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(71) Applicant *(for all designated States except US)*: **MAG AEROSPACE INDUSTRIES, INC.** [US/US]; 1500 Glenn Curtiss Street, Carson, California 90746 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **DANDASI, Sasikanth** [IN/US]; 8312 Delta Drive, Apt. #1, Machesney Park, Illinois 61115 (US). **WINDGASSEN, William** [US/US]; 8031 Cheri Drive, S. Beloit, Illinois 61080 (US). **LOMBARDI, Vincent** [US/US]; 5902 Denbury Lane, Loves Park, Illinois 61111 (US).

(74) Agents: **PRATT, John** et al.; Kilpatrick Stockton LLP, 1100 Peachtree Street, N.E., Suite 2800, Atlanta, GA 30309 (US).

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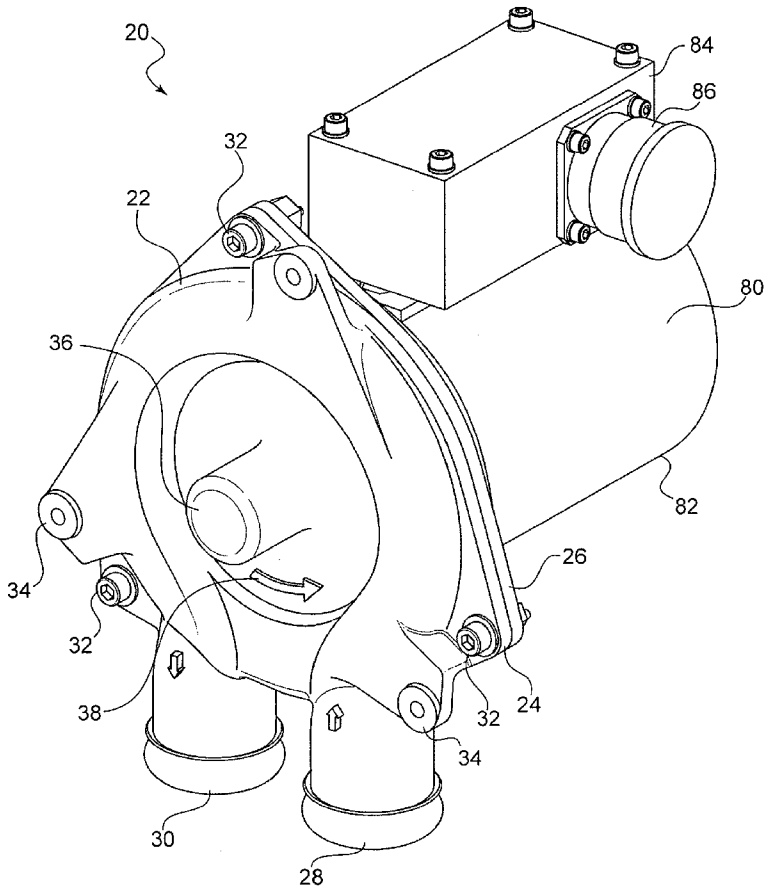
(54) Title: REGENERATIVE VACUUM GENERATOR FOR AIRCRAFT AND OTHER VEHICLES



(57) Abstract: Embodiments of the present invention relate generally to regenerative vacuum generators for use on aircraft or other transportation vehicles. Embodiments of the invention further relate to modified regenerative vacuum generators (20) that provide a larger area for air flow, as well as provide larger RPMs than typical regenerative vacuum generators. Further embodiments of the invention relate to modified regenerative vacuum generators (20) for use on aircraft or other transportation vehicles. These features help generate high flow and vacuum in less time, which ensure a good vacuum system, and allow the generators to be much smaller than generators currently used in these applications.

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REGENERATIVE VACUUM GENERATOR FOR AIRCRAFT AND OTHER VEHICLES

This application claims the benefit of U.S. Provisional Application Serial No. 60/812,739, filed June 12, 2006 titled "Vacuum Generator for Aircraft," the entire contents of which are hereby incorporated by reference.

Field of the Invention

This invention relates generally to vacuum generators for aircraft or other transportation vehicles and, more specifically, to vacuum generators to operate a waste system within an aircraft or vehicle during ground and low altitude operations.

Background of the Invention

Vacuum systems have been used to forcefully withdraw waste and rinse water from the toilet bowl of aircraft toilet systems and through the drain into a waste holding tank. In such systems, the tank is situated remotely and vented to the atmosphere outside the aircraft, and the toilet bowl is situated inside the pressurized passenger cabin and maintained at cabin pressure. At altitudes generally above 15,000 feet, the difference in pressure between the atmospheric pressure outside the aircraft and the cabin pressure inside the aircraft causes sufficient air flow from the toilet bowl to the tank to transport the waste. At ground level and at altitudes generally below 15,000 feet, a vacuum generator is used to artificially create or supplement vacuum in the waste tank and pipes sufficient to transport the waste.

Existing centrifugal vacuum pumps utilize two impellers and one or two diffusers, resulting in a large and complex assembly that takes up valuable space within the aircraft. Due to high inertia of existing impellers, these pumps take some time to reach full speed, which in turn requires significant time to generate high vacuum as well as high power consumption to do so. Accordingly, there is a need for vacuum generator devices that are more efficient, less complex, and less costly to manufacture.

There is also a need for vacuum pumps for use with other transportation vehicles that always remain at ground level or low altitudes. For example, buses, RVs, boats, ships, trains, and other vehicles also have a need for enhanced vacuum systems that are efficient and well-designed.

Brief Description of the Drawings

Fig. 1 is a perspective view of an embodiment of a vacuum generator according to the present invention.

Fig. 2A is an end view of the housing of Fig. 1, and Fig. 2B is a cross-section view of the housing shown in Fig. 1.

Fig. 3 is a perspective view of the motor assembly of Fig. 1.

Fig. 4 shows multiple views of an embodiment of a motor assembly of a vacuum generator according to this invention.

Fig. 5 is a perspective view of the first portion of the housing of Fig. 1.

Fig. 6 is another perspective view of the first portion of the housing of Fig. 1.

Fig. 7 shows one view of an embodiment of a first portion of a housing of a vacuum generator according to the present invention.

Fig. 8 is a perspective view of the second portion of the housing of Fig. 1.

Fig. 9 is another perspective view of the second portion of the housing of Fig. 1.

Fig. 10 shows one view of an embodiment of a second portion of a housing of a vacuum generator according to this invention.

Fig. 11 is a perspective view of a regenerative impeller positioned within the housing of Fig. 1.

Fig. 12 shows multiple views of an embodiment of a regenerative impeller of a vacuum generator according to the present invention.

Fig. 13 is a perspective view of a seal within the housing of Fig. 1.

Fig. 14 is another perspective view of the seal within the housing of Fig. 1.

Fig. 15 shows multiple views of an embodiment of a seal of a vacuum generator according to this invention.

Fig. 16 is a schematic illustration of an exemplary waste disposal system in an aircraft, showing where a vacuum generator is typically positioned in relation to the toilet assembly and other components of a waste disposal system within an aircraft.

Fig. 17A is an end view of another embodiment of a housing of a vacuum generator of this invention, and Fig. 17B is a cross-section view of the housing shown in Fig. 17A.

Summary

Embodiments of the present invention relate generally to regenerative vacuum generators for use on aircraft or other transportation vehicles. Embodiments of the invention further relate to

modified regenerative vacuum generators that provide a larger area for air flow, as well as provide larger RPMs than typical regenerative vacuum generators. Further embodiments of the invention relate to modified regenerative vacuum generators for use on aircraft or other transportation vehicles. These features help generate high flow and vacuum in less time, which ensure a good vacuum system, and allow the generators to be much smaller than generators currently used in these applications.

More specifically, embodiments of the present invention also provide devices and methods for generating vacuum to operate a waste system within an aircraft during ground or low altitude operations. An exemplary embodiment of a vacuum generator of this invention comprises a housing coupled to a motor assembly. In most instances, a single regenerative impeller is positioned within the housing and driven by a drive shaft of the motor assembly to generate vacuum. The use of a single impeller is more efficient than existing devices, such as centrifugal style vacuum generators that utilize two impellers and one or two diffusers, because the single impeller reaches full speed and generates high vacuum in less time and requires less power consumption. A seal may fit within a portion of the housing adjacent the motor assembly. The seal prevents gasses from going into the motor assembly during operation, such that air flows only from the motor assembly to the housing and not vice versa, and also limits gases flowing into the motor assembly when not operating.

In some aspects, the invention relates to an apparatus for generating vacuum on an aircraft or transportation vehicle, comprising a regenerative vacuum generator comprising a single impeller. Further aspects relate to specific regenerative vacuum generator, comprising: a housing with a first portion and a second portion secured together; the first portion and second portion collectively defining a central passageway, a motor assembly coupled to the housing, the motor assembly having a drive shaft; and a regenerative impeller mounted to the drive shaft of the motor assembly, the impeller being positioned within the housing, wherein the central passageway has a cross section and the impeller has a cross-section, and wherein the cross-section of the central passageway is about two to about five times the cross section of the impeller. Another aspect relates to these specific regenerative vacuum generators for use in connection with waste systems of transportation vehicles, such as aircraft.

Detailed Description of the Invention

In one embodiment, the housing of the vacuum system comprises a first portion and a second portion coupled to the first portion, for example, with fasteners. The housing may be made of an aluminum alloy to provide a lightweight construction. Other possible materials for

the housing include titanium, stainless steel, carbon fiber, or any other appropriate material. It is preferred to use materials that are sufficiently lightweight to provide the advantages described, but that also provide the required structural integrity of the design. A seal may be disposed within the housing adjacent to the second portion of the housing around where a drive shaft of the motor assembly extends into the housing. The second portion of the housing has holes in its exterior surface to allow for run out of any debris and condensation from the housing. These holes, the seal, and the vortex design help keep moisture-laden air and semi-solid particles from coming into contact with the motor assembly. When combined, the two housings forms a central passageway which is proportional to the air flow. In some embodiments, the central passageway provides a larger area than passageways that are currently provided on regenerative vacuum regenerators. For example, in one embodiment, the relationship between the cross-section of the impeller and the cross-section of the passageway in which the impeller rotates is increased two to five times, as compared to traditional regenerative vacuum generators. For example, prior art generators provide a ratio of the cross-section of the impeller to the passageway of about 1.7. Embodiments of this invention provide that ratio as between two to five times that. In specific embodiments, the ratio is about 3.5, and in other embodiments, the ratio is about 6.8. This increased ratio helps to provide greater air flow and vacuum generation.

In an exemplary embodiment, the regenerative impeller mounted within the housing to the drive shaft of the motor assembly, and the motor assembly is configured to drive the impeller at speeds of about 10,000 RPM to about 60,000 RPM in other embodiments, about 15,000 RPM to about 50,000 RPM in further embodiments, about 15,000 RPM to about 30,000 RPM in more specific embodiments, about 15,000 RPM to about 25,000 RPM in even more specific embodiments, and up to about 24,000 RPM in even more particular embodiments. This is much higher than existing regenerative pumps typically used in industrial applications, which drive impellers at about 5,000 RPM. Examples of some of the features described in this application that allow this faster speed are that the impeller is made of a relatively lightweight material, it is smaller than typical impellers, the motor is stronger than typical regenerative pumps, the central passageway is larger than in typical regenerative pumps, a seal is provided to help direct air, and the inlet and outlets are specially designed. As described in more detail below, these features, either alone or in combination in various embodiments, can provide a pump that can move air more quickly and generate much higher RPMs than those typically seen with regenerative pumps. The motor assembly may be designed to run on variable frequency power.

In operation, certain embodiments of vacuum generators of this invention work as follows. Upon receiving a flush signal during ground or low altitude operation, the generator is

signaled to turn on in order to generate a vacuum within the waste system. Vacuum is created by evacuating air from the waste tank and discharging it overboard. The generator includes an impeller mounted directly on a motor shaft and is rotated at a high speed, for example at the speeds described above, and in one example, up to about 24,000 RPM in one embodiment. On the periphery of the regenerative impeller there are large number of straight blades. It is advantageous that the blades may be provided as straight, as opposed to being curved, rotated, or bent on the edges like blades of impellers of current regenerative vacuum regenerators. Because the impellers for use with this system are typically smaller than traditional impellers, there is less area for a bend or curve, but it has been found that this design may help reduce noise and makes manufacturing easier. As the impeller spins and its blades or fins pass an inlet port of the housing, a low pressure area is created that draws in air, or other gases. The impeller blades impart motion to the air by centrifugal force, throwing it outward and forward, where it follows the contour of a central passageway within the housing around the impeller and is returned to the base, or root, of the impeller. This action is repeated many times, creating a vortex. Each "regeneration" causes the air to gain pressure, until it reaches the portion of the housing where the air is stripped from the impeller and discharged from the outlet of the vacuum generator.

If used in connection with a vacuum waste system, waste from the toilet bowl is transported to the waste tank when, after a short delay, the toilet assembly flush valve opens, exposing the waste in the toilet bowl to the vacuum created by the vacuum generator. Once the toilet flush valve closes, the vacuum generator continues to operate for a short period of time prior to powering off. Aircraft toilet flush valves, as well as other transportation vehicle flush valves, are well understood by those skilled in the art, and an exemplary aircraft toilet flush valve is described in U.S. Patent No. 4,783,859, which is incorporated by reference herein in its entirety. Although various embodiments of the vacuum generator described herein are discussed primarily in conjunction with use in aircraft, it should be understood that vacuum generators of this invention may be used and useful in other environments, with any necessary modifications being well understood by those skilled in the art.

Referring now to the figures, Fig. 1 shows an exemplary embodiment of a vacuum generator or device 20 according to this invention. Device 20 includes a housing 22 coupled to a motor assembly 80. Ambient air is drawn into motor assembly 80 through vent holes situated on motor assembly 80 (and also used for cooling the motor) and then into housing 22 of device 20. Motor assembly 80 is shown in isolation in Fig. 3, and multiple views of an exemplary embodiment of a motor assembly are shown in the engineering drawings of Fig. 4, including exemplary dimensions, materials, and the like. Motor assembly 80 is preferably made of

aluminum alloy, although other suitable materials may be used, such as titanium, stainless steel, carbon fiber, or any other appropriate material. It is preferred to use materials that are sufficiently lightweight to provide the advantages described, but that also provide the required structural integrity of the design.

Motor assembly 80 includes a motor housing 82 and an electrical box 84 mounted atop motor housing 82. Mounting electrical box 84 away from the components within motor housing 82 protects the electronics of motor assembly 80 from the heat given off by the motor during operation. An electrical connector 86 extends from electrical box 84 for connection of device 20 to the electrical power of the aircraft or other environment within which device 20 may be used. A drive shaft 88 extends from motor assembly 80. A portion of drive shaft 88 extends into housing 22, as shown in Fig. 2B, and an impeller 60 and seal 70 within housing 22 is mounted on and rotated by drive shaft 88, as generally described above for example. Threaded holes 90 receive fasteners, such as fasteners 96 shown in Fig. 2B, for securing housing 22 to motor assembly 80.

Housing 22 comprises a first portion 24 and a second portion 26. In addition to Figs. 1, 2A, and 2B, first portion 24 is shown in isolation in Figs. 5 and 6, and multiple views of an exemplary embodiment of a first portion are shown in the engineering drawings of Fig. 7. Similarly, second portion 26 is shown in isolation in Figs. 8 and 9, and multiple views of an exemplary embodiment of a second portion are shown in the engineering drawings of Fig. 10. First and second portions 24 and 26 are secured with fasteners 32. Fasteners 32 extend through holes 33 in first portion 24 (as shown in Figs. 5 and 6) and corresponding holes 43 in second portion 26 (as seen best in Figs. 8 and 9). First portion 24 also includes holes 34 for mounting housing 22 to other structure within an aircraft or other environment in which device 20 may be used. A protrusion 36 in first portion 24 defines a cavity 37 (see Fig. 6) within which a portion of drive shaft 88 extends when housing 22 and motor assembly 80 are fully assembled. Both first and second portions 24 and 26 of housing 22 are preferably made from aluminum alloy. Other suitable materials well known to those skilled in the art may be used.

Housing 22 includes an inlet 28 and an outlet 30. Inlet 28 is formed by inlet portion 28A of first portion 24 (see Fig. 6) and inlet portion 28B of second portion 26 (see Fig. 9). Similarly, outlet 30 is formed by outlet portion 30A (see Fig. 6) and outlet portion 30B (see Fig. 9). As shown in Fig. 5, arrows mark the inlet and outlet, and an arrow 38 marks the rotational direction of impeller 60 and the air within housing 22. As shown in Figs. 6 and 9, in certain embodiments, the diameter of inlet 28 decreases as the inlet opening extends further into housing 22 leading to a central passageway 40 in housing 22. This helps increase velocity of air entering the system, and

helps decrease the velocity of air as it exits the system. Central passageway 40 is formed by a channel 40A in first portion 24 and a channel 40B in second portion 26, which join together to form passageway 40 when first and second portions 24 and 26 are secured together. The cross-sectional area of the central passageway 40 is increased by about two to about five times compared to traditional regenerative impeller generators in order to achieve about two to about five times more air flow. The ratios between the cross-sections of the impeller and the passageway are described above. This enlarged passageway, combined with the tapered inlet and outlet and higher RPMs will generate higher flow and vacuum in less time, which ensure a good vacuum system. Moreover, certain embodiments of the impeller generators described may be smaller in their overall dimension than impeller generators that are currently provided, and they are much smaller than the centrifugal generators that are currently used on aircraft to create vacuum for waste systems.

In one embodiment, passageway 40 is generally tubular as it circles around housing 22 toward outlet 30. Impeller 60 is mounted inside housing 22 such that it draws air through inlet 28 and through passageway 40. As shown in Figs. 6 and 9, the diameter of outlet 30 increases as the outlet opening extends from adjacent central passageway 40 toward the exit of housing 22.

The velocity of the air moving through housing 22 increases as the diameter of the air passageway is reduced from the inlet, and decreases as central passageway 40 widens into outlet 30. In an embodiment, the air velocity is about Mach 0.5 in the central passageway and is about Mach 0.1 at the outlet and inlet. As is well understood by those skilled in the art, Mach 1.0 (or the speed of sound) is not a constant, but depends on the altitude (or actually the temperature at that altitude). For example, an aircraft flying Mach 1.0 at sea level is flying about 1225 km/h (661 Knots, 340 m/s), while a plane flying Mach 1.0 at 30,000 ft is flying 1091 km/h (589 knots, 303 m/s).

Second portion 26 of housing 22, shown in isolation in Figs. 8 and 9, includes a central portion 42 within which channel 40B is formed and three flanges 44 that includes holes 43 for receiving fasteners to secure second portion 26 to first portion 24. Second portion 26 includes openings 46 for mounting housing 22 to a portion of motor assembly 80, and an aperture 48 through which drive shaft 88 of motor assembly 80 extends. Holes 50 and grooves 52 extending therefrom allow for debris and condensation to run out of housing 22 during operation. Referring now to Fig. 9, a section inside channel 40A has an outer diameter 54, a center diameter 56, and an inner diameter 58 that defines aperture 48. The stepped configuration shown allows a seal 70 to be used within housing 22 within center diameter 56 such that the seal accomplishes its intended purpose while not interfering with second portion 26 and impeller 60.

Seal 70 is shown in isolation in Figs. 13 and 14, in cross-section in Fig. 2B, and multiple views of an exemplary embodiment of a seal are shown in the engineering drawings of Fig. 15. The outer diameter of seal 70 is about the same as center diameter 56 of second portion 26 of housing 22. Seal 70 prevents gasses from going into motor assembly 80 during operation, such that the only air flow (other than that within housing 22) is from motor assembly 80 to housing 22. Seal 70 allows air through the motor vent holes into the housing, which acts as a coolant to the motor. Seal 70 is preferably made from stainless steel, although other materials, such as aluminum or an aluminum alloy, titanium, carbon fiber, or any other materials that may provide a seal with the desired function may also be used. Seal 70 includes an opening 72 through which drive shaft 88 passes from motor assembly 80 and into housing 22. An angled outer portion 74 is configured such that a tight clearance is maintained with second portion 26 at center diameter 56. A central portion 76 leading to an inner wall 78 fits through aperture 48 in second portion 26.

Impeller 60 is mounted on drive shaft 88 within housing 22 through an opening 66 using a slight press fit and generally operates as described above. Impeller 70 is shown in isolation in Figs. 11 and 12, in cross-section in Fig. 2B, and multiple views of an exemplary embodiment of an impeller are shown in the engineering drawings of Fig. 13. Impeller 60 includes straight fins 62 with a rib 64 between each fin 62, producing air flow on both sides of impeller 60. In a preferred embodiment, impeller 60 is made from aluminum or an aluminum alloy, although other materials are possible such as titanium, stainless steel, carbon fiber, or any other appropriate material. It is preferred to use materials that are sufficiently lightweight to provide the advantages described, but that also provide the required structural integrity of the design.

It should be understood that the below ranges and dimensions are provided as examples only and in no way are they intended to limiting of the designs described herein. They are simply provided for purposes of illustration and to describe one specific set of embodiments that may be manufactured. With that caveat, possible dimension ranges for the above-described components may include the following ranges:

- Housing (22): height of about 5.5” – 7.5”
- Inlet/outlet (28/30):
  - inner diameter: about 0.5” – 1.25”
  - outer diameter: about 1.0” – 1.5”
- Impeller (60) – diameter of about 3.5”-5.5” (preferably about 4”)
- Seal (70): diameter of about 0.5”- 2.0”

Again, without intending to be limiting, in an alternate embodiment, for example the design shown in FIG 17, possible ranges may also be:

- Housing (122): height of about 8.5" to 10.5"
- Inlet/outlet (128/130):
  - inner diameter: about 1.25" to 2.25"
  - outer diameter: about 2" to 2.5"
- Impeller (160): diameter of about 3.5" – 5.5" (preferably about 4.8")
- Seal: diameter of about 0.5" - 2.0"

Fig. 16 is a schematic illustration of an exemplary waste disposal system in an aircraft, showing where a vacuum generator such as device 20 is typically positioned in relation to the toilet assembly and other components of a waste disposal system within an aircraft. Figs. 17A and 17B show another embodiment of a housing 122 of a vacuum generator. As can be seen from the drawings, housing 122 is configured differently than housing 22 of device 20 in that it is larger that housing 22, but housing 122 still includes first and second portions 124 and 126 joined by one or more fasteners 132, an inlet 128, an outlet 130, and an impeller 160 mounted on a drive shaft 188 within housing 122 such that it creates air flow through a passageway 140 in housing 122.

The foregoing description of the exemplary embodiments of the invention has been presented only for the purposes of illustration and description and is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations are possible in light of the above teaching. The embodiments were chosen and described in order to explain the principles of the invention and their practical application so as to enable others skilled in the art to utilize the invention and various embodiments and with various modifications as are suited to the particular use contemplated. Alternative embodiments will become apparent to those skilled in the art to which the present invention pertains without departing from its spirit and scope.

Claims

What is claimed is:

1. An apparatus for generating vacuum on an aircraft or transportation vehicle, comprising a regenerative vacuum generator comprising a single impeller.

2. The apparatus of claim 1 adapted for use within an aircraft vacuum waste system.

3. A regenerative vacuum generator, comprising:

a housing with a first portion and a second portion secured together; the first portion and second portion collectively defining a central passageway,

a motor assembly coupled to the housing, the motor assembly having a drive shaft; and

a regenerative impeller mounted to the drive shaft of the motor assembly, the impeller being positioned within the housing,

wherein the central passageway has a cross section and the impeller has a cross-section, and wherein the cross-section of the central passageway is about two to about five times the cross section of the impeller.

4. The regenerative vacuum regenerators of claim 3, further comprising a seal positioned within and adjacent the second portion of the housing.

5. The regenerative vacuum regenerator of claim 4, wherein the seal is located between the impeller and second portion of the housing and is positioned on the drive shaft of the motor assembly.

6. The regenerative vacuum generator of claim 4, wherein the seal limits air flow from the housing into the motor assembly.

7. The regenerative vacuum generator of claim 4, wherein the seal helps air flow through motor vent holes into the housing, which reduces the heat generated by the motor.

8. The regenerative vacuum generator of claim 3, wherein the housing comprises an inlet and an outlet, through which air enters and leaves respectively, wherein the diameter of the inlet decreases leading to the central passageway and the diameter of the outlet increases extending away from the central passageway.

9. The regenerative vacuum generator of claim 8, wherein the change in diameter at the inlet and outlet increases the velocity of air in the central passageway and decreases the velocity of air outside the apparatus.

10. The regenerative vacuum generator of claim 3, wherein the central passageway cross section is about two times larger than the cross-section of the impeller to provide increased flow rate.

11. The regenerative vacuum generator of claim 3, wherein the central passageway cross section is about four times larger than the cross-section of the impeller to provide increased flow rate.

12. The regenerative vacuum generator of claim 3, wherein the components are made from a lightweight material.

13. The regenerative vacuum generator of claim 12, wherein the lightweight material is aluminum or an aluminum alloy.

14. The regenerative vacuum generator of claim 3, wherein the second portion of the housing includes holes for releasing debris and condensation from the housing.

15. The regenerative vacuum generator of claim 3, wherein the impeller comprises a plurality of straight fins spaced apart around a periphery of the impeller with a rib in between each fin to induce air flow on both sides of the impeller.

16. The regenerative vacuum generator of claim 3, wherein the impeller is a single impeller that rotates at about 10,000 RPM to about 60,000 RPM.

17. The regenerative vacuum generator of claim 3, wherein the impeller is a single impeller that rotates at up to about 15,000 RPM to about 30,000 RPM.

18. The regenerative vacuum generator of claim 3, wherein the system generates high flow and high vacuum in less time than traditional regenerative vacuum generators in order to provide a good flush in the aircraft vacuum waste system.

19. The regenerative vacuum generator of claim 3, configured for use in a vacuum waste system for an aircraft.

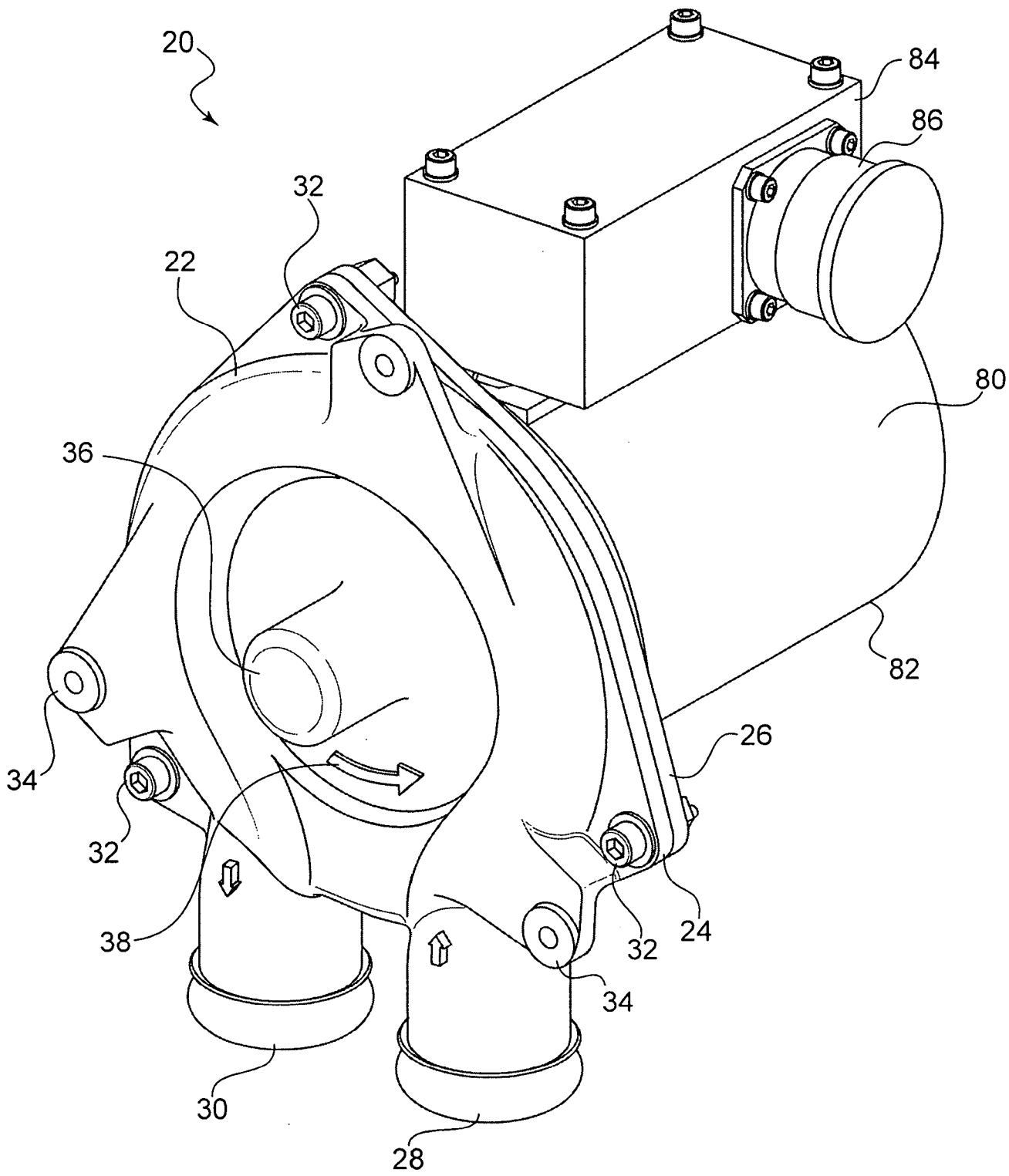

FIG. 1

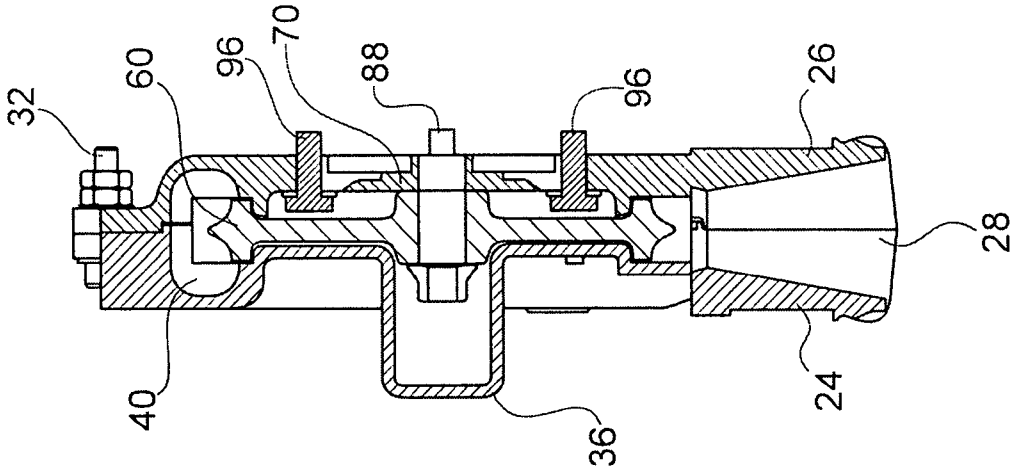

FIG. 2B

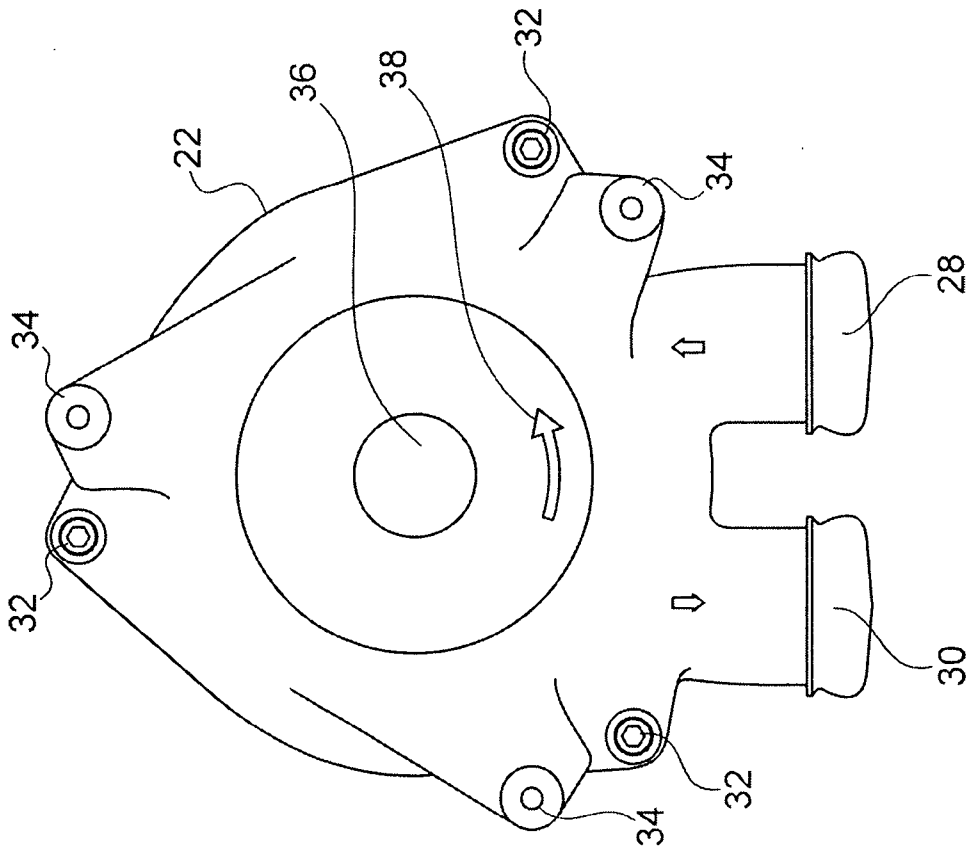

FIG. 2A

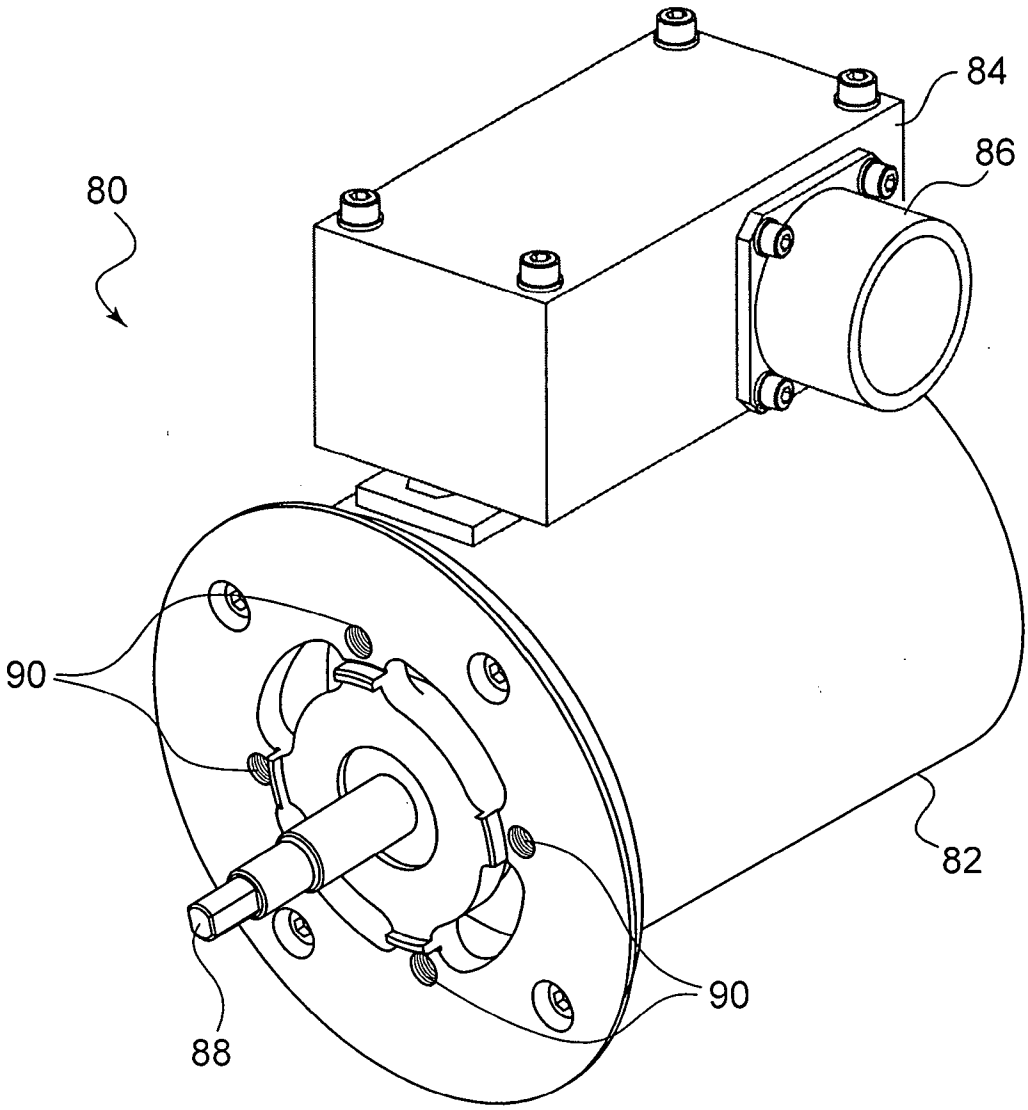

FIG. 3

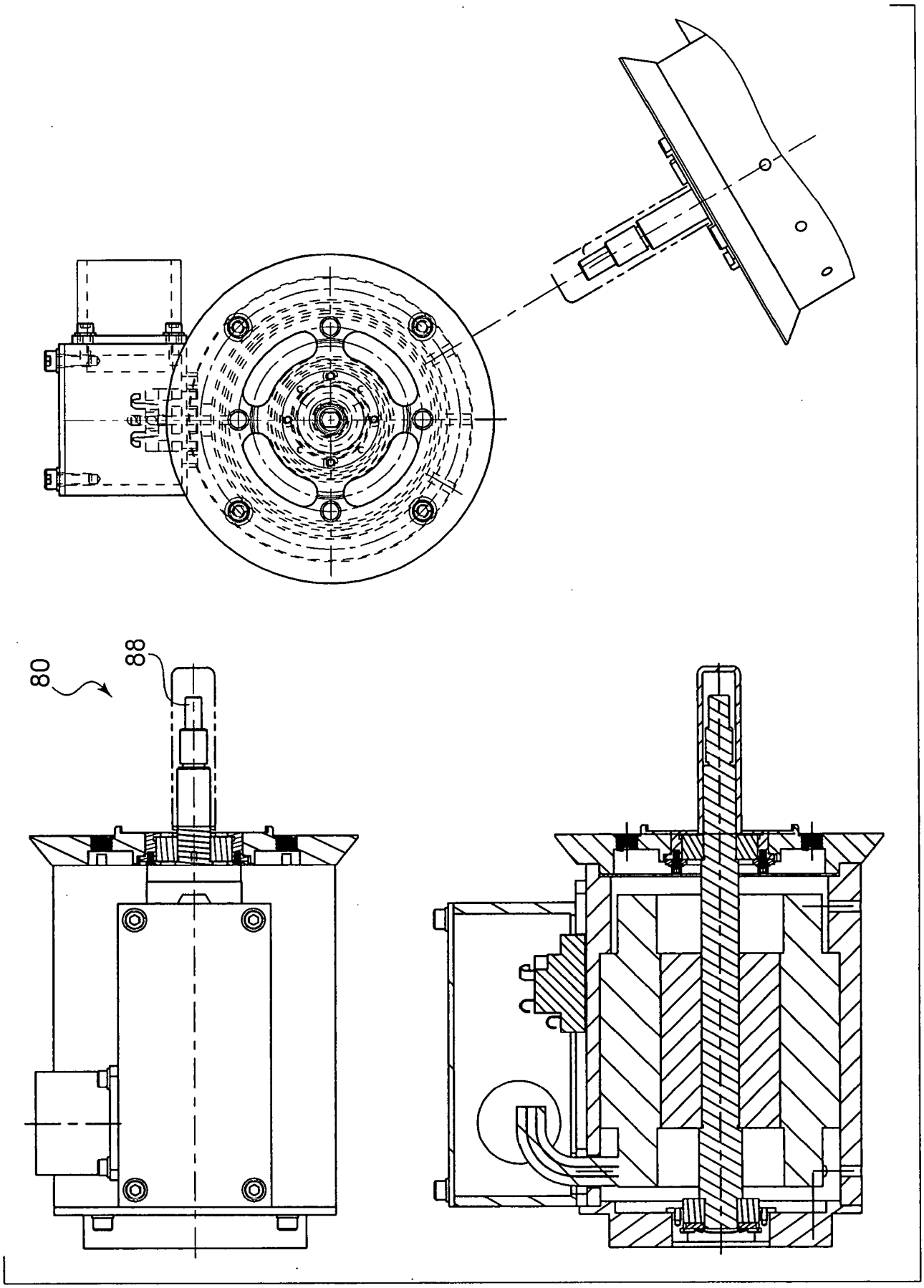

FIG. 1

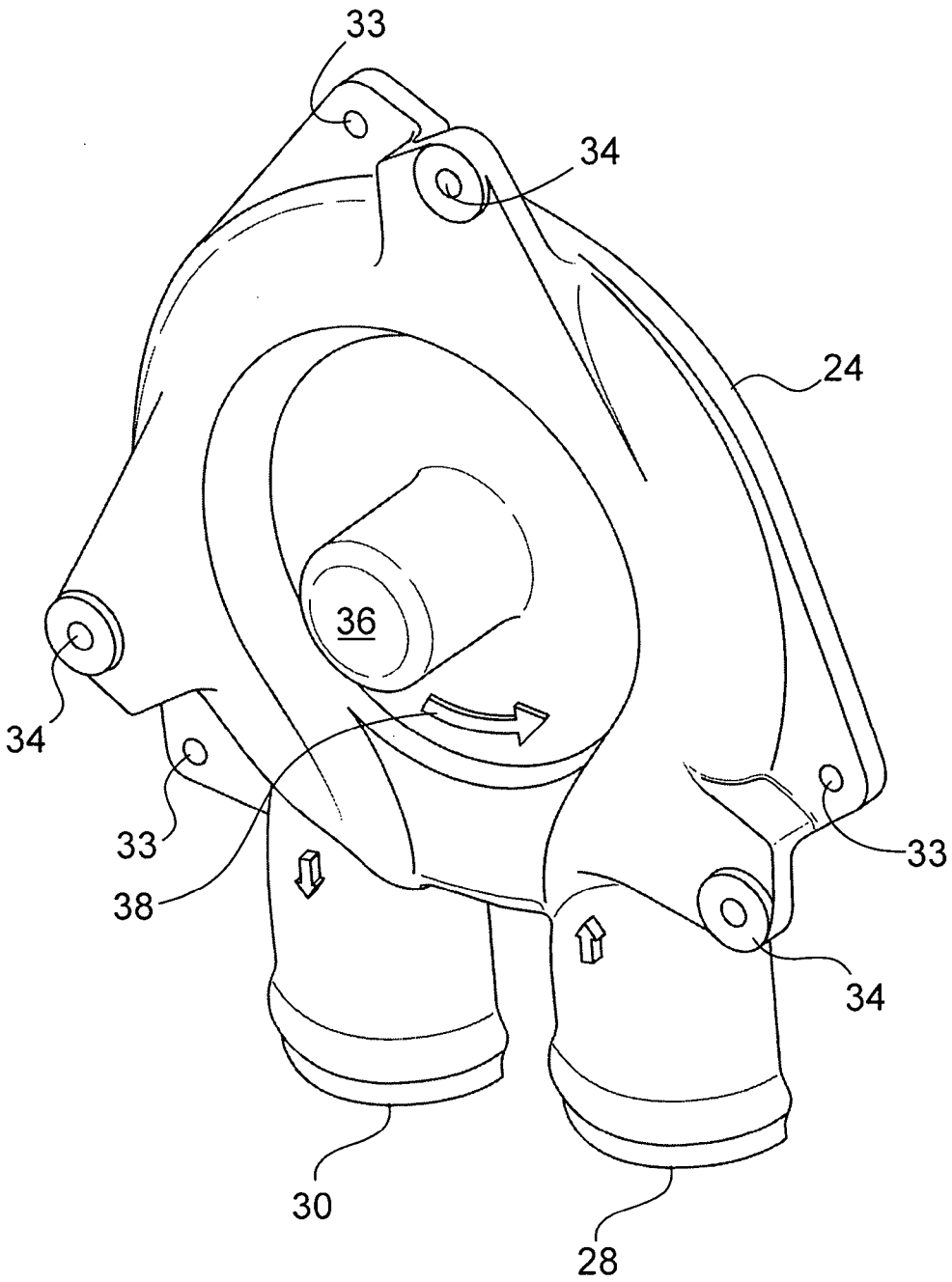

FIG. 5

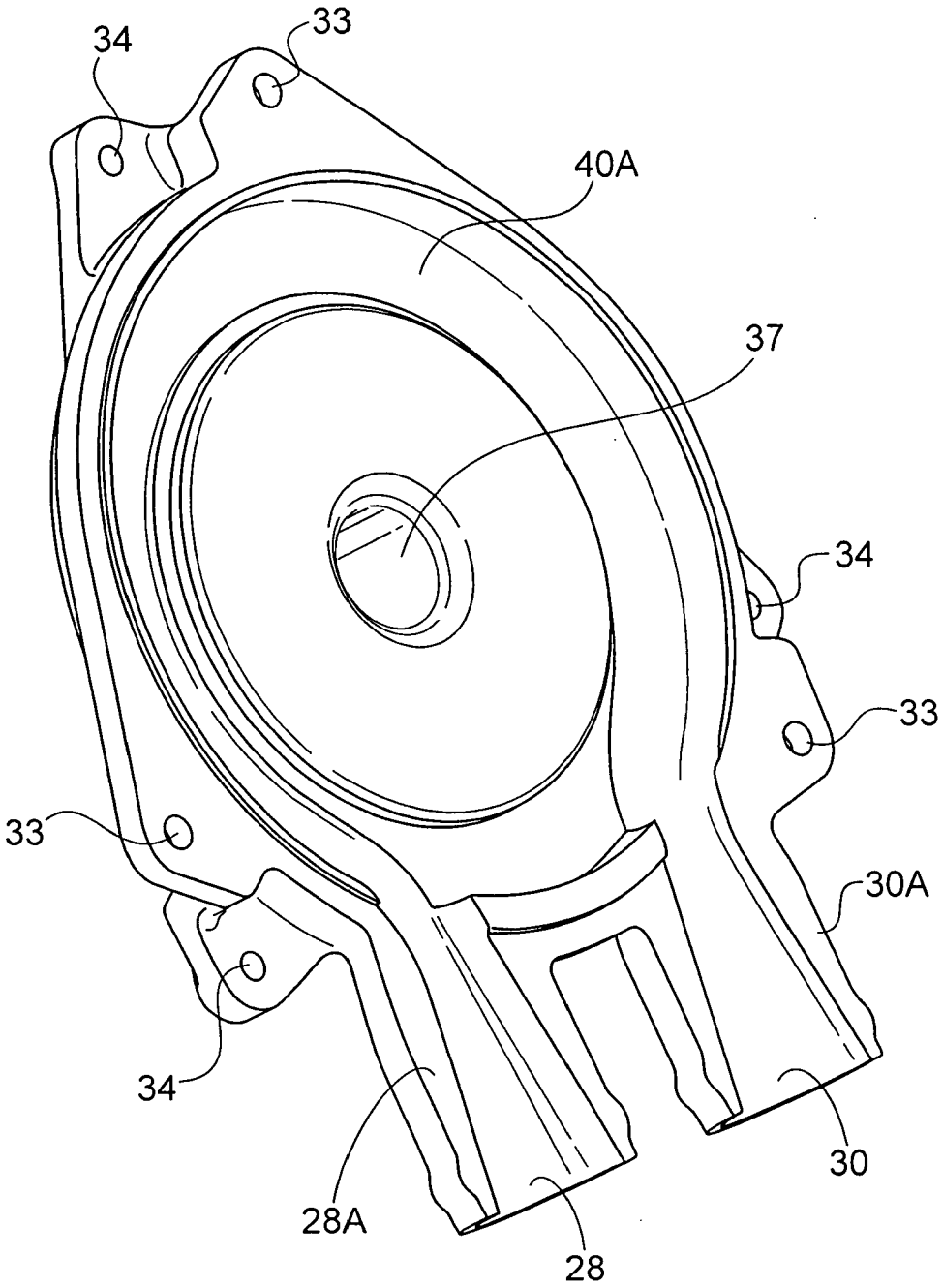

FIG. 6

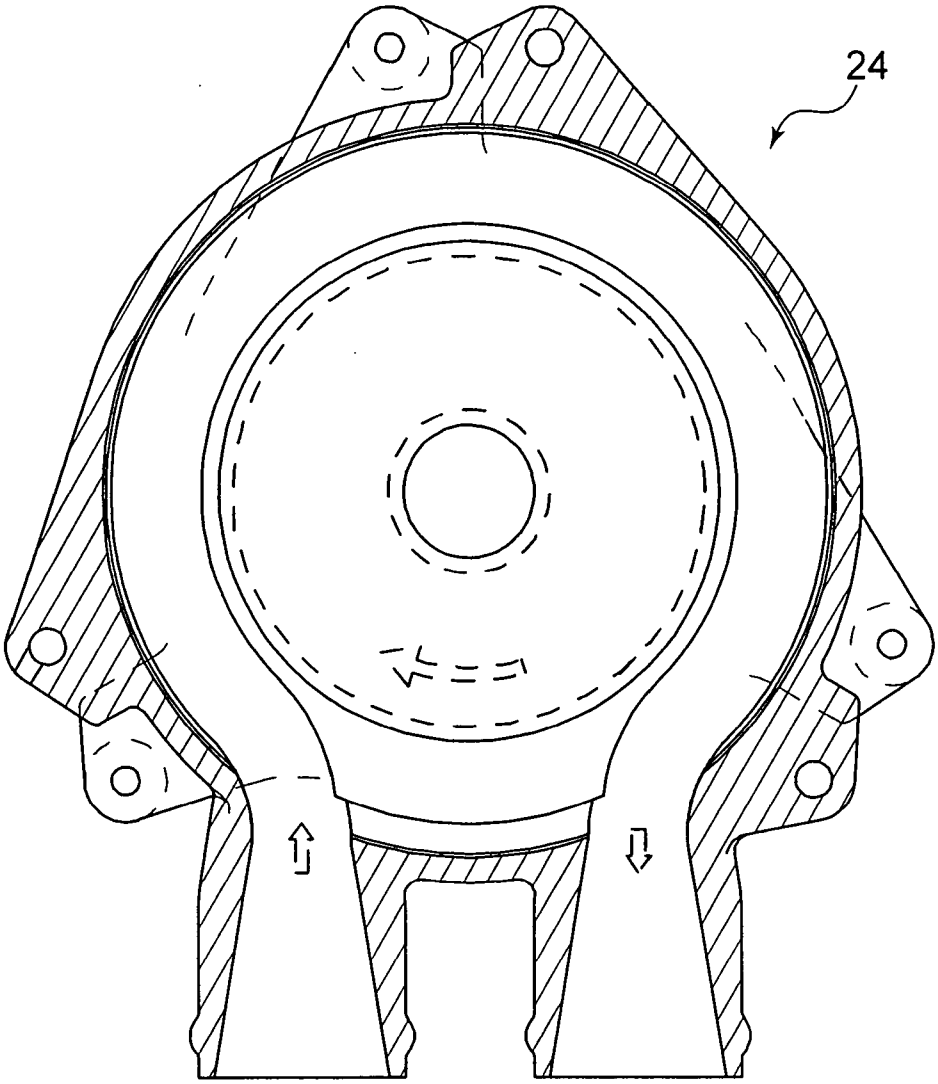

FIG. 7

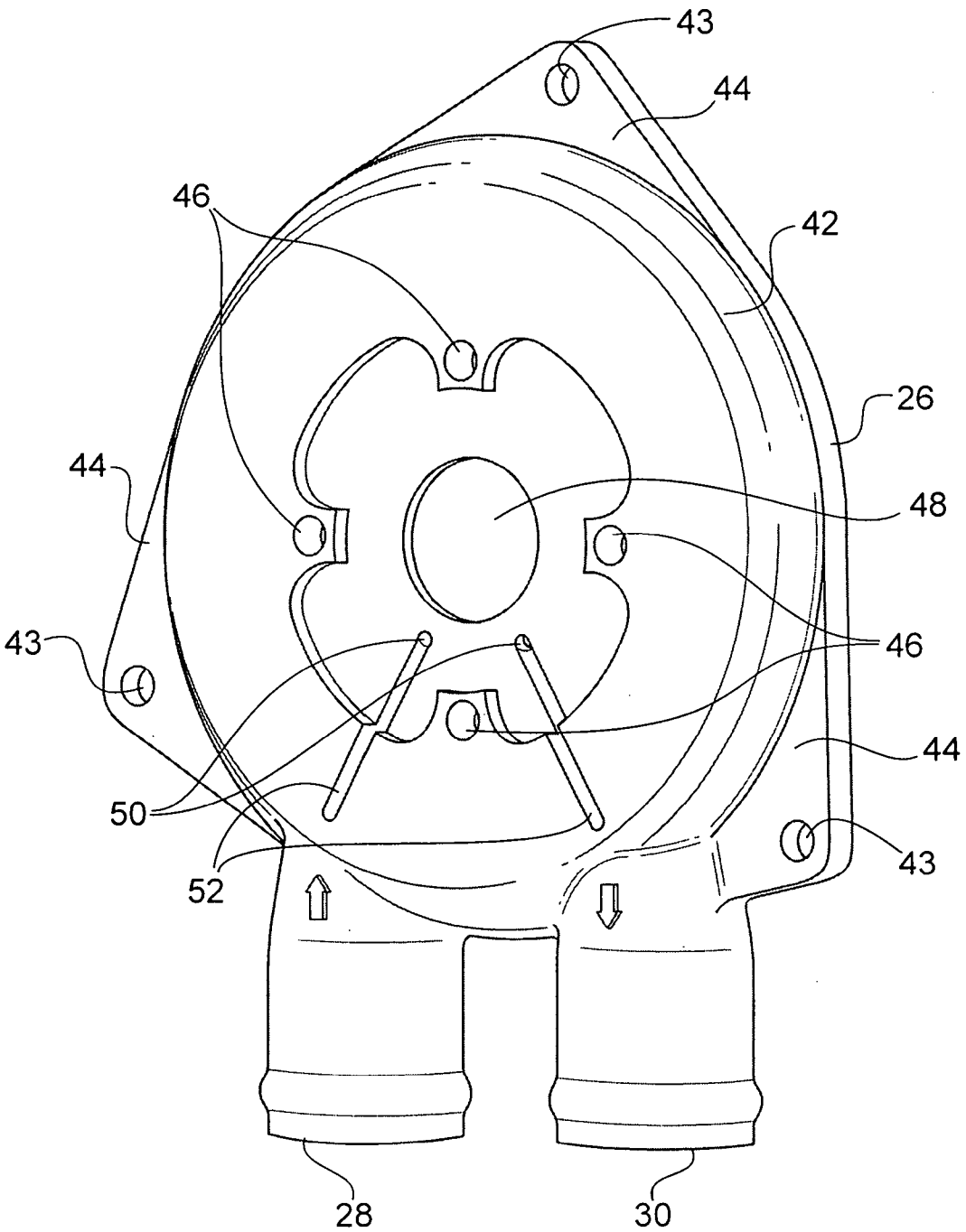

FIG. 8

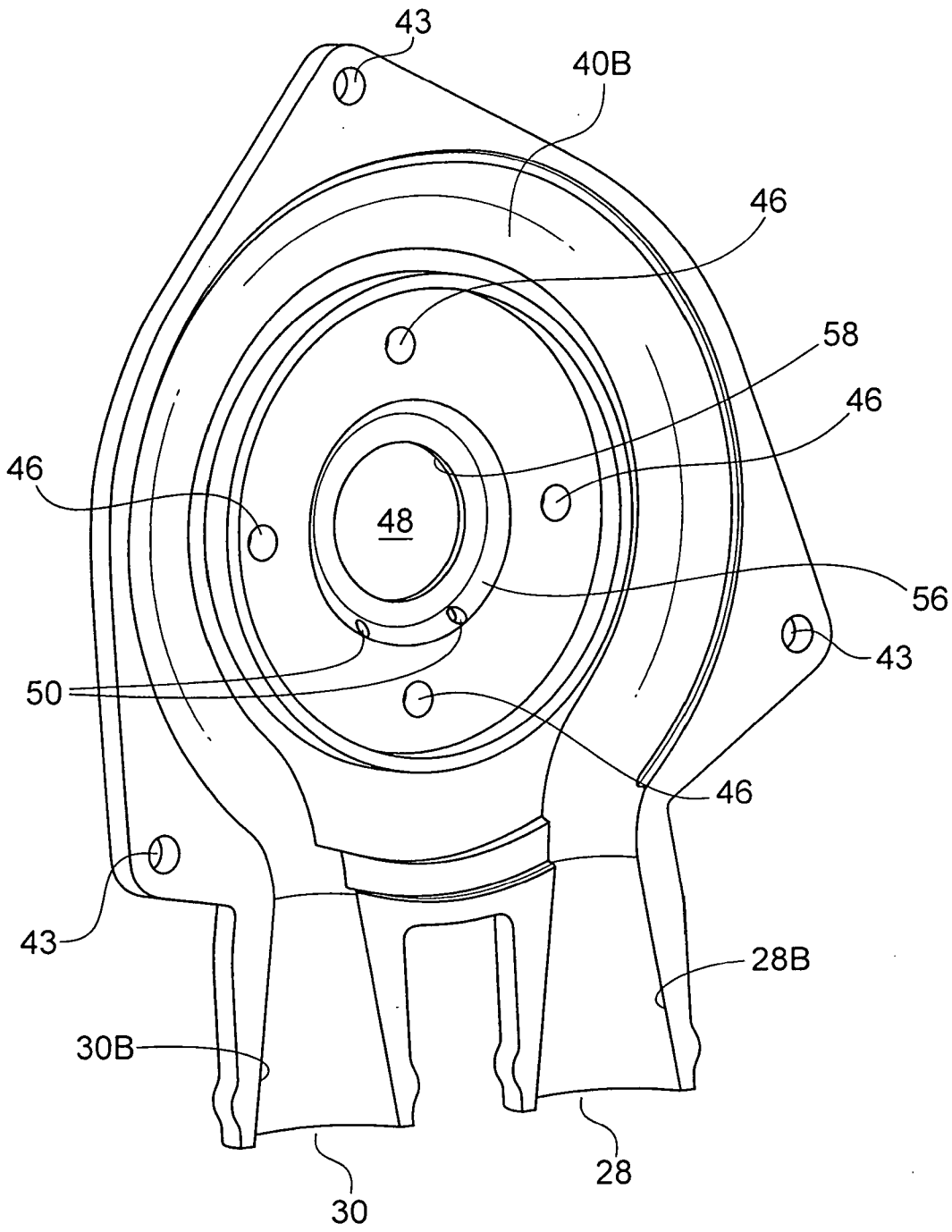

FIG. 9

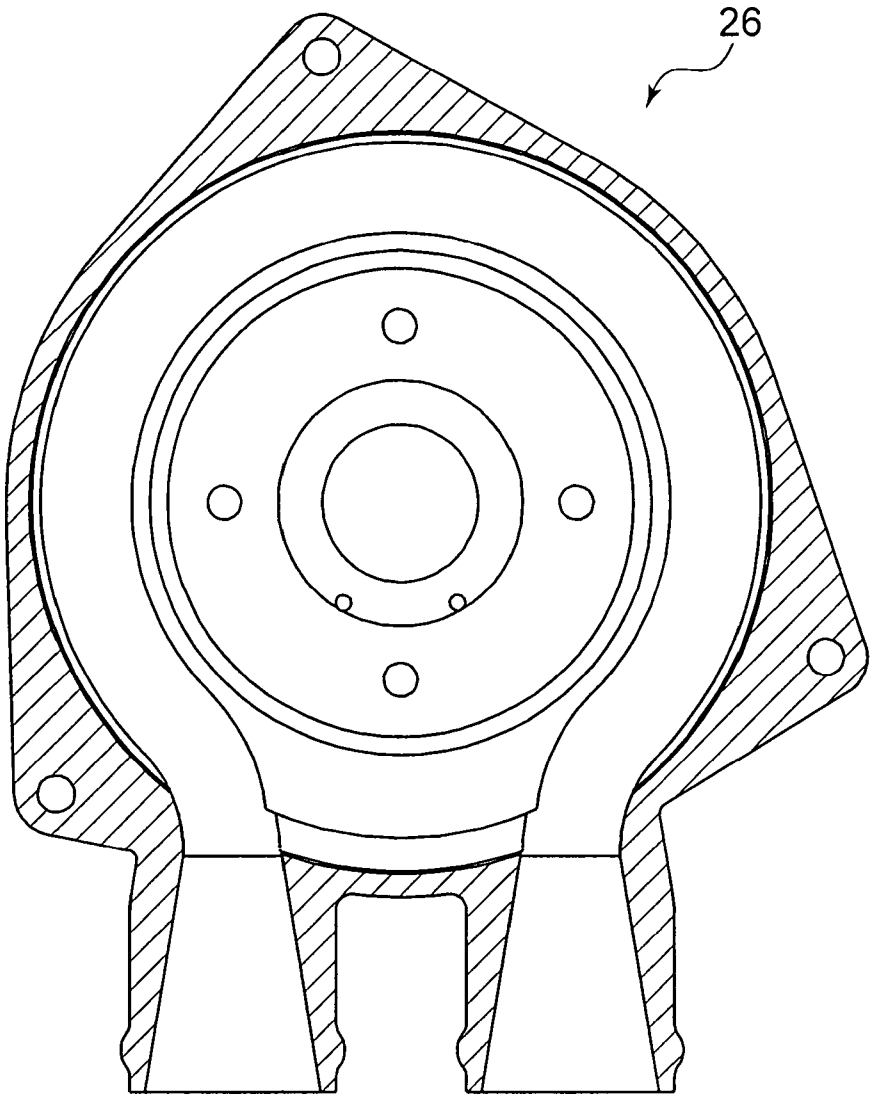

FIG. 10

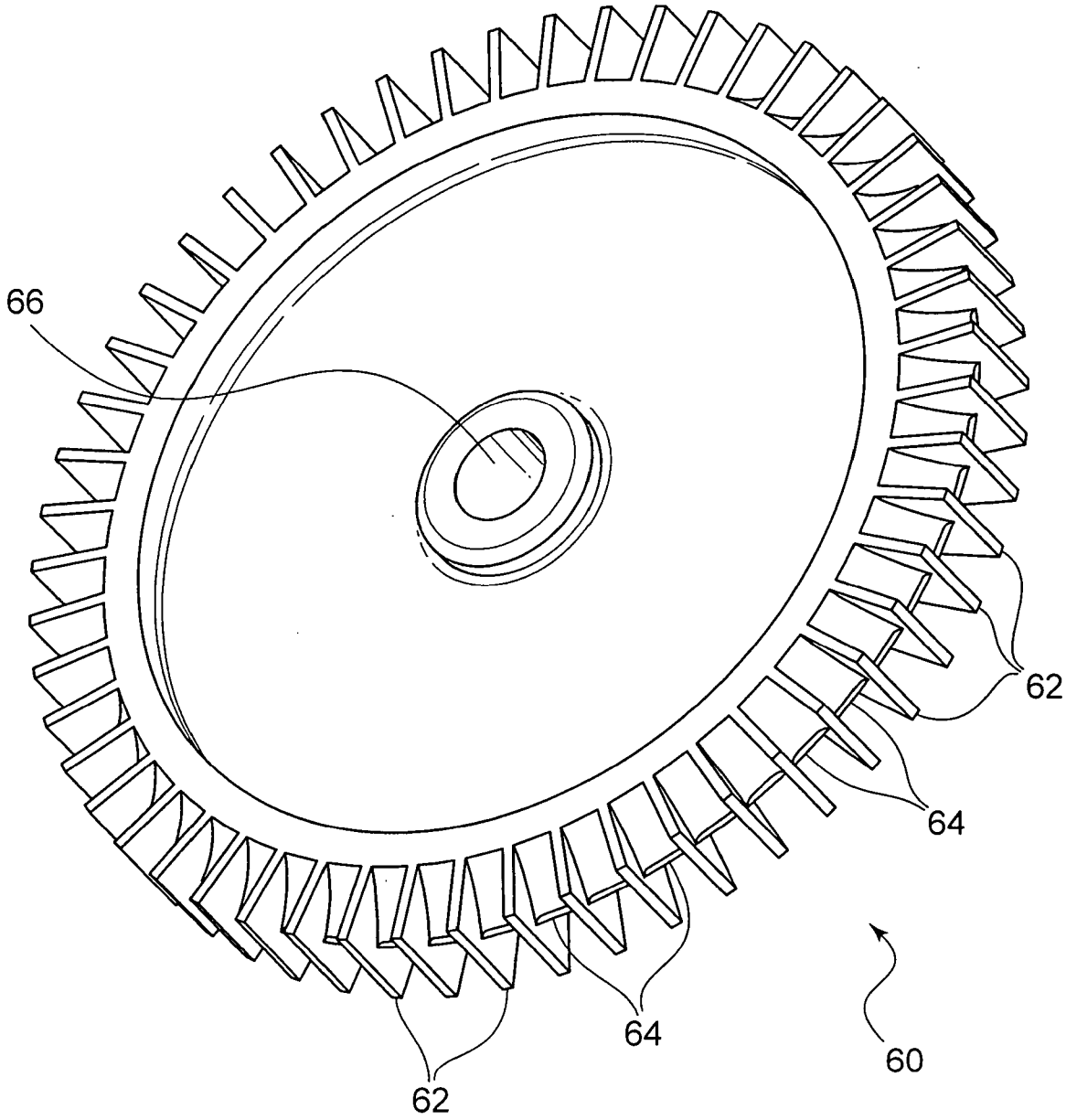

FIG. 11

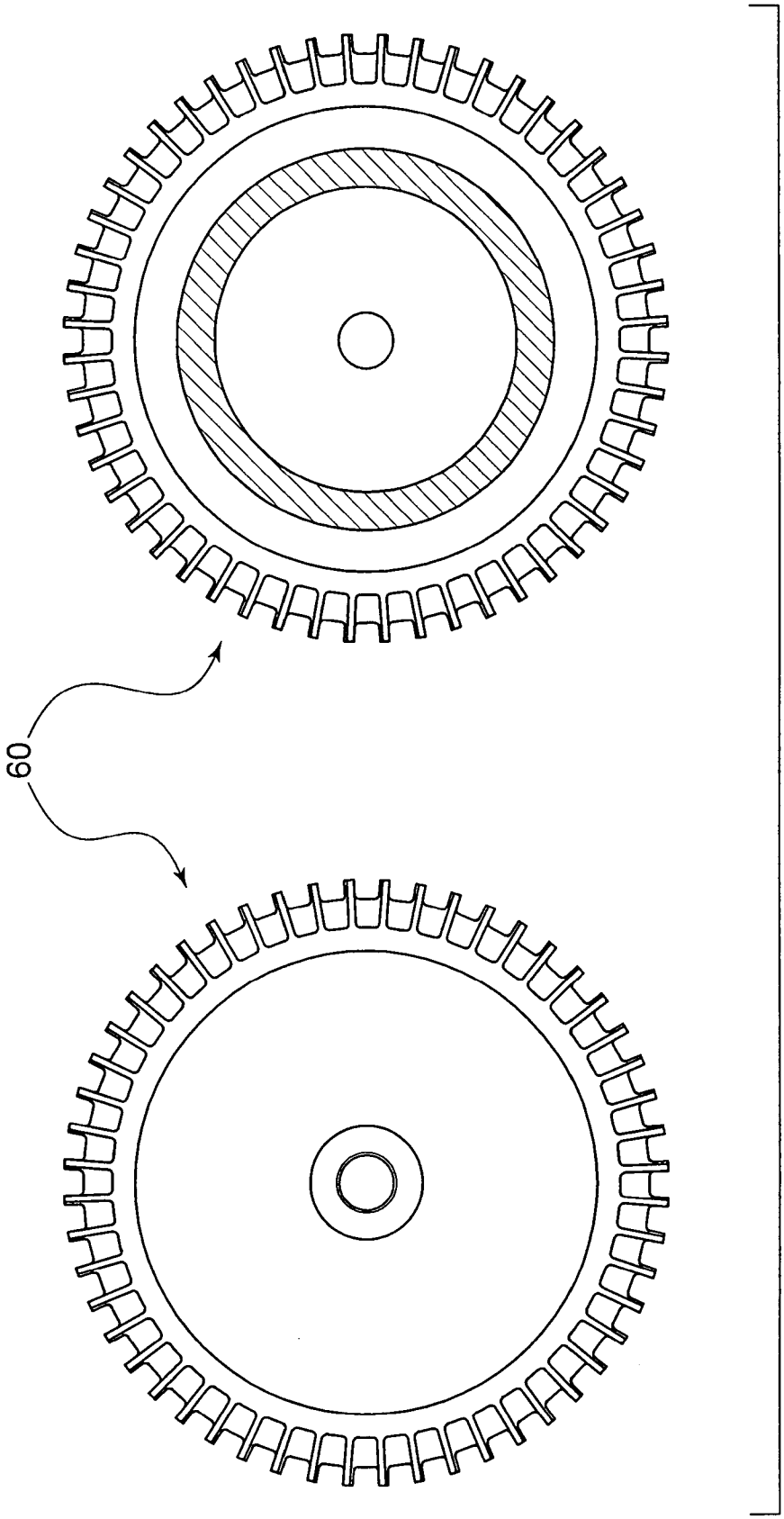

FIG. 12

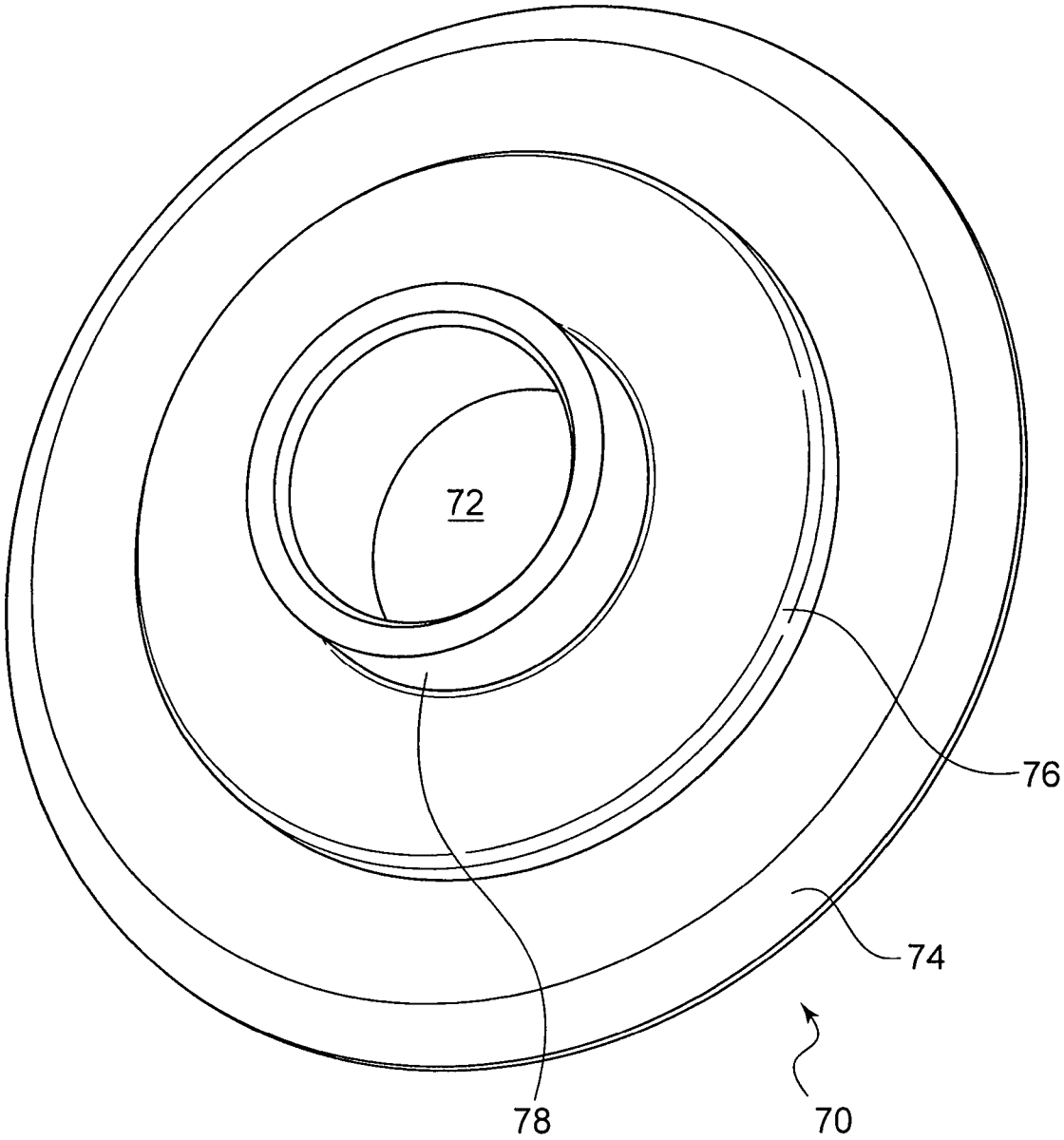

FIG. 13

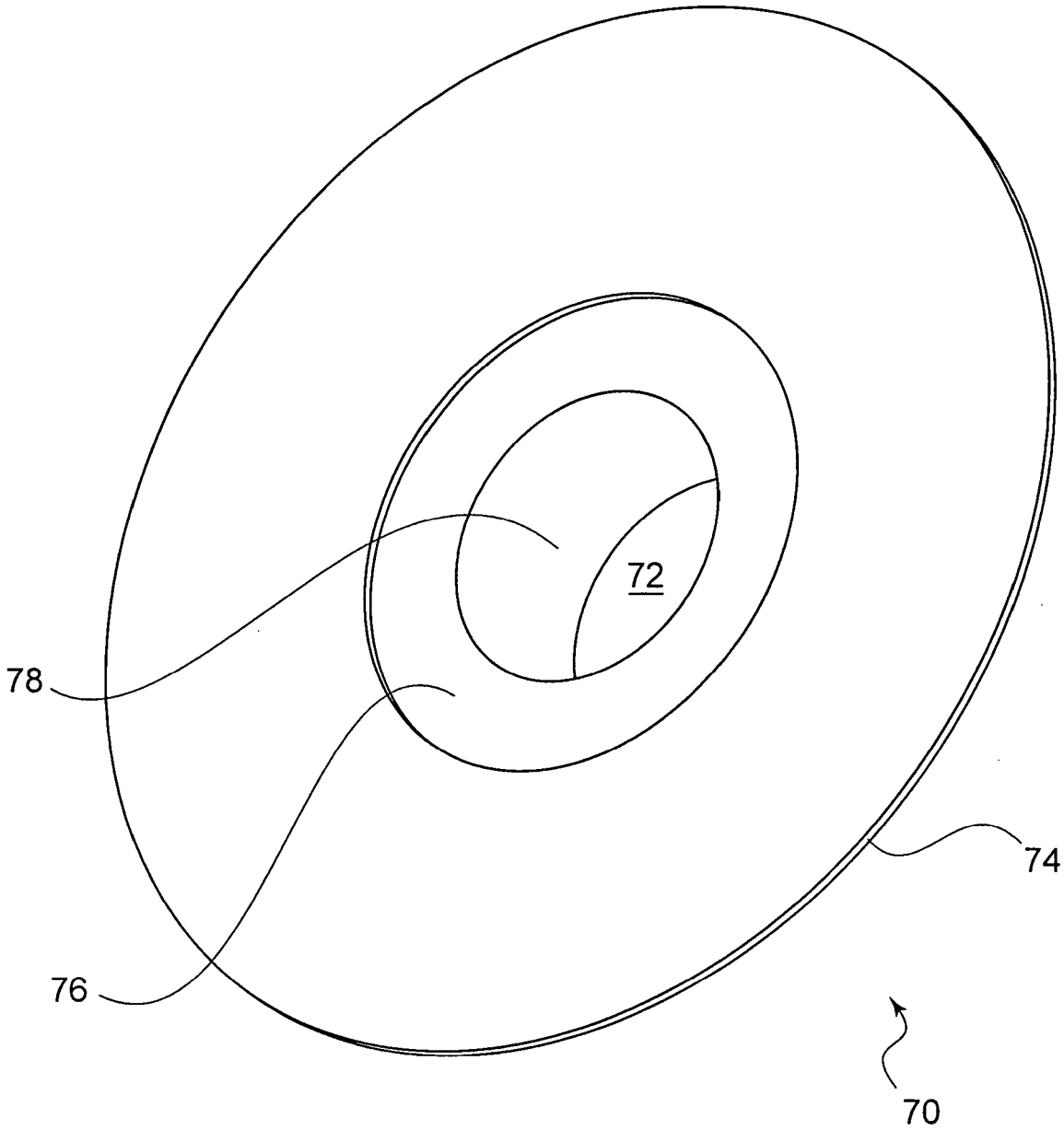

FIG. 14

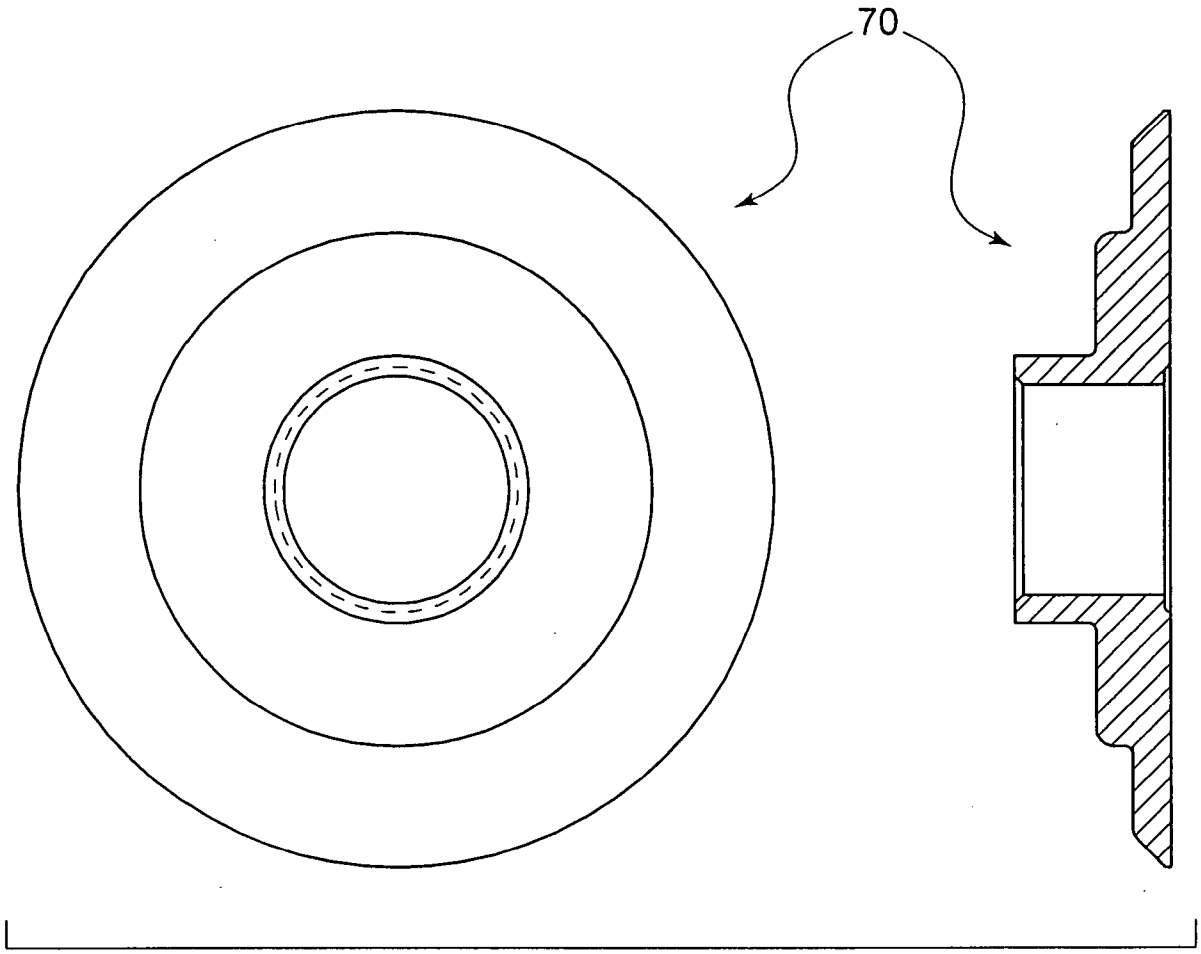

FIG. 15

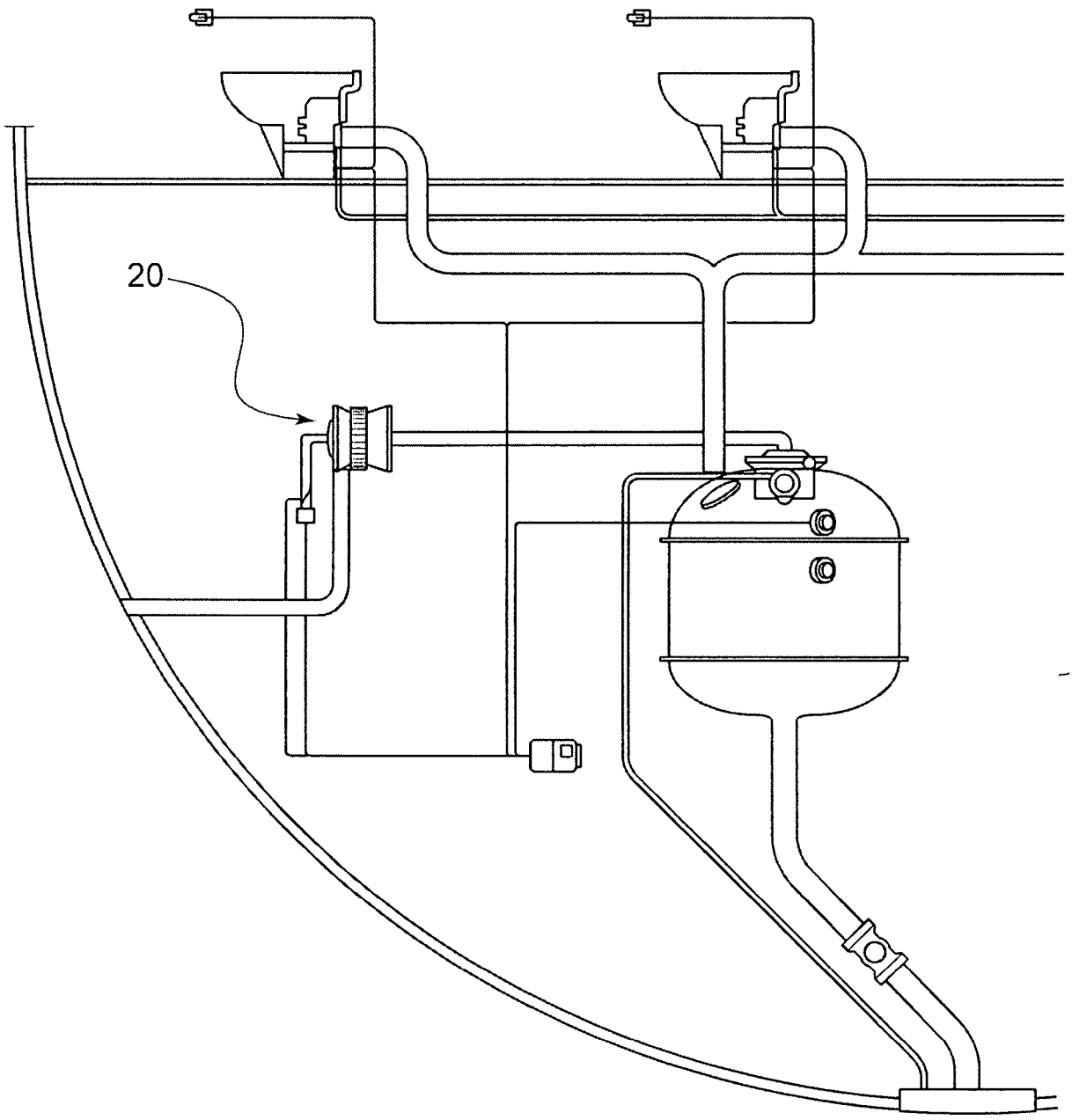

FIG. 16

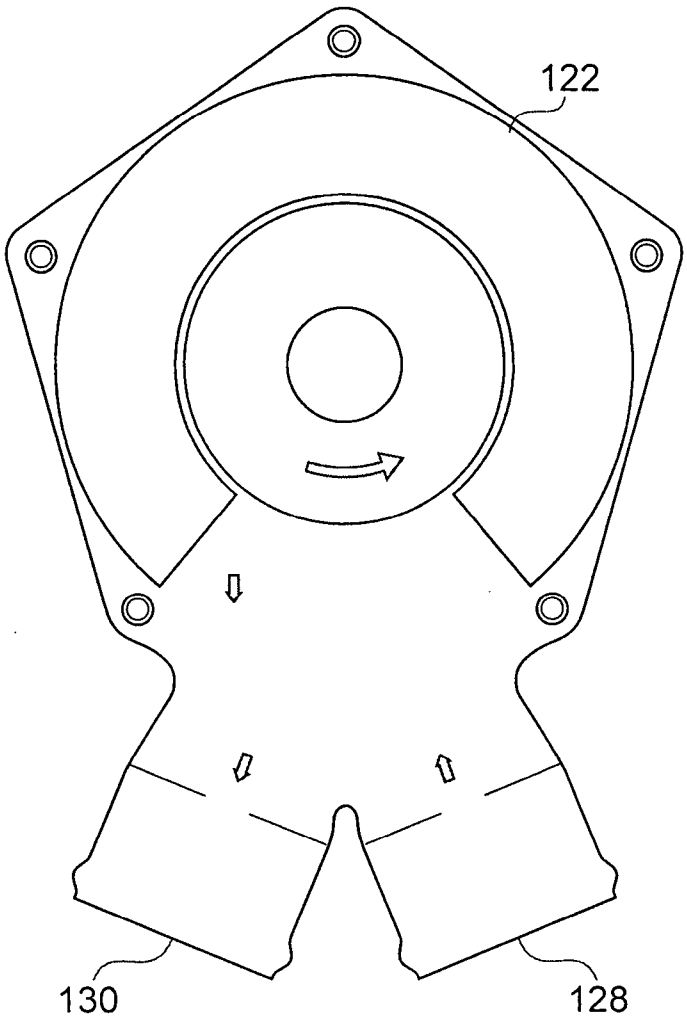

FIG. 17A

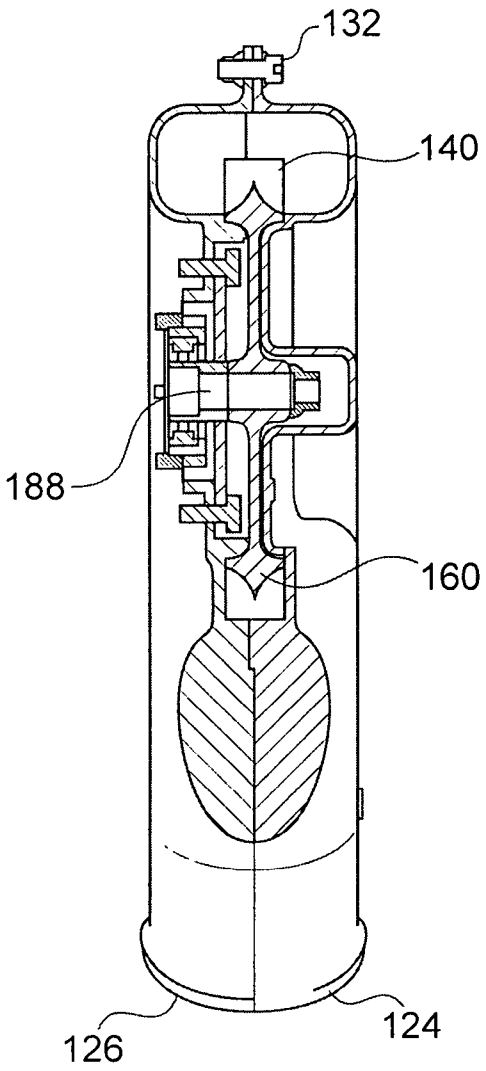

FIG. 17B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2007/070890

A. CLASSIFICATION OF SUBJECT MATTER
INV. B64D11/02 B61D35/00 B60R15/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B64D B60R B61D F04D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 3 915 589 A (VANDER LINDEN DALE B) 28 October 1975 (1975-10-28) abstract; figures 2,4,12	1,3,10, 15 2,4-9, 11-14, 16,17,19
P,X	EP 1 729 010 A (ESAM SPA [IT]) 6 December 2006 (2006-12-06) paragraphs [0001], [0002], [0004], [0014]; figures 1-4	1,3,10
Y	US 5 732 417 A (PONDELICK MARK A [US] ET AL) 31 March 1998 (1998-03-31) column 1, line 6 column 2, line 11 - line 14; figure 1	2,19

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 October 2007	06/11/2007

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Dorpema, Huijb

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2007/070890

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 103 01 613 A1 (PIERBURG GMBH [DE]) 29 July 2004 (2004-07-29) abstract; figure 1	4-6
Y	EP 1 134 419 A (WILO GMBH [DE] WILO AG [DE]) 19 September 2001 (2001-09-19) abstract; figures 3,4	7
Y	US 2 340 747 A (HANSEN ODD A) 1 February 1944 (1944-02-01) figure 4	8,9
Y	DE 101 08 631 A1 (SIEMENS AG [DE] NASH ELMO IND GMBH [DE]) 12 September 2002 (2002-09-12) figure 3	11
Y	US 2005/118014 A1 (OLIVIER MARC [US] ET AL) 2 June 2005 (2005-06-02) paragraph [0051]	12,13
Y	GB 2 126 652 A (BRITISH GAS CORP) 28 March 1984 (1984-03-28) abstract; figure 2	14
Y	US 6 755 611 B1 (KABASAWA TAKASHI [JP] ET AL) 29 June 2004 (2004-06-29) column 1, line 30 - line 33	16,17
A	EP 0 863 314 A (BUSCH GMBH K [DE]) 9 September 1998 (1998-09-09) paragraph [0051]; figures 3-6	3,10,11
A	DE 202 14 104 U1 (NASH ELMO IND GMBH [DE]) 3 April 2003 (2003-04-03) seal between housing 24 and shaft 6 in Fig. 1	4-6

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 18

Claim 18 only claims a performance, defined by way of parameters, in qualitative terms only as compared to "traditional regenerative vacuum generators" in combination with a result to be achieved. Such a claim does not allow for a meaningful search.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.5), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2007/070890

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 18
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful International search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers allsearchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search reportcovers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2007/070890

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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DE 20214104 U1	03-04-2003	AU 2003271574 A1 WO 2004031587 A1	23-04-2004 15-04-2004