE 10 is a reduced cross-sectional view of the air pre-cleaner of FIGURE 9 along the line 10-10;

FIGURE 11 is a cross-sectional view of a base of the air pre-cleaner of FIGURE 14 along line 11-11;

10 FIGURE 12 is an enlarged perspective view of a vane assembly of the air pre-cleaner of FIGURE 9;

FIGURE 13 is a top plan view of an impeller of the air pre-cleaner of FIGURE 9;

FIGURE 14 is a perspective view of the base portion of the air pre-cleaner of FIGURE 9;

15 FIGURE 15 is a perspective view of a cover for an air pre-cleaner according to a fourth preferred embodiment of the present invention; and

FIGURE 16 is a cross-sectional view of the air pre-cleaner according to the present invention employing the cover of FIGURE 15.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, the showings are for purposes of illustrating preferred embodiments of the invention only and not for purposes of limiting same, 25 FIGURE 1 shows an exploded perspective view of an air pre-cleaner according to a first preferred embodiment of the present invention.

The air pre-cleaner comprises a hood 10 having an end wall 12 and a skirt 14 depending therefrom. The end wall and the skirt together form a first chamber 16 (FIG. 3). A plurality of spaced, aligned, openings 18 on the end wall 12 communicate with the first chamber 16. Protruding radially outwardly from the skirt are a plurality of tabs 22 each having an aperture 24 extending therethrough. Positioned beneath the hood 10 is a vane assembly 30. The vane assembly comprises a 35

centrally located dome 32 including a top wall 34 and a peripheral skirt 36. With reference now also to FIGURE 3, a stem 38 extends axially from the top wall 34 parallel to the skirt 36. The skirt 36 and the stem 38 define between them an annular chamber 40. An opening 42 extends through the stem 38. The opening comprises an enlarged diameter upper hexagonally shaped socket section 44, as is best illustrated in FIGURE 1, and a reduced diameter circular section 46.

With reference now to FIGURE 4, a plurality of vanes 50 each have a radially inner end 52 secured to the skirt 36 of the dome 32 and a radially outer end 54 secured to a collar 60 encircling the dome. Extending radially outwardly of the collar 60, at a bottom edge thereof, is a horizontal wall 62. A flange 64 extends substantially perpendicular from the horizontal wall 60. As shown in FIGURE 1, extending radially outwardly from the horizontal wall 62 are a plurality of tabs 66 each having an aperture 68 extending therethrough. With reference now also to FIGURE 2, the collar also includes a protruding radial section 70 located between a pair of the tabs 66.

Referring again to FIGURE 1, positioned adjacent the vane assembly 30 is a rotating impeller assembly 80. The rotating impeller assembly comprises a hub 82 having a bore 84 extending axially therethrough. As shown in FIGURE 4, the bore includes a first section 86 of a first diameter, a second section 88 of a second, and smaller, diameter and a third section 90 of a third diameter. Preferably, the first and third sections 86 and 90 of the bore 84 have the same diameter. As best illustrated in FIGURE 1, preferably four arms 94 radiate away from the hub 82. Secured to the hub 82 are a plurality of first blades 96 each of which is aligned with a respective one of the arms 94. The first blades are thus located at the proximal ends of the several arms. Each first blade 96 includes a first section 98

which is positioned above its respective arm 94 and a second section 100 which is positioned below its respective arm. Located at the distal ends of each of the arms 94 is a respective second blade 104.

Also provided is a fastening means for securing the rotating impeller assembly 80 to the vane assembly 30. The fastening means comprises a bolt 108 and a locknut 110. The locknut is hexagonally shaped and is positioned in the hexagonally-shaped socket section 44. The bolt extends upwardly through the hub 82 from the bottom end of the rotating impeller assembly 80. A pair of bearings 112, 113 are positioned in the respective first and third sections 86 and 90 of the hub bore 84. The bearings 112, 113 enable the rotating impeller assembly to smoothly rotate in relation to the vane assembly 30. A tubular bearing spacer 114 is inserted in the bore 84 between the two bearings to prevent side loading of the bearings. Also provided is a conventional washer 116. A step washer is illustrated with the smaller diameter end of the washer resting on the adjacent bearing and the larger diameter end resting on the stem 38. Alternatively, two washers of different diameters can be stacked.

The air pre-cleaner further comprises a base 120. With reference now again to FIGURE 1, the base 120 includes an side wall 122 including a curved first section 124 and a curved second section 126, which has a lesser curvature than the first section and extends outwardly in relation to the first section 124. Also provided is a base wall 130 to which the side wall 122 is secured. The side wall and the base wall cooperate to form a chamber 132. Adjacent ends of the first and second sections 124 and 126 form between them a channel 134 which defines a dirty air exit opening 136. Also provided in the base is a clean air exit opening or port 140 which is centrally located on the base wall and is encircled by a sleeve 142 depending from an outer side

of the base wall. The sleeve 142 is of a smaller diameter than is the side wall 122. Defined in the sleeve 142 are a plurality of spaced slots 144. These slots are conventional and are meant to enable the base to be compressed when mounted on an intake stack of a conventional internal combustion engine by means of a conventional encircling clamp (not illustrated).

With reference now to FIGURE 3, a ring-shaped collar 146 is positioned on an inner side of the base wall 130 and encircles the clean air exit opening 140. The smooth, curved shape of the collar 146 facilitates a laminar air flow for the exiting air. A laminar air flow is advantageous from the standpoint that it increases the speed of the air flowing through the exit opening thus reducing the pressure drop to the internal combustion engine caused by the presence of the air pre-cleaner. An inwardly tapering section 148 of the clean air opening 140 extends along a portion of the sleeve 142 from the collar 146. This section 148 also promotes laminar airflow. In addition, the narrowed air exit opening formed between the section 148 and the second section 100 of each first blade 96 causes the airflow to speed up. This principle of physics is known as the Venturi effect. An increase in the speed of airflow may cause an increase in the speed of rotation of the impeller assembly enhancing the efficiency of the air pre-cleaner.

Extending radially outward from the first vertical wall section 122 are a plurality of protrusions 150 each having a respective opening 152 extending longitudinally therein. The tabs 22, 66 and the protrusion 150 are aligned such that their respective openings 24, 68 and 152 are coaxial so as to accommodate conventional fasteners 154 in order to secure the hood 10 to the vane assembly 30 and both of these components to the base 120. This is illustrated in FIGURE 4.

While in the figures the fasteners 154 are

illustrated as extending downwardly from the hood 10, it may be advantageous to have the fasteners extend upwardly from the base 120 in order to reduce the chance of rain damage to the fasteners employed in the air pre-cleaner.

5           With the air pre-cleaner illustrated herein, atmospheric air flows horizontally through the openings 18 in the hood 10 and into the first chamber 16. In the chamber, the air flows around the dome 32 and across the vanes 50. As best illustrated in FIGURE 5, due to the  
10 smooth curved shape of the vanes 50, the air acquires a strong swirling motion as it flows into a second chamber 160 defined between the vane assembly 30 and the base 120. As best illustrated in FIGURE 5, the inlet vanes 50 are fully concave to inlet airflow resulting in maximum  
15 spin for any given forward motion. The concave vanes 50 will provide more spin for a given amount of forward motion. The degree of concavity changes along the length of the vane. In other words, as is illustrated in FIGURE 5, the vanes are more convex at their leading  
20 edge than at their trailing edge.

The swirling nature of the air flow impels heavier than air dirt particles and moisture radially outward in the second chamber. The swirling nature of the air flow propels the blades 96 and 104 to begin rotation of the  
25 rotating impeller assembly 80 thereby increasing the rotational vortex and further propelling particles in the airstream radially outward. These particles then flow through the channel 134 and out the dirty air exit port 136. In the meanwhile, clean air flows radially  
30 inward toward the clean air exit port 140. The clean air flows out the exit port 140, through the sleeve 142 and into the intake of the adjacent internal combustion engine.

It should be apparent that the dome 34 blocks  
35 direct access of the inlet air to the clean air exit port 140. As best shown in FIGURES 3 and 4, the skirt

14 of the dome extends slightly below the inlet air vanes 50 further restricting direct access of the inlet air to the clean air exit port. It should also be apparent from FIGURE 3 that the annular chamber 40 is open to the second chamber 160 and provides additional area for the spinning air to enter the clean air exit port.

Any dirt particles or moisture which enters the openings 18 and flows across the vanes 50, even if it were to reach the base wall 130, would be prevented from entering the clean air exit port opening 140 due to the presence of the ring-shaped collar 146. Rather, all such dirt particles will fall by gravity to the lowest point of the second chamber 160. Also, due to the urging of the spinning air, the dirt will be swept up by the outer blades 104. The dirt will exit through the dirty air exit channel 134 and the outlet port 136 thereof.

The location of the collar 60 is such as to partially mask the second blades 104 providing higher vane speed for better ejection. The reduced diameter of the vane assembly, i.e. of the collar 60 and the vanes 50, allows the hood 10 to be of a larger diameter than the vane assembly and still seat on the base 120. This provides a shorter assembly height than the known air pre-cleaners of this type.

An optimized diameter is provided for the driven vanes 104 as compared with the known air pre-cleaners. While the inclusion of a spinning impeller moves energy from the air stream, it does not hinder airflow and, indeed, often improves it.

With reference again to FIGURE 3, dirt particles are prevented from becoming trapped in an area 162 defined between the outer wall of the collar 60 and an inner wall of the skirt 14 because of the horizontal orientation of the entire air pre-cleaner assembly. Any dirt which may become trapped at this location will, due

to gravity, fall to the bottom end thereof. From this location, inlet air will push the dirt either back into the atmosphere or into the air pre-cleaner.

In the first preferred embodiment of the present invention, the hood 10, vane assembly 30, rotating impeller assembly 80 and base 120 are all made of a suitable conventional thermoplastic material. Of course, it should be recognized that one or more of these components could also be made from any other conventional type of material, such as a metal, e.g. aluminum or the like. However, it has been found that the manufacture of at least the vane assembly 30, from a thermoplastic material is advantageous because it allows the vanes 50 to be molded into a fully concave shape at a reasonable cost.

With reference now to FIGURE 6, illustrated there is another type of hood 180 used for an air pre-cleaner according to a second preferred embodiment of the present invention. In this embodiment, like components are identified by like numerals with a primed (') suffix and new components are identified by new numerals.

A hood 180 comprises a top wall 182 and a side wall 184 including a plurality of openings 186 extending therethrough. It should be apparent from FIGURE 6 that the top wall has an outer section or overhang 188 which extends radially outward from the side wall 184. Also extending radially outward from the side wall 184 are a plurality of protrusions 190, each having a bore 192 extending therethrough. The hood 180 is employed when the air pre-cleaner of the present invention is used in a vertical orientation. The top wall 182 and the overhang 188 prevent rain from entering the air pre-cleaner.

The air pre-cleaner according to the second preferred embodiment of the present invention also includes a vane assembly 30', a rotating impeller assembly 80' and a base 120' as in the first embodiment.

As is illustrated in FIGURE 7, the hood top wall 182 and side wall 184 form a chamber 194 for allowing inlet air into the air pre-cleaner. The air pre-cleaner of the second preferred embodiment illustrated in FIGURE 7 is meant to be accommodated on an intake stack which is vertically oriented. In contrast, the hood 10 illustrated in FIGURES 1-4 is meant to be accommodated on an intake stack which is horizontally oriented. In this way, rain is not ingested in great quantities in the intake stack. Rather, the openings 18 in the hood 10 are horizontally oriented as are the openings 186 in the hood 180.

Any dirt which may become trapped between an outer wall of the vane assembly 30' and an inner side of the side wall 184 will simply flow out through the apertures 186 back into the atmosphere when the dirt reaches the level of the lowest one of the apertures 186.

Referring to FIGURES 8A and 8B, together an exploded perspective view of an air pre-cleaner is shown according to a third preferred embodiment of the present invention. The air pre-cleaner comprises a hood 310 having an end wall 312 and a skirt 314 depending therefrom. The end wall and the skirt together form a first chamber 316 (FIGURE 10). A plurality of spaced, aligned, openings 318 are provided on the skirt 314. The openings 318 communicate with the first chamber 316. Located on a collar 322 encircling a distal end of the skirt 314 are a plurality of spaced tabs 324. The tabs protrude from the collar. Each tab has an opening 326 extending therethrough. The hood 310 has a slight taper from the end wall 312 to a distal end of the skirt 314. This construction, in conjunction with the vertical openings or slots 318 allow for easy moldability of the hood.

Positioned beneath the hood 310 is a vane assembly 330. As shown in FIGURE 12, the vane assembly comprises a centrally located dome 332 including a top wall 334

and a peripheral skirt 336. With reference now also to FIGURE 10, a stem 338 extends axially from the top wall 334 parallel to the skirt 336. The skirt 336 and the stem 338 define between them an annular chamber 340. An opening 342 extends through the stem 338. The opening  
5 comprises an enlarged diameter upper hexagonally shaped socket section 344 as is best illustrated in FIGURE 8B and a reduced diameter circular section 346.

Referring again to FIGURE 12, a plurality of inlet vanes 350 each have a radially inner end 352 secured to  
10 the skirt 336 of the dome 332 and a radially outer end 354 secured to a collar 360 encircling the dome. Extending radially outwardly from the collar 360 at a bottom edge thereof is a ledge or horizontal wall 362. An annular rib 364 is defined adjacent the radially  
15 outer periphery of the horizontal wall 362.

In one embodiment, the depth of each vane 350 is on the order of approximately one inch (2.54 cm.). However, the vane depth could be greater on larger models of the air pre-cleaner. The pitch of each vane  
20 350 is twisted to keep the chord width relatively constant over the full vane length. This provides a constant length flow path and essentially a constant velocity over the entire vane surface. The object is to force the air flow around the outer perimeter at lower  
25 flow rates providing maximum centrifugal force for the spin diameter and forward expansion volume which are available in the air pre-cleaner. An alternate construction would be to have the vane chord slightly wider at the inner diameter than at the outer diameter.  
30 The vanes 350 are inclined slightly away from the direction of air movement in a plane perpendicular to forward motion of the entering air. For example, if the entering air is forced to flow clockwise, then the inlet vanes 350 will terminate slightly counter clockwise at  
35 the outer diameter in relation to the inner diameter. To this end, it can be seen that a somewhat triangular

portion 366 of each vane, which is located immediately adjacent the dome 332. The portion 366 is wider at its bottom end than at its top end and is canted in relation to a plane of the vane 350. During the course of development of the instant air pre-cleaner, it has been found that for best particle separation, the air must be forced toward the outer walls of the separation chamber.

Referring now to FIGURE 8A, positioned adjacent the vane assembly 330 is a rotating impeller assembly 380. With reference now also to FIGURE 13, the rotating impeller assembly comprises a hub 382 having a bore 384 extending axially therethrough. As best shown in FIGURE 10, the bore includes a first section 386 of a first diameter, a second section 388 of a second and smaller diameter, and a third section 390 of a third diameter. Preferably, the first and third sections 386 and 390 of the bore 384 have the same diameter. Preferably, four arms 394 radiate away from the hub 382. Of course, more or less than four arms could be employed for the rotating impeller assembly. This would depend to some extent on the size of the air pre-cleaner. Secured to the hub are plurality of first blades 396, each of which is aligned with a respective one of the arms 394. As best shown in FIGURE 8A, the first blades are thus located at the proximal ends of the several arms. Each first blade 396 includes a first section 398 which is positioned above its respective arm and a second section 400 which is positioned below its respective arm.

Located at the distal ends of each of the arms 394 is a respective second blade 404. Each second blade is of compound shape. Each second blade 404 includes a first section 406 which is substantially aligned with its respective arm 394 and a second section 408 which is oriented at an angle to the first section 406. The ejection blades of the impeller are large in relation to other designs on the market. They are of a shape that will not unload with increasing static pressure. In one

embodiment, each first section 406 has approximately a .5 inch (1.27 cm.) width inclined away from the direction of rotation by 10 degrees over a 1.3 inch (3.3 cm.) length. The second section 408 is approximately .25 inches (.64 cm.) in width and is inclined away from the direction or rotation at approximately 45 degrees. The relationship of the sizeable first blades 396 and the compound second blades 404 combine to provide a blade assembly which will not unload or cavitate at increasing static pressures. These blades combine to convert the rotational velocity of the impeller to static pressure at the ejection ports better than straight, forward or backward curved blades.

The unique shape of the second blades 404 combined with the fact that these blades are enclosed on the top and bottom and masked from the rotating air which leaves the inlet vanes 350 -- and because the blades are rotating in the perimeter of the air leaving the inlet vanes -- provides for particle extraction by both low pressure and centrifugal force as well as by mechanical separation.

A fastening means secures the rotating impeller assembly 380 to the vane assembly 330. The fastening means comprises a bolt 420 and a lock nut 422. The lock nut is generally hexagonally shaped and is positioned in the hexagonally shaped socket section 344. The bolt extends through the hub 382 from the bottom end of the rotating impeller assembly 380. A pair of bearings 424 and 426 are positioned in the respective first and third sections 386 and 390 of the hub bore 384. The bearings 424 and 426 enable the rotating impeller assembly to smoothly rotate in relation to the vane assembly 430. A small washer 428 is positioned between a head of the bolt and the lower bearing 424. A large size conventional washer 430 and a step washer 432 are located adjacent the upper bearing 426. The smaller diameter end of the step washer rests on the upper

bearing 426. Alternatively, two washers of different diameters can be stacked. A sleeve spacer 432 is located in the hub bore 384 and extends between the bearings, as shown in FIGURE 10.

The air pre-cleaner further comprises a base 440. With reference now to FIGURE 14, the base 440 includes an side wall 442 and a base wall 443. Also provided is at least one inwardly curved cut off wall 444. The cut off wall 444 includes a first section 446, which is substantially parallel to the side wall 442 and a second section 448 which merges into the side wall. Defined between the first stator vane section 446 and the side wall 442 is an opening 448 which leads to an exhaust port 450. The exhaust port is defined at the junction of the base wall 443 with the side wall 442. A barrier wall 452 extends from the cut off wall 444 to the side wall 442 separating the first and second sections 446 and 448 of the cut off wall. The barrier wall 452 serves to stiffen the cut off wall 444 in relation to the side wall 442 of the base 440. Preferably, three such cut off walls are located on the base 440 in a substantially equally spaced manner. Also, three separate exhaust ports 450 are provided on the base. The cut off walls serve to shear the air being spun around by the second blades 404 to force it out the outlet ports 450.

With reference now also to FIGURE 11, a clean air exit opening or port 460 is centrally located on the base wall 443 and is encircled by a sleeve 462 depending from an outer side of the base wall. The sleeve 462 is of smaller diameter than is the side wall 442. Defined in the sleeve 462 are a plurality of spaced slots 464. These slots are conventional and enable the base to be compressed or expanded when mounted on an intake stack of a conventional internal combustion engine by means of a conventional encircling clamp (not illustrated).

A ring shaped rib 466 is positioned on an annular

step 467 at the inner periphery of the base wall 443 and encircles the clean air exit opening 460. The smooth curved shape of the rib facilitates a laminar air flow for the exiting air. Extending radially outwardly from the side wall 442 are a plurality of spaced protrusions 470. Each of the protrusions has an upwardly extending tab 472. In this embodiment four such protrusions are provided. These protrusions are aligned with the protrusions 324 on the hood 310. The tabs 472 extend through the slots 364 in the vane assembly 330 and into the openings 326 in order to secure the hood 310 to the base 440. As shown in FIGURE 9, a clip 473 is fastened over the cooperating protrusions 470 and 324.

Spaced around the inner periphery of the sleeve 462 are a set of stator vanes 474. Each of these vanes has a first end 476 which tapers toward the sleeve 462 and a second end 478 which extends inwardly away from the sleeve 462. The stator vanes 474 cooperate with the inner blades 396 of the impeller assembly 380 and provide an area of laminar flow. The stator vanes are useful in that they help to keep the rotational energy of the air in contact with the impeller assembly, thereby urging the impeller to spin more vigorously. Thus the stator vanes 474 prevent the loss of rotational energy while allowing straightened flow through a boundary region. Moreover, the stator vanes serve a structural purpose. The second ends 478 thereof act as a secondary stop when the air pre-cleaner is positioned on a tube or adapter leading to the intake of an internal combustion engine. Thus, the stator vanes in cooperation with the impeller assembly allow more air flow and better ejection of particulates at all flow rates.

Combined with the exhaust ports 450 which are of a somewhat restricted area, a much higher ejection pressure is attained than is available on conventional air pre-cleaners. The higher ejection pressure is

considered important in the use of the air pre-cleaner of the present invention in an in line configuration as sufficient exhaust pressure must be generated to offset the restriction of the inlet ducting by the air pre-cleaner itself. Also, by removing as much of the rotational energy from the air as possible, and by increasing the resistance of the drive impeller air flow through the air pre-cleaner is increased.

With the air pre-cleaner illustrated herein, atmospheric air flows horizontally through the openings 318 in the hood 310 and into the first chamber 316. In the first chamber, the air flows upwardly over the collar 360 and then downwardly around the dome 332 and across the vanes 350. As is best illustrated in FIGURE 12, due to the smooth curved shape of the vanes 350, the air acquires a strong swirling motion as it flows into a second chamber 480 (FIGURE 10) defined between the vane assembly 330 and the base 440. The inlet vanes 350 are fully concave to inlet air flow resulting in maximum spin for any given forward motion.

The swirling nature of the air flow impels heavier than air dirt particles and moisture radially outward in the second chamber 480. The swirling nature of the air flow propels the blades 396 and 404 to begin rotation of the rotating impeller assembly 380 thereby increasing the rotational vortex and further propelling particles in the air stream radially outward.

In the meanwhile, clean air flows radially inward toward the clean air exit port 460. The clean air flows out the exit port 460 through the sleeve 462 and into the intake of the adjacent internal combustion engine.

It should be apparent that the dome 334 blocks direct access of the inlet air to the clean air exit port 460. As best shown in FIGURE 10, the skirt 314 of the dome extends slightly below the inlet air vanes 350 thereby further restricting direct access of the inlet air to the clean air exit port.

The relatively large ledge or horizontal wall 362 is advantageous because it accommodates the partially shrouded ejection impeller (i.e. the second blades 404) and eliminates the need for an overhang of the rain hat top or hood 310 while allowing the hood to taper slightly from top to bottom.

The upper portion or first section 398 of the first blade 396 functions as a drive impeller creating a pressure under the dome 332 less than at the outlet ports 350. The impeller portion adjacent the dome is wider than the open area of the dome and in close proximity to the surface thereof. This prevents air movement into the low pressure area 340 beneath the dome 332 improving both particle separation and the utilization of rotational energy. Air flow through the hub bore 384 is retarded by the large diameter washer 430.

Any dirt, particles or moisture which enter the openings 318 and flow across the vanes 350, even if they were to reach the base wall 443 would be prevented from entering the clean air exit port opening 460 due to the presence of the ring-shaped rib 466 and the step 467. Rather, due to the urging of the spinning air, the dirt will be swept up by the outer blades 404. This dirt will exit through the dirty air exit channels 448 and the outlet ports 450 thereof.

The location of the collar 360 is such as to partially mask the second blades 404 providing higher vane speed for better ejection. The reduced diameter of the vane assembly, i.e. of the collar 360 and the vanes 350 allows the hood 310 to be of a larger diameter than the vane assembly and still seat on the base 440. This provides a shorter assembly height than the known air pre-cleaners of this type.

With reference again to FIGURE 10, dirt particles are prevented from becoming trapped in an area 472 defined between the outer wall of the collar 360 and an

inner wall of the skirt 314 because intrushing air will sweep the particles up. The inlet air will push the dirt either back into the atmosphere or into the air pre-cleaner.

5 It is noted that the openings 316 are so shaped that they are wider on the bottom than on the top. Thus, more air flows in at the bottom end of each opening than at the top end thereof.

10 In the third preferred embodiment of the present invention, the hood 310, the vane assembly 330, the rotating impeller assembly 380 and the base 440 are all made of a suitable conventional thermoplastic material such as by injection molding. In one embodiment, the thermoplastic material is a conventional glass filled nylon. In another embodiment, the thermoplastic is a  
15 conventional ABS. Of course, it should be recognized that one or more of these components could also be made from any other conventional type of material such as a metal, e.g. aluminum or the like. However, it has been found that the manufacture of at least the vane assembly  
20 330 from a thermoplastic material is advantageous because it allows the vanes 350 to be molded into the desired complex shape at a reasonable cost. Similarly, the complex shape of the base 440 can be molded at a reasonable cost.

25 It is evident from FIGURE 10 that reinforcing ribs 482 extend between the central shaft 338 and the dome top surface 334. These stiffen the vane assembly 330. A set of spaced ribs 482 are preferably provided.

30 With reference now to FIGURE 15, illustrated there is another type of hood 500 used for an air pre-cleaner according to a fourth preferred embodiment of the present invention. In this embodiment, like components are identified by like numerals with a primed (') suffix and new components are identified by new numerals. The  
35 hood 500 comprises a top wall 502 and a side wall 504. A plurality of spaced openings 506 extend through the

top wall 502. It should be apparent from FIGURE 15 that the top wall 502 does not overhang the side wall 504. Also extending radially outwardly from the side wall 504 are a plurality of protrusions 510. Extending each protrusion is an opening 512.

5 As shown in FIGURE 16, the air pre-cleaner according to the fourth preferred embodiment of the present invention also includes a vane assembly 330', a rotating impeller assembly 380' and a base 440' as in the third embodiment.

10 As is illustrated in FIGURE 16, the hood top wall 502 and the side wall 504 form a first chamber 520 for allowing inlet air into the air pre-cleaner. The air pre-cleaner of the fourth preferred embodiment illustrated in FIGURE 16 is meant to be accommodated on  
15 an intake stack which is substantially horizontally oriented. In contrast, the hood 310 illustrated in FIGURES 8-14 is meant to be accommodated on an intake stack which is substantially vertically oriented. In  
20 this way, rain is not ingested in great quantities in the intake stack. Rather, the openings 506 in the hood 500 are horizontally oriented as are the openings 318 in the hood 310.

Any dirt which may become trapped between an outer wall of the vane assembly 330' and the inner side of the  
25 side wall 504 will simply fall by gravity to the lowest point of the first chamber and flow out through the lowest aperture 506 and back into the atmosphere when the dirt reaches the level of the lowest aperture.

The invention has been described with reference to  
30 preferred embodiments. Obviously, modifications and alterations will occur to others upon the reading and understanding of the preceding specification. It is intended that the invention be construed as including  
35 all such alterations and modifications insofar as they come within the scope of the appended claims or the equivalents thereof.

What is claimed is:

1. An air pre-cleaner that separates particulates from air comprising:

5 a hood having at least one opening through which air enters the pre-cleaner;

10 a vane assembly including a centrally positioned dome, a collar encircling said dome and a plurality of vanes each vane being connected at an inner end to said dome and at an outer end to said collar, each vane being angled in relation to a horizontal plane;

a rotating impeller assembly rotatably mounted to said vane assembly; and

15 a base on which said vane assembly and said hood are supported, wherein said hood, said vane assembly and said base are secured to each other, wherein said base comprises:

20 a clean air outlet port located in said base,

a dirty air outlet port located in said base, and,

25 a stator vane mounted on said base, said stator vane being located adjacent said clean air outlet port, said stator vane extending parallel to an axis of said clean air outlet port.

2. The air pre-cleaner of claim 1 wherein said hood comprises a plurality of spaced aligned openings through which air enters the pre-cleaner.

3. The air pre-cleaner of claim 1 wherein said base comprises:

a side wall;

5 a base wall secured on a first face thereof to said side wall and extending substantially radially inward from said side wall, said clean air outlet opening being

defined in said base wall;

a sleeve secured to a second face of said base wall and encircling said clean air outlet opening defining a clean air outlet port; and,

10 a stator vane secured to said base adjacent said clean air outlet port.

4. The air pre-cleaner of claim 3 wherein said base dirty air outlet port is defined in at least one of said side wall and said base wall of said base.

5. The air pre-cleaner of any preceding claim wherein said base further comprises a thickened toroidal wall section encircling said clean air outlet port.

6. The air pre-cleaner of any preceding claim wherein said base further comprises a sleeve encircling said outlet port and wherein a plurality of spaced stator vanes are located on said sleeve.

7. The air pre-cleaner of any preceding claim further comprising a stator vane positioned adjacent said dirty air exhaust port.

8. The air pre-cleaner of any preceding claim wherein said rotating impeller assembly comprises:

a hub;

at least one arm secured to and extending radially outward from said hub;

5 a first blade mounted at a distal end of said at least one arm; and,

a second blade mounted at a proximal end of said at least one arm.

9. The air pre-cleaner of claim 8 wherein said first blade comprises a first section and a second section, wherein said second section extends at an obtuse angle

in relation to said first section.

10. The air pre-cleaner of claim 8 wherein said blade comprises a first section which extends approximately parallel to said arm and a second section which extends at an acute angle in relation to said arm.

11. The air pre-cleaner of claim 10 wherein said first section of said blade is larger in area than is said second section of said blade.

12. The air pre-cleaner of claim 8 wherein said impeller assembly further comprises four arms, each including a first blade and a second blade, said arms being spaced from each other so as to have a cruciform shape.

13. The air pre-cleaner of claim 8 further comprising a fastener for securing said impeller assembly to said housing and a bearing positioned between said impeller assembly and said housing for enabling rotation of said impeller assembly in relation to said housing.

14. The air pre-cleaner of any preceding claim wherein a pitch of each inlet vane of said vane assembly is twisted to keep a chord width of each inlet vane relatively constant over the full vane length.

15. The air pre-cleaner of any preceding claim wherein a vane chord of each inlet vane of said vane assembly is slightly wider at an inner diameter than at an outer diameter of that inlet vane.

16. The air pre-cleaner of any preceding claim wherein each vane is inclined away from a direction of air movement in a plane perpendicular to forward motion of the entering air.

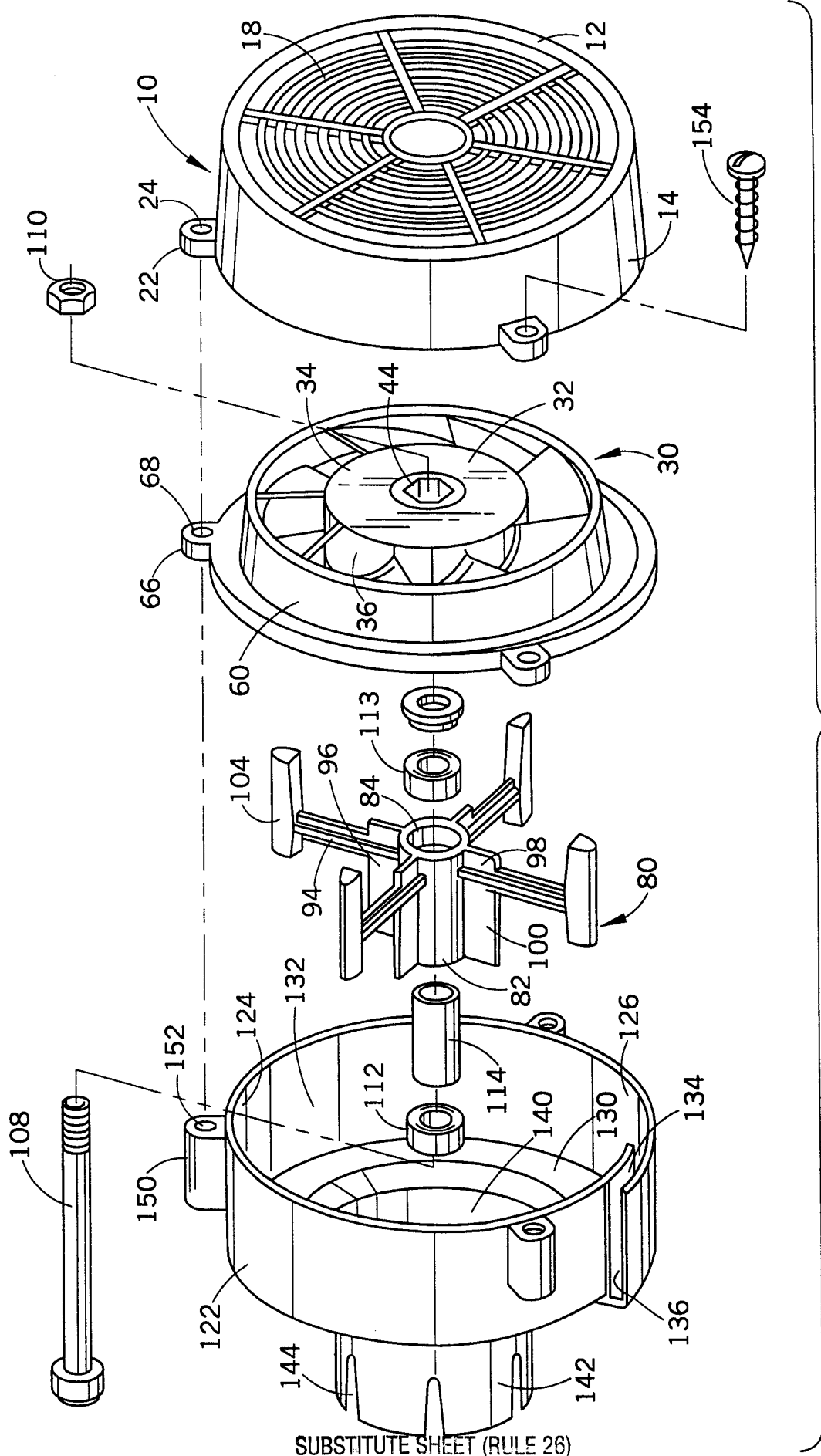


FIG. 1

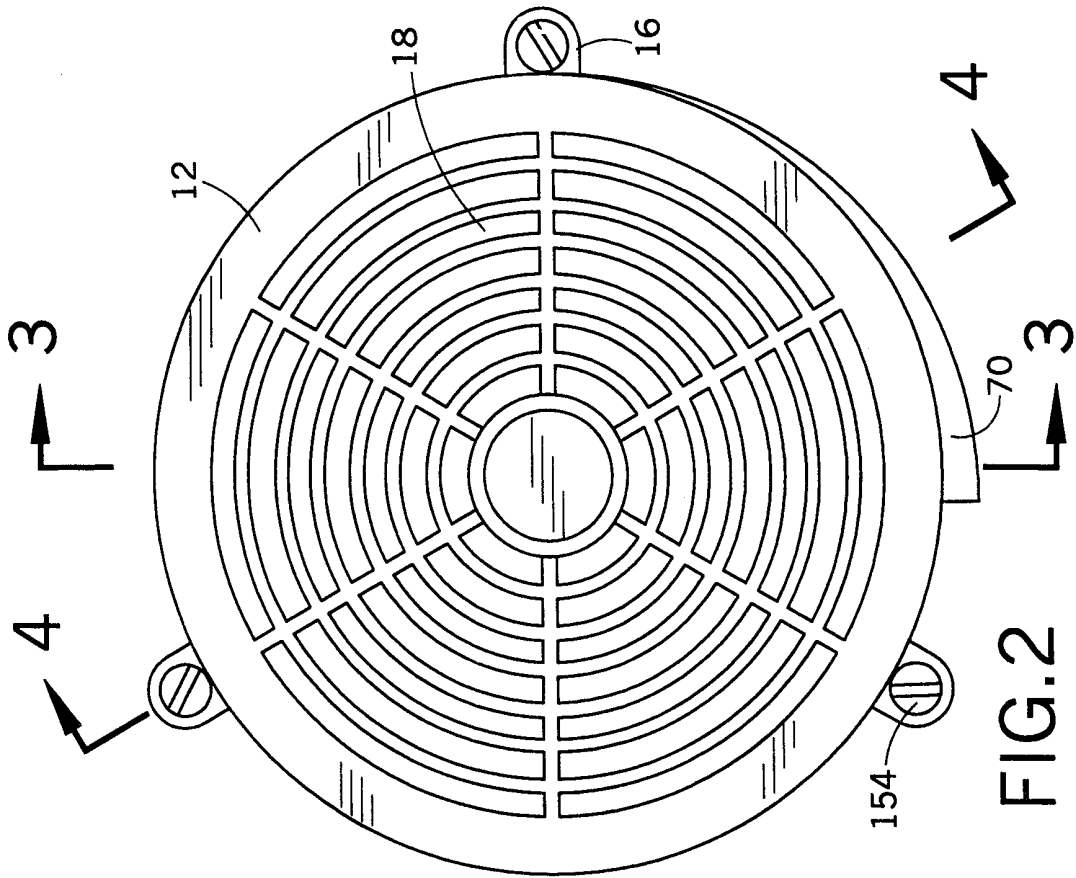


FIG. 2

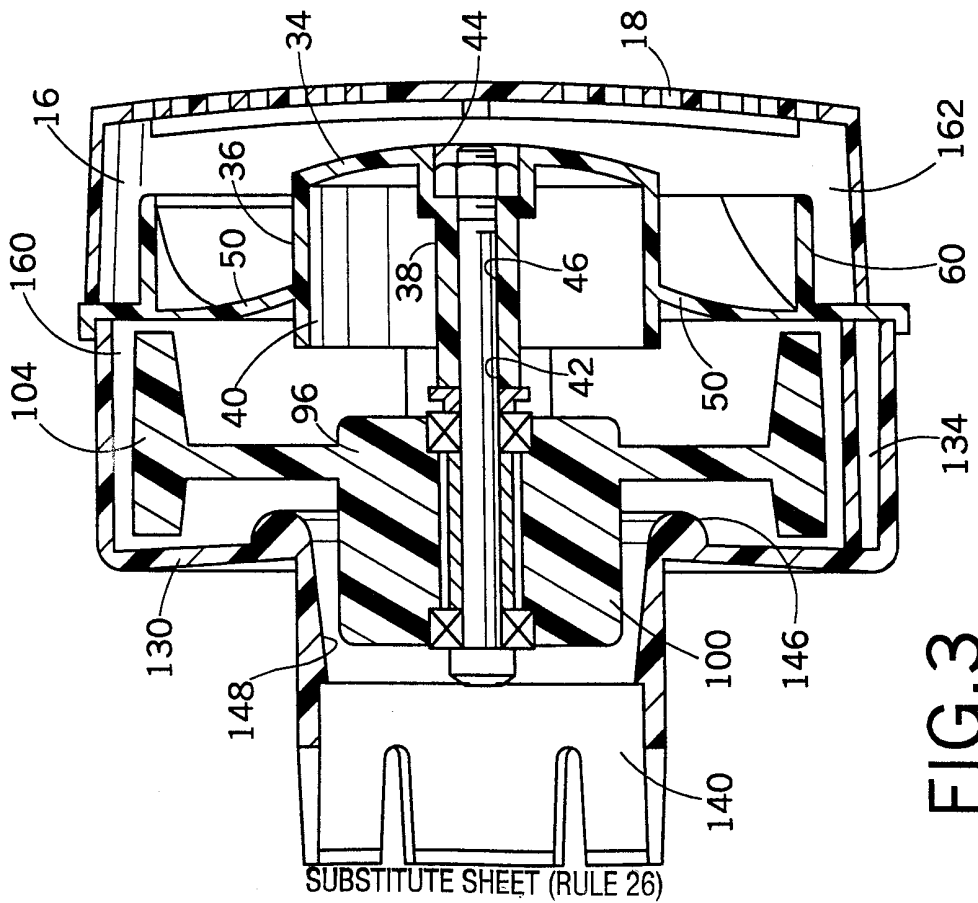


FIG. 3

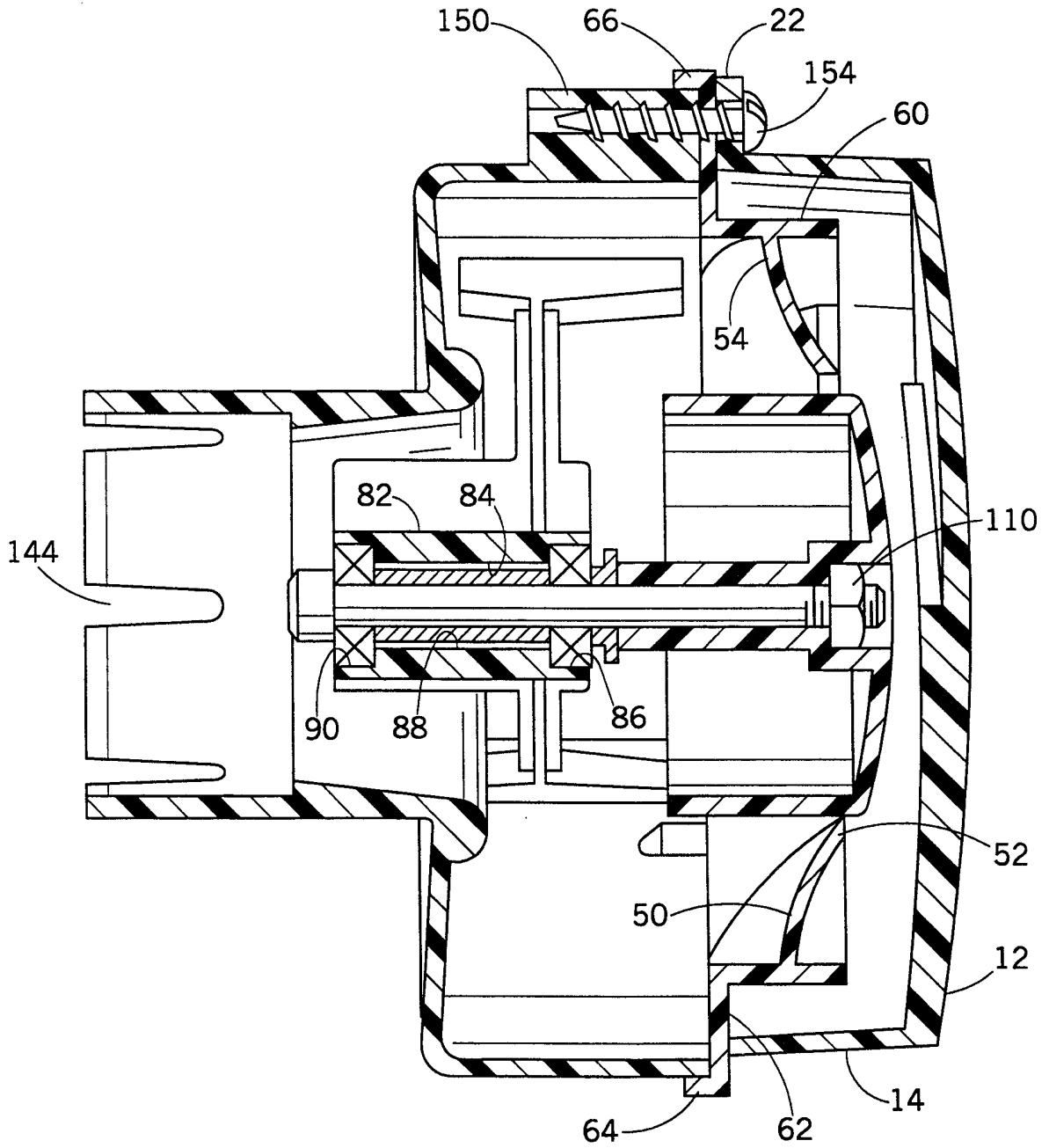


FIG.4

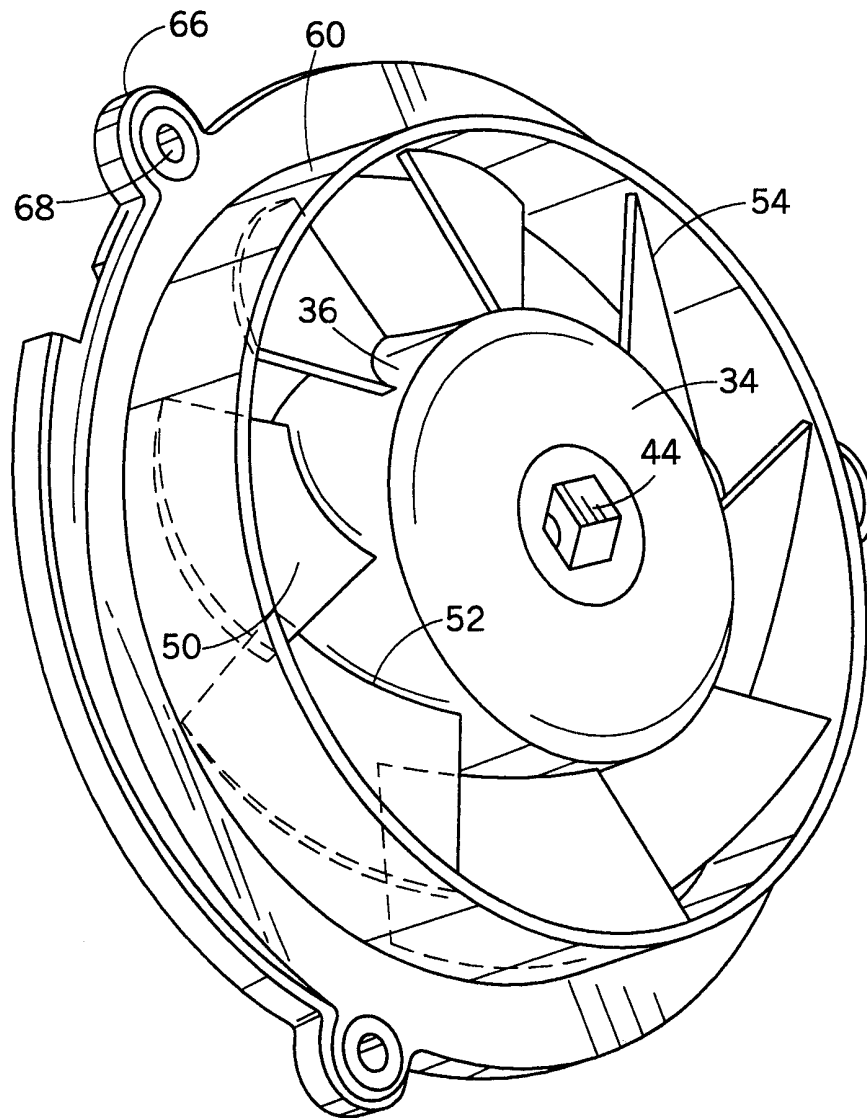


FIG.5

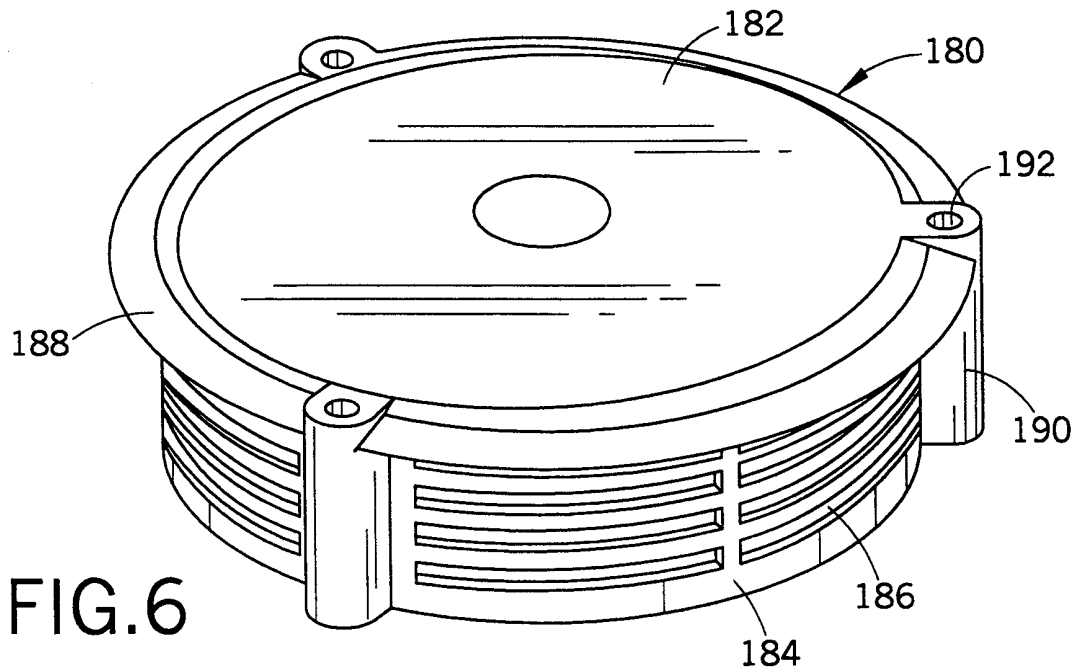


FIG. 6

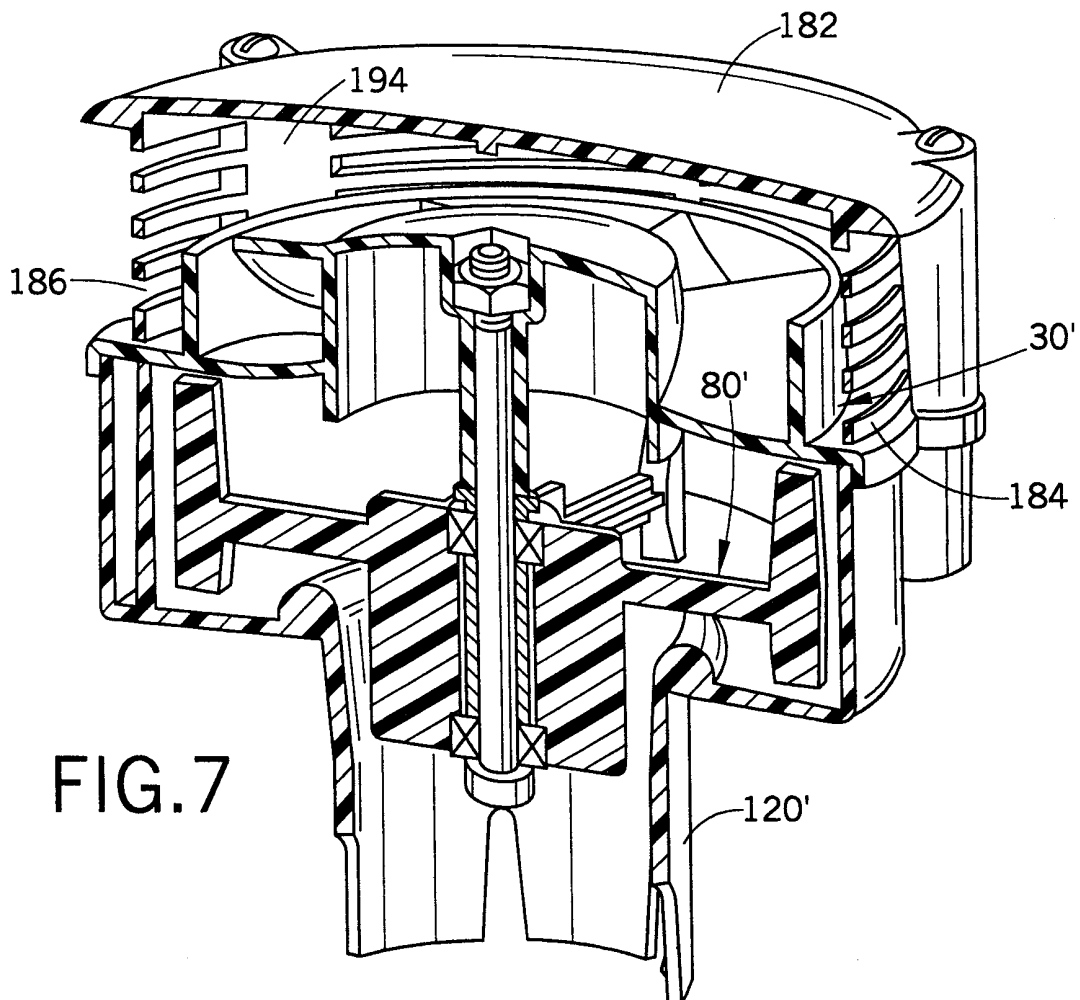


FIG. 7

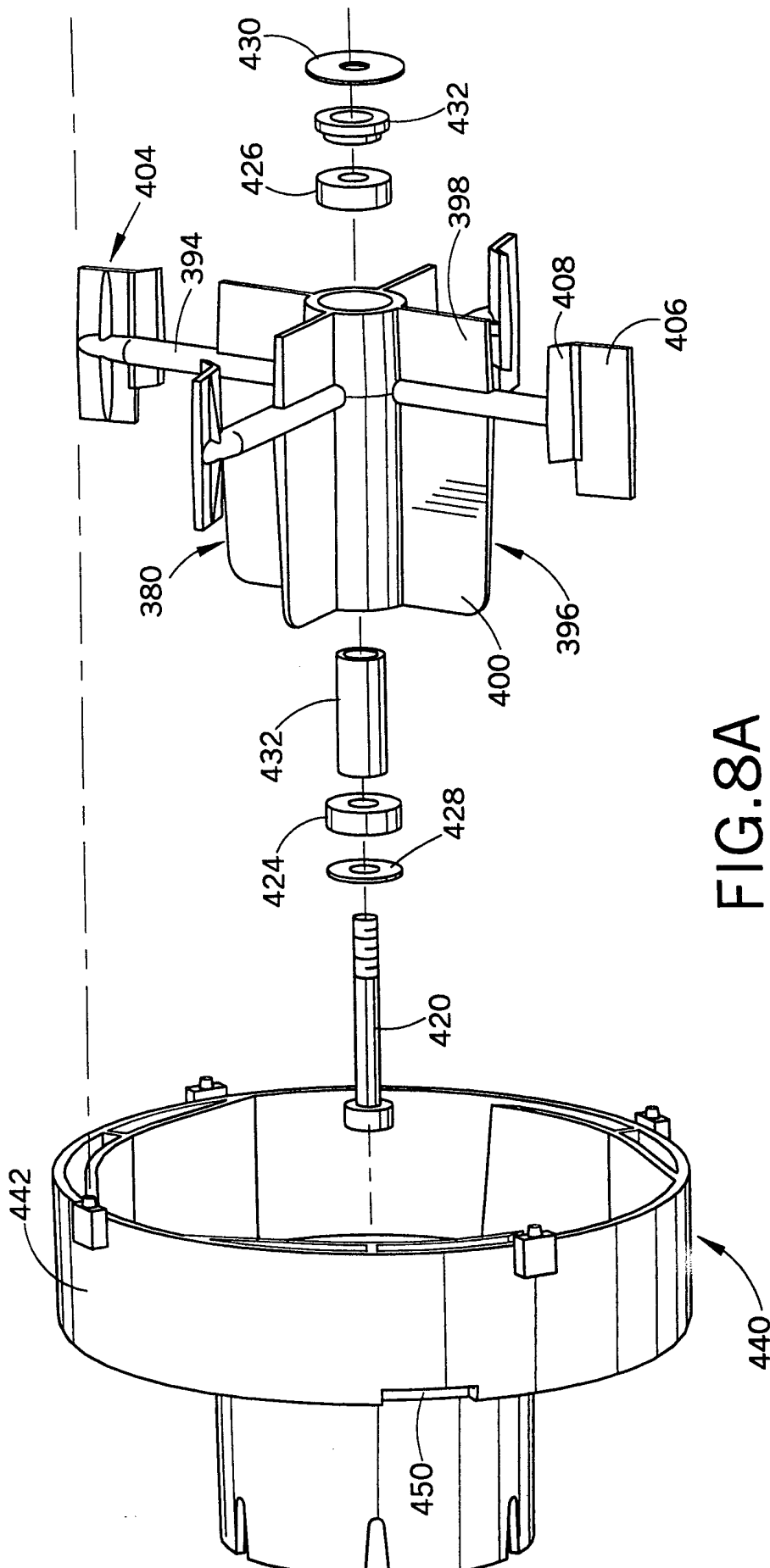


FIG. 8A

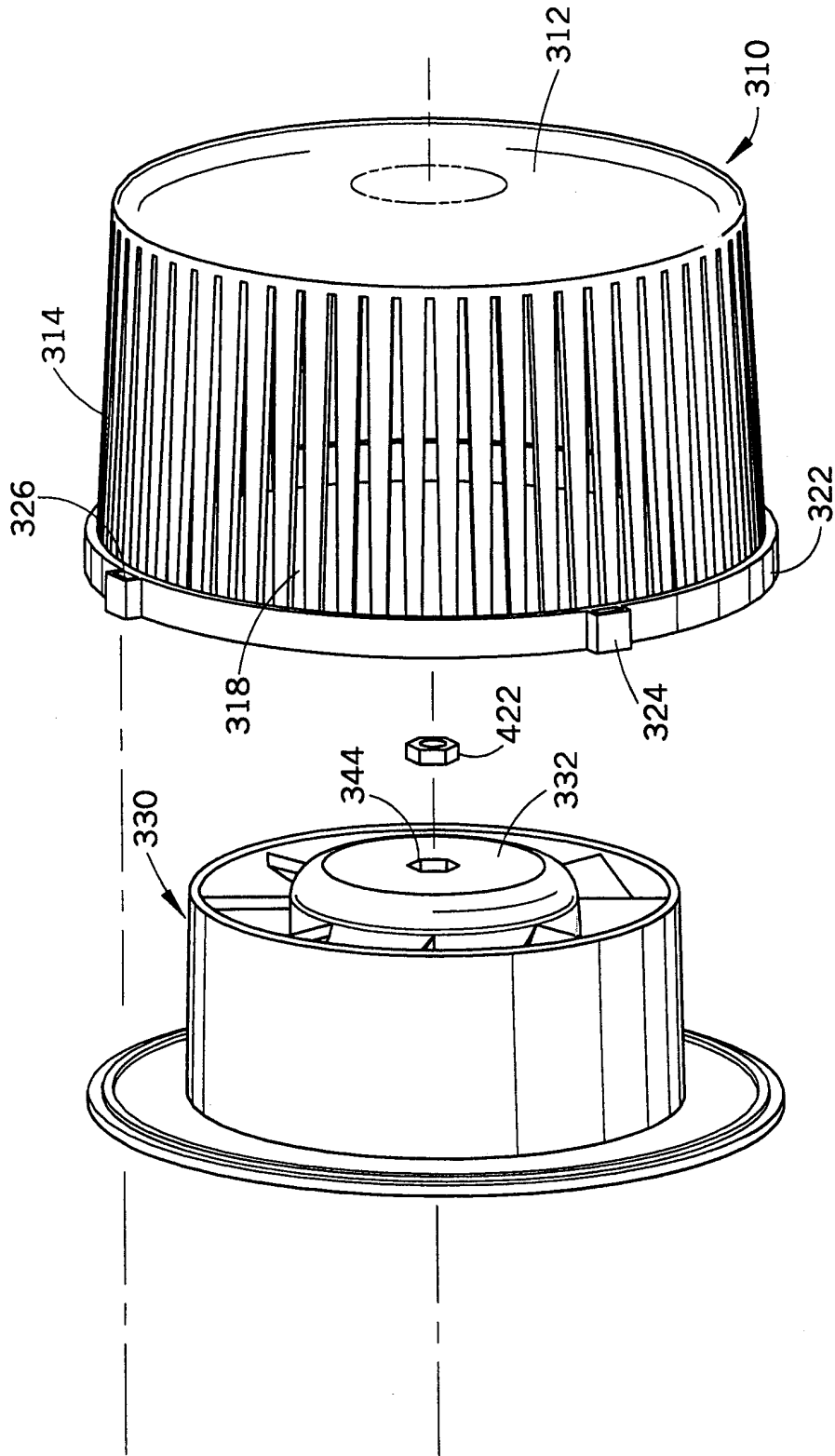


FIG. 8B

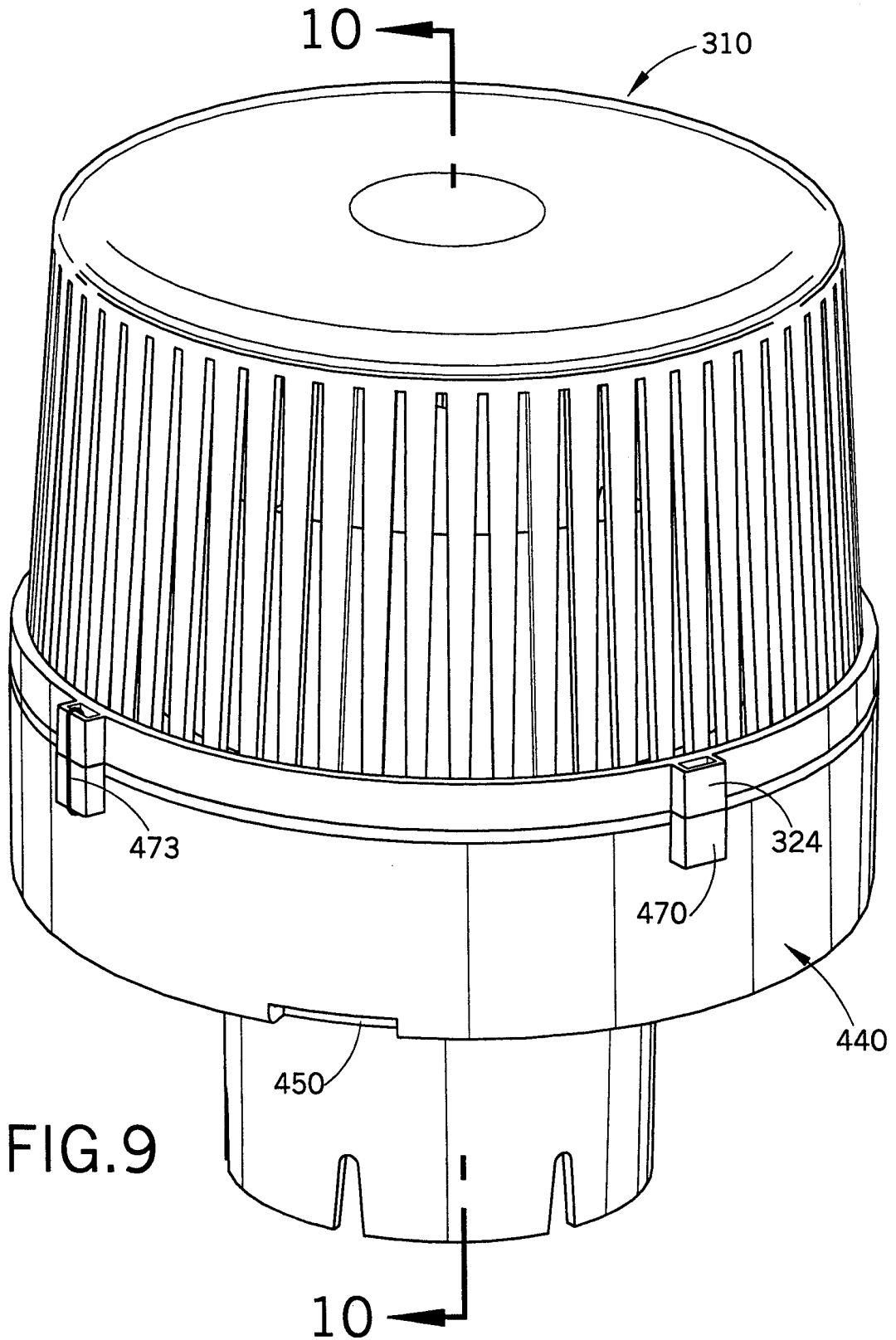


FIG. 9

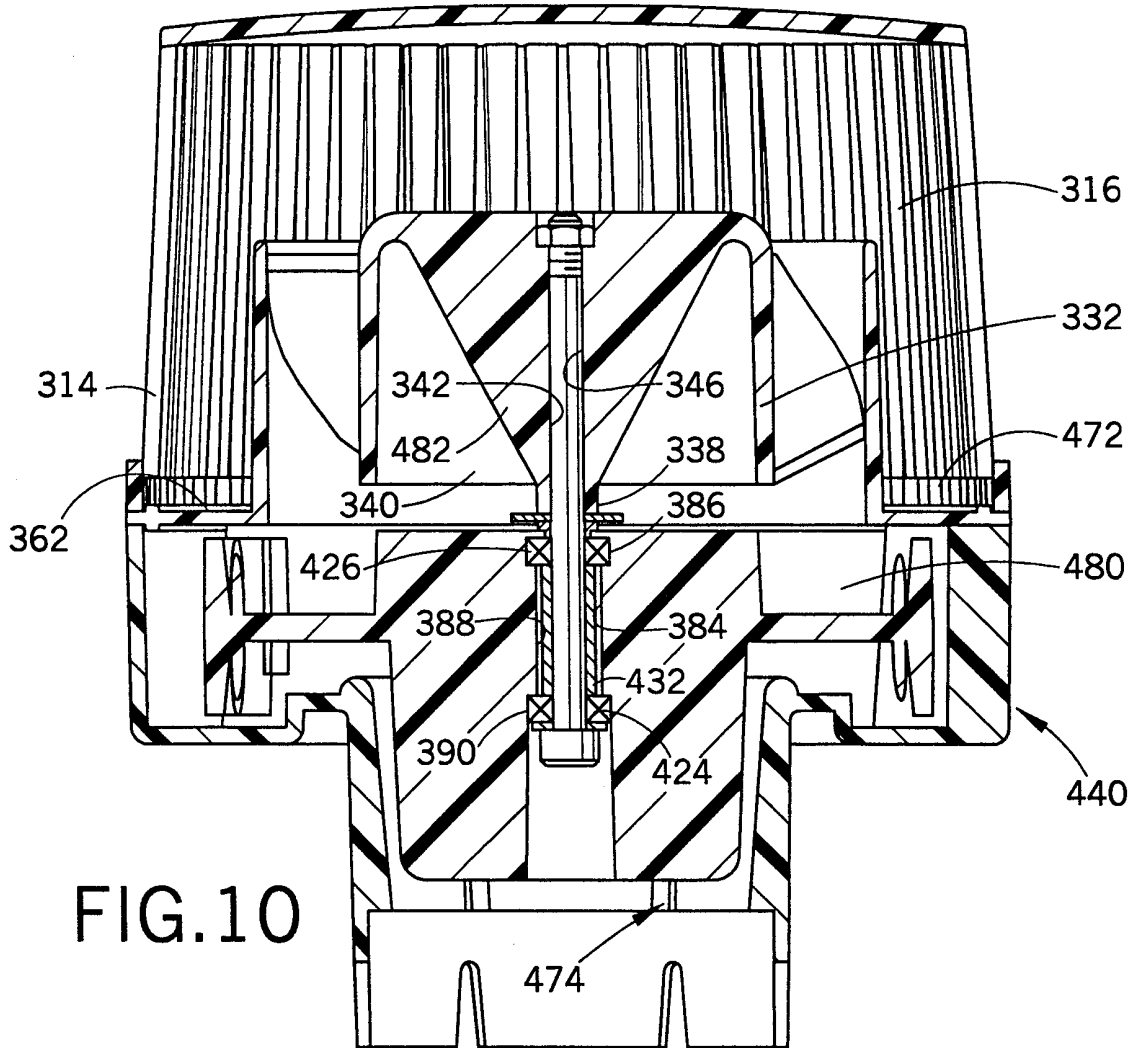


FIG. 10

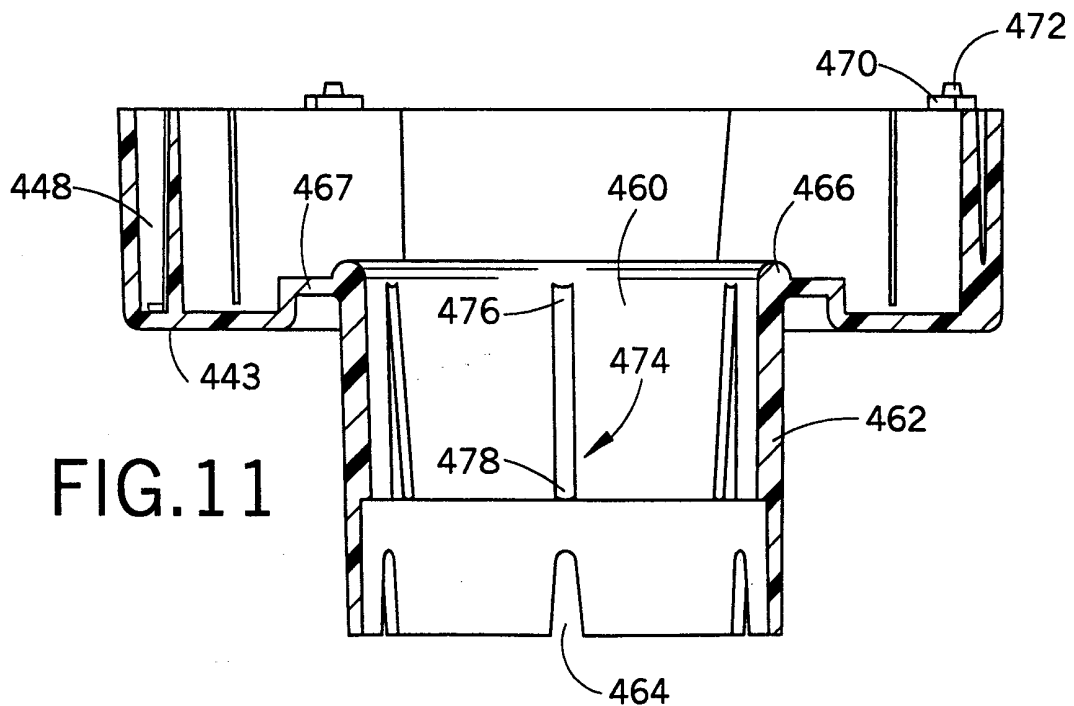


FIG. 11

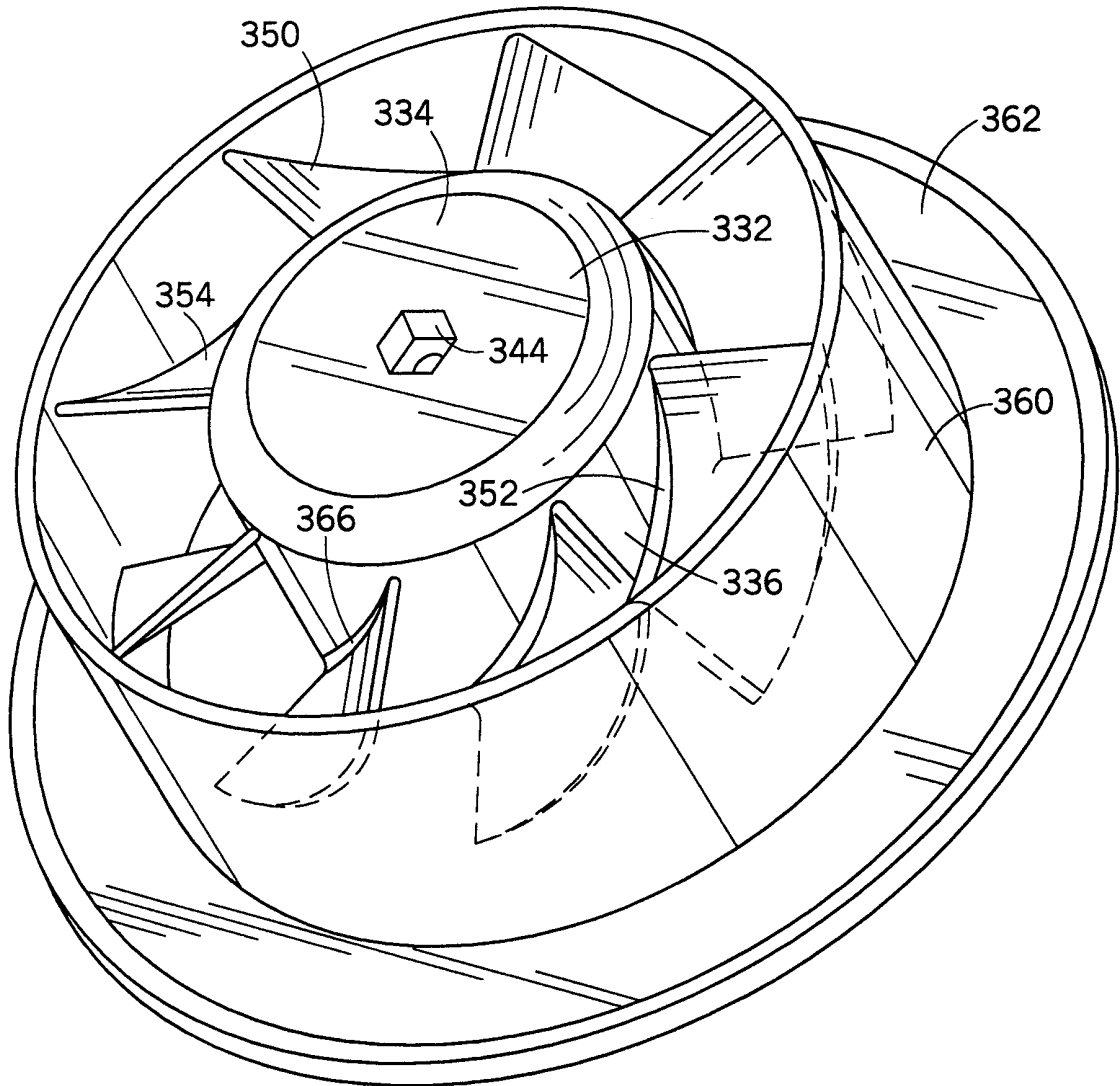


FIG.12

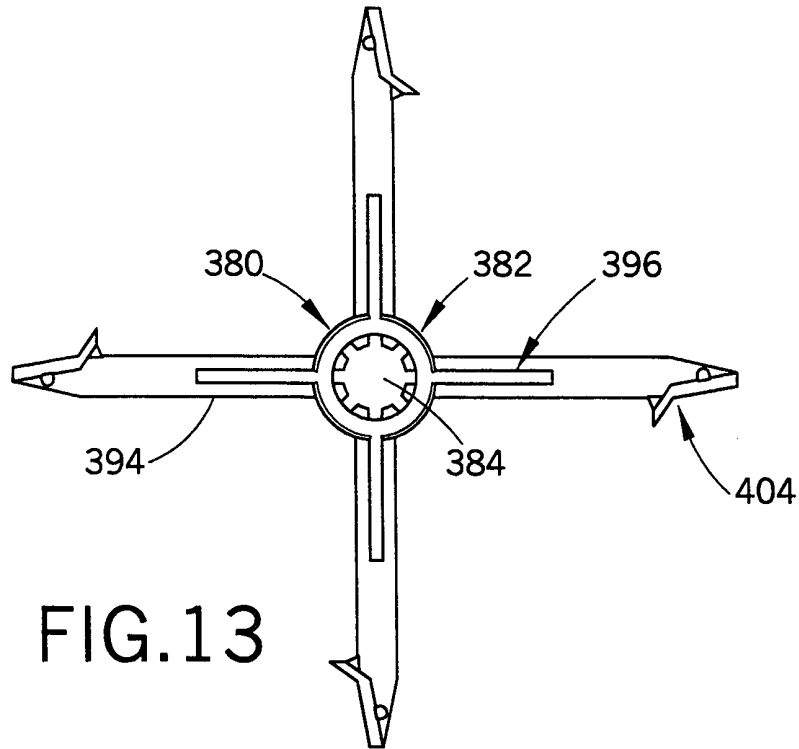


FIG. 13

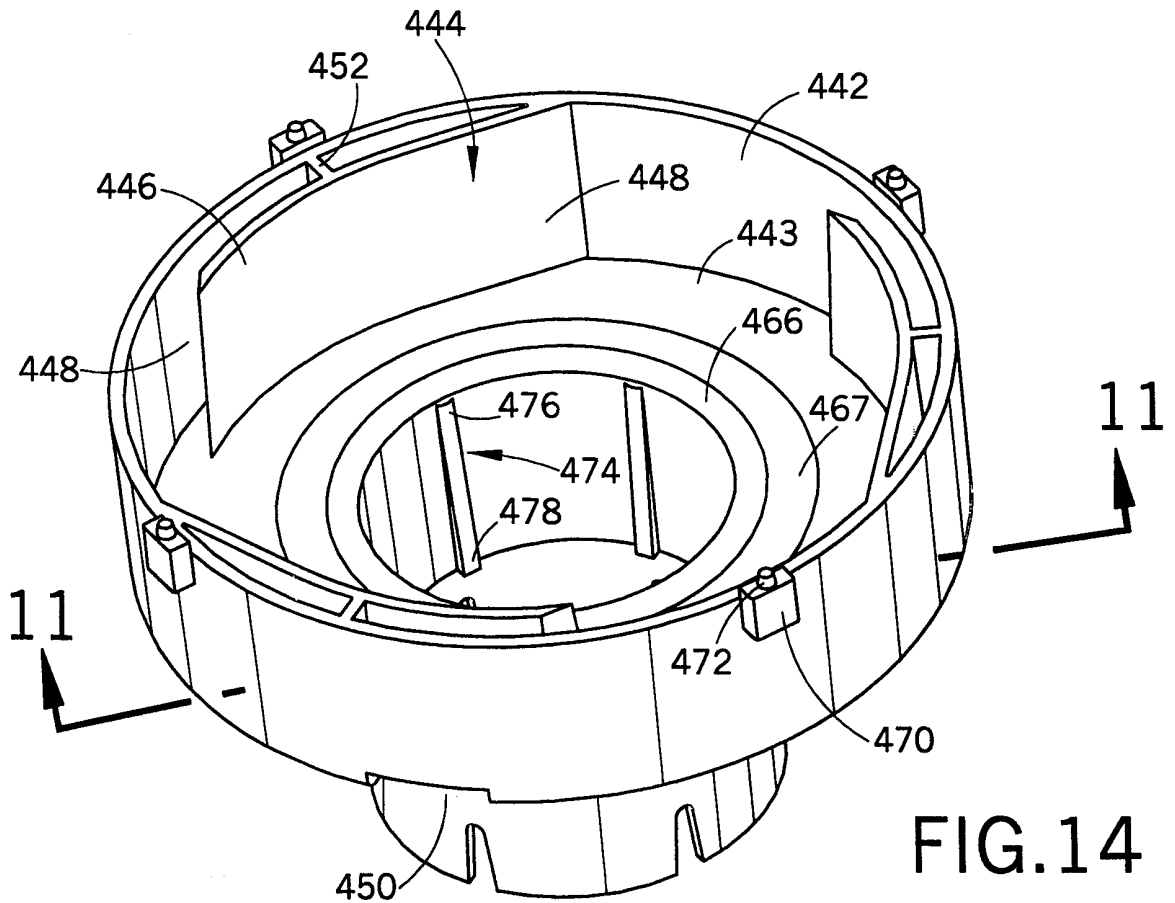


FIG. 14

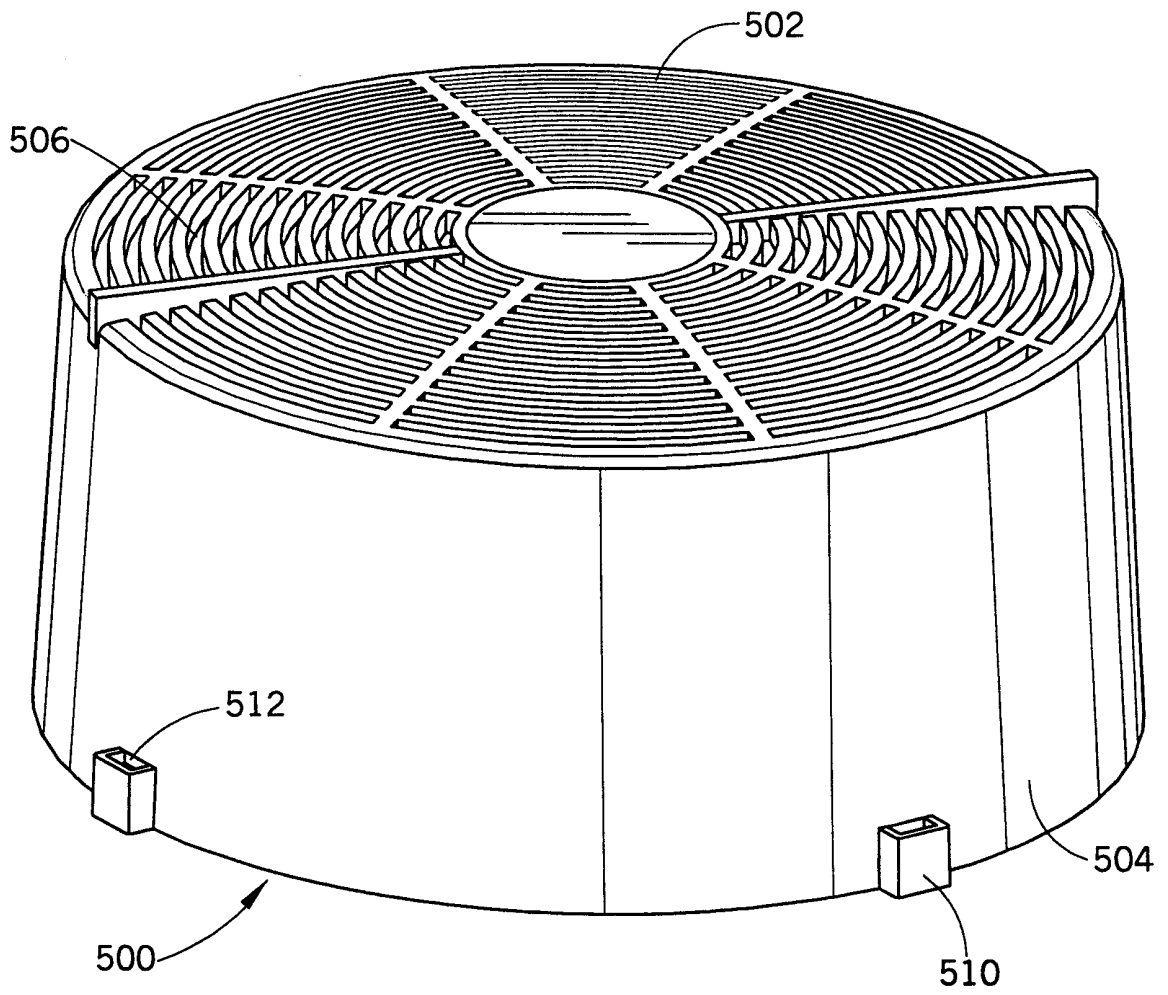


FIG. 15

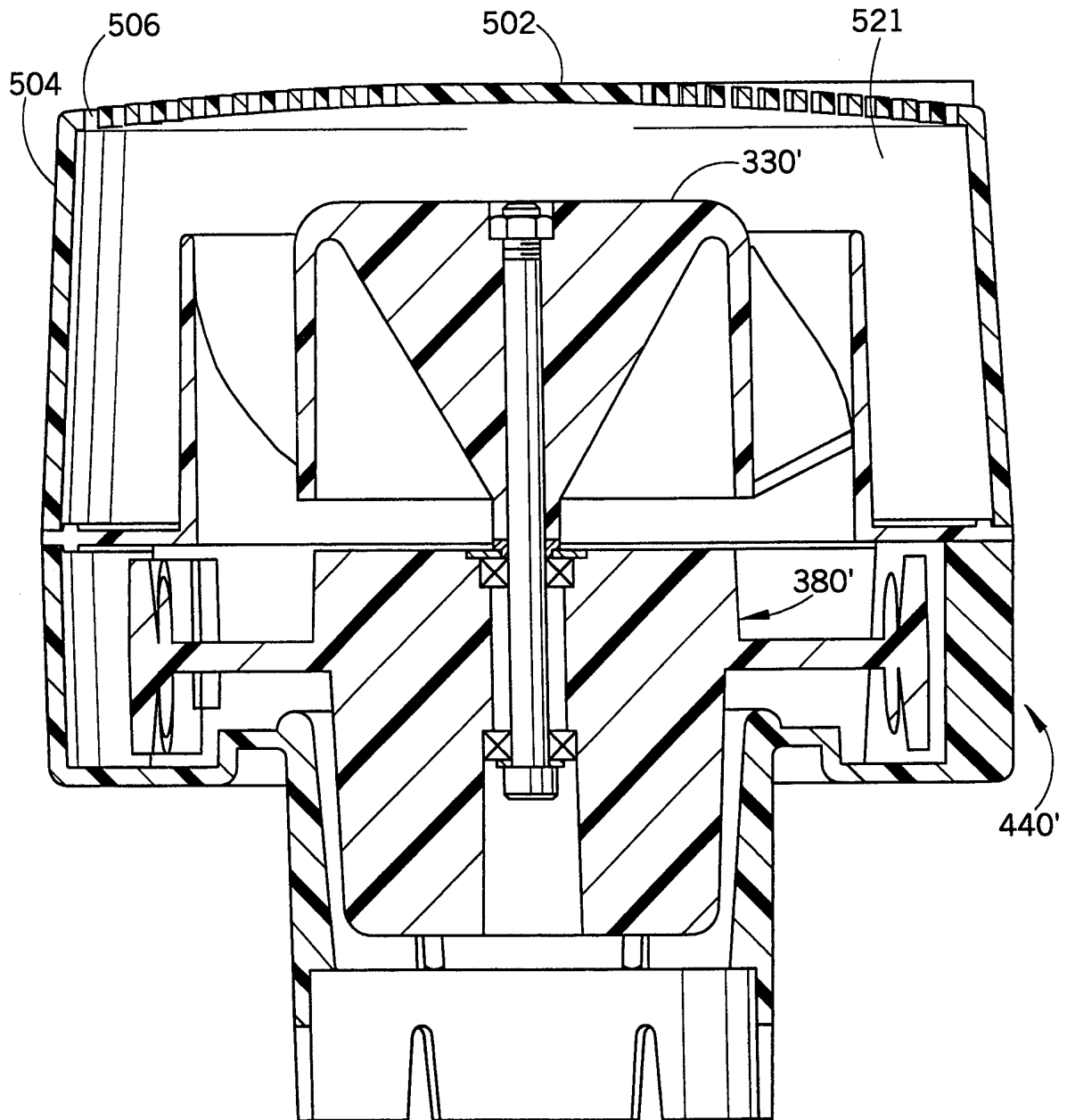


FIG. 16