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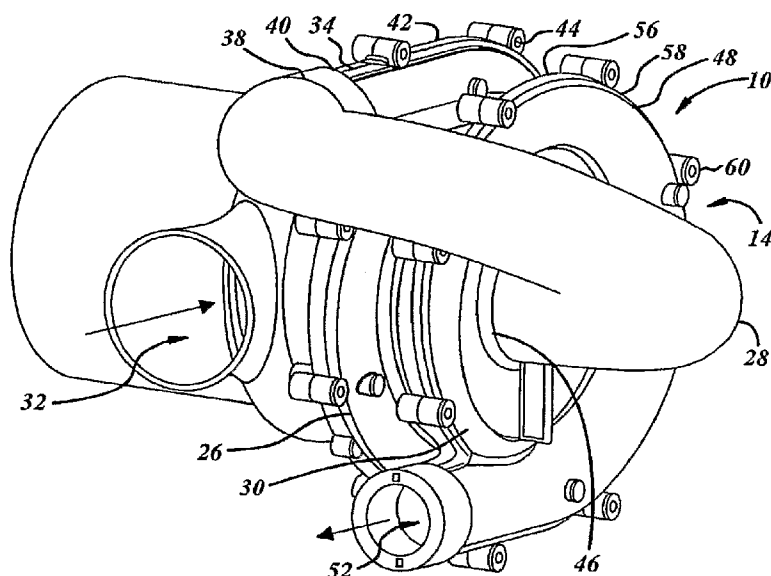
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(54) Title: FUEL CELL COMPRESSOR SYSTEM



(57) Abstract: A multi-stage fuel cell centrifugal compressor system comprising a motor, including a shaft, and a compressor connected to the motor. The compressor includes a first stage inlet; first housing fluidly connected to the first stage inlet; and first impeller driven by the shaft for imparting fluid flow through a first stage of the system. The compressor further includes a first stage outlet fluidly connected to the first housing; a second stage inlet; a second housing fluidly connected to the second stage inlet; a second impeller for imparting fluid flow through a second stage; a second stage outlet fluidly connected to the second housing; and a pipe extending between the first stage outlet and the second stage inlet. The pipe fluidly connects the first stage outlet to the second stage inlet, thereby directing at least a portion of fluid from the first stage to the second stage of the system.

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FUEL CELL COMPRESSOR SYSTEM

RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 60/750,225 filed December 14, 2005, hereby incorporated by reference in its entirety.

BACKGROUND

a. Field of Invention

[0002] The invention relates generally to a fuel cell compressor system, including a multi-stage fuel cell centrifugal compressor system that uses a pipe to transfer fluid from a first stage to a second stage of the compressor system.

b. Description of Related Art

[0003] During a portion of their operation, fuel cells generally require that the fluid entering the fuel cell stack be at a high pressure with low flow. A single stage centrifugal compressor is generally not able to operate under these conditions because they exist in the region beyond the surge point of the compressor. In a compressor with multiple sequential stages the surge line is determined by the pressure differential across each stage which compounds to produce an overall higher compressor system pressure and shifts the surge line to a higher pressure to allow for an expanded operation range.

[0003] A single stage centrifugal compressor is generally not able to compress the fluid effectively to the pressure needed without reaching high rotor speeds, which can be beyond the capability of standard, mass-produced bearings. In conventional compressors with multiple sequential stages, fluid can be compressed to a first pressure in a first stage and then further compressed to a higher pressure in a second stage utilizing lower compressor rotor speed. Conventional multi-stage compressors generally employ U-turn type internal transitions with flow diffusers to direct fluid flow from a first stage to a second stage of the compressor. However, such conventional U-turn type transitions can result in narrow efficiency regions, which can impact total system efficiency of the compressors operating range, for example, as a result of poor off-peak compressor performance.

[0004] There is a desire for a fuel cell compressor system that minimizes pressure loss between stages of the compressor in order to improve fuel cell efficiency. Additionally, there is a desire for fuel cell compressor systems that can be configured to be tightly packaged so as to decrease space and packaging requirements, particularly since the geometry of the

compressor volute for conventional fuel cell compressor system is typically relatively complex. For instance, conventional compressor volutes commonly utilize a circular cross-section that sweeps from a small diameter at the start of the volute to a large diameter at the outlet of the volute. Such geometries usually require investment casting, which can result in both increased cost and slower production. As such, there is also a desire for a fuel cell compressor system with a modified compressor volute geometry that improves manufacturability of the compressor volute.

SUMMARY

[0005] In an embodiment, the invention provides a multi-stage fuel cell centrifugal compressor system comprising a motor, including a shaft driven by a motor, and a compressor connected to the motor. The compressor includes a first stage inlet; first housing fluidly connected to the first stage inlet; and first impeller driven by the shaft for imparting fluid flow through a first stage of the system. The compressor further includes a first stage outlet fluidly connected to the first housing; a second stage inlet; a second housing fluidly connected to the second stage inlet; a second impeller driven by the shaft for imparting fluid flow through a second stage; a second stage outlet fluidly connected to the second housing; and a pipe extending between the first stage outlet and the second stage inlet. The pipe fluidly connects the first stage outlet to the second stage inlet, thereby directing at least a portion of fluid from the first stage to the second stage of the system. A method of manufacturing a fuel cell centrifugal compressor is also provided. It is noted that the "pipe" may include or comprise other forms of fluid connectors, including, without limitation, a fluid conveyance tube or flexible fluid-connecting devices (e.g., hoses or other fluid conduits).

[0006] The use of an external cross-over fluid conveyance tube that, *inter alia*, is configured to minimize losses, can broaden the efficiency regions for the compressor, resulting in an overall efficiency improvement of the compressor system within a broader or full operating range.

[0007] An improved multi-stage fuel cell compressor system can provide some advantages. Among other things, an improved multi-stage fuel cell compressor system can serve to minimize pressure loss over a wide operating range between subsequent stages of a system by using a pipe to direct fluid flow from a first stage to a second stage, for example, in place of a U-turn transition. Additionally, a compressor volute geometry that includes, for instance, a stretched circular cross-section can improve the manufacturability of the

compressor volute for use in connection with a multi-stage fuel cell compressor system. Further, compressor surge can be reduced or avoided because each compressor stage can have a lower pressure ratio than a single stage compressor boosting to the same pressure ratio.

[0010] These and other features of this invention will become apparent to those skilled in the art from the following detailed description, which illustrates features of this invention by way of example.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

[0012] Fig. 1 is a perspective view of a multi-stage fuel cell compressor system in accordance with an exemplary embodiment of the present invention.

[0013] Fig. 2 is a top view of a multi-stage fuel cell compressor system in accordance with an exemplary embodiment of the present invention.

[0014] Fig. 3 is a cross-sectional view of a multi-stage fuel cell compressor system in accordance with an exemplary embodiment of the present invention.

[0015] Fig. 4 is a cross-sectional view of a multi-stage fuel cell compressor system in accordance with an exemplary embodiment of the present invention.

[0016] Fig. 5 is a perspective view of a coupling for a fuel cell compressor system in accordance with an exemplary embodiment of the present invention.

[0017] Fig. 6 is a partial cross-sectional view of a housing for a fuel cell compressor system showing an uncrimped crimp joint.

[0018] Fig. 7A is a cross-sectional view of a prior art compressor volute.

[0019] Fig. 7B is a cross-sectional view of a compressor volute in accordance with an exemplary embodiment of the present invention.

DETAILED DESCRIPTION

[0020] Reference will now be made in detail to embodiments of the invention, examples of which are illustrated in the accompanying drawings. While the invention will be described in conjunction with the embodiments, it will be understood that they are not intended to limit the invention to these embodiments. On the contrary, the invention is intended to cover alternatives, modifications and equivalents, which may be included within the spirit and scope of the invention as defined by the appended claims.

[0021] Figs. 1-2 generally illustrate a perspective and top view, respectively, of a multi-stage fuel cell compressor system 10 in accordance with embodiments of the invention. Illustrated system 10 includes a motor 12 and compressor 14.

[0022] Referring to Figs. 3-4, which generally illustrates a cross-sectional view of a multi-stage fuel cell compressor system, motor 12 includes a shaft 16. Motor 12 may comprise an electric motor and can be configured to drive shaft 16. In an embodiment, a bearing 18 may be disposed within the compressor 14 in which the rotor of motor 12 may be connected or attached directly to compressor shaft 16. In other embodiments, a plurality of bearings may be disposed within compressor 14. Bearing 18 (or a plurality of bearings) may be provided for accommodating rotational movement of shaft 16, as shaft 16 may be a common shaft for driving two impellers for a system, such as system 10 as described further below. In an embodiment, the shaft 16 may extend in a generally axial direction between motor 12 and compressor 14.

[0023] Compressor 14 is configured to compress incoming fluid to a higher pressure for use in a fuel cell. The compressor 14 may be connected to motor 12, for example, through a coupling 20. Referring to Fig. 5, coupling 20 may include a plurality of pins 22 for coupling motor 12 to compressor 14. In the illustrated embodiment, coupling 20 includes three angularly-spaced pins. Referring again to Figs. 3-4, in an embodiment, a bearing 24 or plurality of bearings may be disposed within the compressor. Further, in an embodiment, a plurality of bearings may be disposed within the motor. In another embodiment, at least one bearing may be disposed within both motor 12 and compressor 14. Compressor 14 may include a first stage 26, a pipe 28, and a second stage 30. By including multiple stages, compressor 14 may generally achieve higher pressure than a conventional single-stage compressor, even with lower rotational speeds of operation.

[0024] In the illustrated embodiment, first stage 26 is configured to be able to compress incoming fluid to a first-stage pressure. The first stage 26 may be located downstream of motor 12. With reference to Figs. 1-4, first stage 26 may include inlet 32, housing 34, impeller 36, and outlet 38.

[0025] First stage inlet 32 can be configured to receive fluid into first stage 26 of compressor 14. In an embodiment, first stage inlet 32 can be configured at a non-axial angle relative to shaft 16. For example, in the illustrated embodiment, first stage inlet 32 is provided substantially perpendicular to shaft 16. In an embodiment, a fluid can enter first stage inlet 32 at a non-axial angle relative to shaft 16 and, if desired, can be routed, e.g.,

radially, through a filter. The fluid may then be turned axially into first stage 26, so that the fluid flows axially into first stage 26.

[0026] A first housing 34 may be configured for retaining fluid as it is transferred through the first stage 26 of system 10. First housing 34 can be fluidly connected to inlet 32. In an embodiment, first housing 34 may comprise a first portion (e.g., first half) 40 and a second portion (e.g., second half) 42 that are connected using a plurality of fasteners 44, which may include conventional fastening means (e.g., receiving portions and corresponding screws or bolts), disposed about an outer surface of both first portion 40 and second portion 42. In a particular embodiment, a plurality of fasteners 44 may be disposed substantially around the outer perimeter of the first portion 40 and second portion 42.

[0027] Referring to Fig. 6, in another embodiment, portions about a surface (e.g., outer surface) of the first and second portions 40,42 of the housing 34 may be connected by means of a secondary operation. Such secondary operation may include crimping, welding, gluing (and/or using adhesive), or a combination of two or more of the foregoing. For example, and without limitation, portions of the outer surfaces of the first and second portions 40,42 may be crimped together to form at least a portion of housing 34. By way of an illustrated example, tabs such as those generally illustrated, i.e., tabs 43,59, may be bent or folded down during a crimping operation. In an embodiment, first housing 34 may comprise a volute.

[0028] Referring again to Figs. 1-4, first impeller 36 may be configured for rotation within first housing 34 to pressurize fluid that is routed through first stage 26 of system 10. The first impeller 36 is at least partially surrounded by housing 34. First impeller 36 can be driven by shaft 16 to impart fluid flow through a first stage 26 of system 10. In a particular embodiment, first impeller 36 may be coupled to shaft 16. As impeller 36 is rotated within housing 34, first-stage pressurized fluid can be produced.

[0029] First stage outlet 38 can be configured to direct first-stage pressurized fluid to second stage 30 of system 10 for further pressurization. In an embodiment, first stage outlet 38 may be configured at a non-axial angle relative to shaft 16. For some embodiments, first stage outlet 38 may be provided substantially perpendicular to shaft 16. First stage outlet 38 is fluidly connected to housing 34.

[0030] As illustrated in the embodiments, a pipe 28 is provided and configured to transfer first-stage pressurized fluid from first stage 26 to second stage 30 for further pressurization. In an embodiment, pipe 28 extends between first stage outlet 38 and second stage inlet 46 to fluidly connect first stage outlet 38 to second stage inlet 46. Pipe 28 thereby can direct at

least a portion of a fluid from first stage 26 to second stage 30 of system 10. In an embodiment, at least a portion of pipe 28, which may be an external cross-over pipe, is outside of or external to compressor 14. In an exemplary embodiment, pipe 28 may be comprised of a polymer or plastic material. In an embodiment, pipe 28 may be comprised of polypropylene or acrylonitrile butadiene styrene (ABS).

[0031] Second stage 30 can be configured to further compress fluid in the system. That is, a first-stage pressurized fluid may be further pressurized to a second-stage pressurized fluid. In an embodiment, second stage 30 may include inlet 46, housing 48, impeller 50, and outlet 52.

[0032] A second stage inlet 46 can be configured for receiving fluid from pipe 28 into second stage 30 of compressor 14. In an embodiment, second stage inlet 46 may be substantially aligned with shaft 16 such that fluid may flow into the second stage 30 in an axial direction.

[0033] Second housing 48 can be configured for retaining fluid as it is transferred through second stage 30 of system 10. In an embodiment, second housing 48 is fluidly connected to inlet 46. If desired, a nose cone 54 may be included and disposed within second housing 48. In a manner similar to that involving first housing 34, second housing 48 may comprise a first portion (e.g., a first half) 56 and a second portion (e.g., a second half) 58 that are connected using a plurality of fasteners 60 disposed about or around an outer surface of both first portion 56 and second portion 58 in an embodiment. In a particular embodiment, the plurality of fasteners 60 may be disposed substantially about and around the outer perimeter of the first portion 56 and second portion 58. Referring to Fig. 6, in another embodiment, and as generally discussed in connection with first housing 34, the first and second portions 56, 58 of second housing 48 may be connected together (e.g., crimped together) about or around portions of an outer surface of the first and second portions 56, 58 to form the housing 48. By way of example, but without limitation, tab 59 and or tab 43 could be bent or folded down as part of a crimping operation. In an embodiment, second housing 48 may comprise a volute.

[0034] Referring again to Figs. 1-4, second impeller 50 can be configured for rotation within second housing 48 to pressurize fluid that is routed through first stage 30 of system 10. In an embodiment, second impeller 50 is at least partially surrounded by housing 48 and is driven by shaft 16 for directing fluid flow through a second stage 30 of system 10. In a particular embodiment, second impeller 50 may be coupled to shaft 16. In an embodiment,

second impeller 50 may be coupled to shaft 16 at a position on the shaft adjacent to first impeller 36. Moreover, in embodiments of the system, second impeller 50 may be arranged back-to-back with respect to first impeller 36. Generally, as impeller 50 is rotated within housing 48, second-stage pressurized fluid can be produced.

[0035] A second stage outlet 52 can be provided to direct second-stage pressure fluid away from compressor 14 for further use or processing, such as directing fluid toward an inlet of a fuel cell. In an embodiment, second stage outlet 52 may be configured to be at a non-axial angle relative to shaft 16 and, if desired, may be provided substantially perpendicular to shaft 16. Second stage outlet 52 is fluidly connected to housing 48.

[0036] In another aspect of the invention, a method of manufacturing a fuel cell centrifugal compressor is provided. As generally shown in Fig. 7A, conventional compressor volutes commonly employ a circular cross section with a diameter that gets larger as it sweeps around a compressor outlet 62. In an embodiment of the invention, a compressor volute 64, such as generally illustrated in Fig. 7B, may include a stretched circular cross-section, as compared to the conventional compressor volute of Fig. 7A.

[0037] The inventive method of manufacturing a fuel cell centrifugal compressor comprises forming a first piece of a volute, forming a second piece of a volute, and connecting the first and second pieces. The forming step may comprise die-casting, forging, or stamping. In an embodiment, the volute includes a compressor outlet 62 and has an inner surface 66 extending straight from a first side 68 of compressor outlet 62, a portion with a curve 69, and a portion extending to second side 70 of compressor outlet 62. In an embodiment of the invention, such as generally illustrated, the transition from the portion with a curve 69 to the portion extending to second side 70 may include substantially straight segment 72, and may further include a substantially perpendicular corner 74 (i.e., when viewed in cross section). The configuration of the disclosed embodiment can, among other things, eliminate the peninsula-like cross-sectional formation generally identified in Fig. 7A, which can potentially improve flow and manufacturability.

[0038] By way of example, and without limitation, the modified structure and geometry of inventive compressor volute 64, among other things, can improve the manufacturability of the inventive compressor volute 64 by allowing the inventive compressor volute 64 to generally be die-cast in two pieces without typical die-lock concerns. Since investment casting is not required to produce a compressor volute with such a modified geometry,

manufacturing costs may be reduced and production rates may be increased. The modified geometry can also help serve to maintain tangential entry to the volute from the impeller.

[0039] The foregoing descriptions of specific embodiments of the present invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, and various 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 its practical application, to thereby enable others skilled in the art to utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the claims appended hereto and their equivalents.

CLAIMS

What is claimed is:

1. A multi-stage fuel cell compressor system, comprising:
 - a motor, including a shaft driven by the motor; and
 - a compressor connected to the motor, the compressor including:
 - a first stage inlet;
 - a first housing fluidly connected to the first stage inlet;
 - a first impeller at least partially surrounded by the first housing, the first impeller driven by the shaft for imparting fluid flow through a first stage of the system;
 - a first stage outlet fluidly connected to the first housing;
 - a second stage inlet;
 - a second housing fluidly connected to the second stage inlet;
 - a second impeller at least partially surrounded by the second housing, the second impeller driven by the shaft for imparting fluid flow through a second stage of the system;
 - a second stage outlet fluidly connected to the second housing; and
 - a pipe extending between the first stage outlet and the second stage inlet for fluidly connecting the first stage outlet to the second stage inlet thereby directing at least a portion of a fluid from the first stage to the second stage of the system.
2. A system in accordance with claim 1, wherein the motor comprises an electric motor.
3. A system in accordance with claim 1, wherein the first stage inlet is at a non-axial angle relative to the shaft.
4. A system in accordance with claim 1, wherein the first stage outlet is at a non-axial angle relative to the shaft.
5. A system in accordance with claim 1, wherein the second stage inlet is substantially aligned with the shaft.

6. A system in accordance with claim 1, wherein the second stage outlet is at a non-axial angle relative to the shaft.
7. A system in accordance with claim 3, wherein the non-axial angle is substantially perpendicular.
8. A system in accordance with claim 1, wherein the first impeller and the second impeller are arranged back-to-back.
9. A system in accordance with claim 1, wherein the motor is located upstream of the first stage.
10. A system in accordance with claim 1, wherein at least a portion of the fluid flows axially into the first stage.
11. A system in accordance with claim 1, further comprising one or more bearings disposed within the motor.
12. A system in accordance with claim 1, further comprising one or more bearings disposed within the compressor.
13. A system in accordance with claim 1, further comprising a drive coupling for coupling the motor to the compressor.
14. A system in accordance with claim 13, wherein the drive coupling includes a plurality of pins.
15. A system in accordance with claim 14, wherein the coupling includes three pins that are angularly spaced.
16. A system in accordance with claim 1, further comprising a nose cone disposed within the second housing.
17. A system in accordance with claim 1, wherein a first portion and a second portion of the first housing are connected using a plurality of fasteners disposed about an outer surface portion of each of the first and second portions.
18. A system in accordance with claim 1, wherein a first portion and a second portion of the first housing are connected about an outer surface of each of the first and second portions by a secondary operation.

19. A system in accordance with claim 18, wherein the secondary operation includes crimping, welding, gluing or using adhesive, or a combination of two or more of the foregoing.
20. A system in accordance with claim 18, wherein the outer surface substantially comprises the perimeter of one or both of the first and second portions.
21. A system in accordance with claim 1, wherein at least a portion of the pipe is an external cross-over pipe.
22. A system in accordance with claim 1, wherein at least a portion of the pipe is comprised of a polymer or plastic material.
23. A system in accordance with claim 22, wherein at least a portion of the pipe is comprised of polypropylene or acrylonitrile butadiene styrene (ABS).
24. A method of manufacturing a fuel cell centrifugal compressor, comprising:
forming a first piece of a volute;
forming a second piece of a volute; and
connecting the first piece and second piece to form a volute including a compressor outlet, wherein the volute includes an inner surface that extends from a first side of the compressor outlet, includes a curved portion, and extends to a second side of the compressor outlet.
25. A method in accordance with claim 24, wherein the forming comprises die-casting, forging, or stamping.

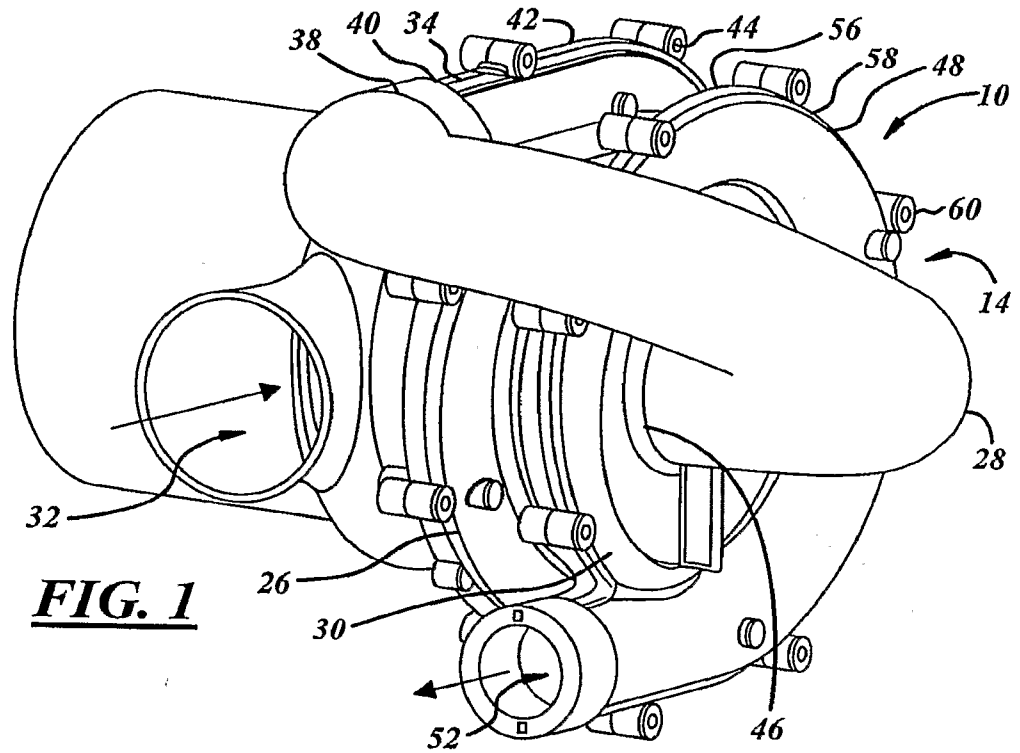


FIG. 1

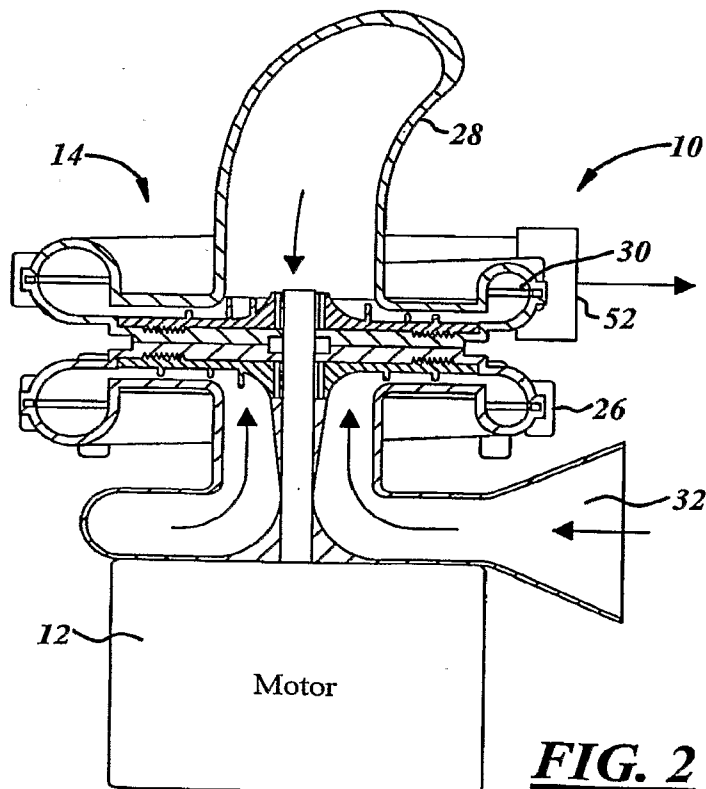
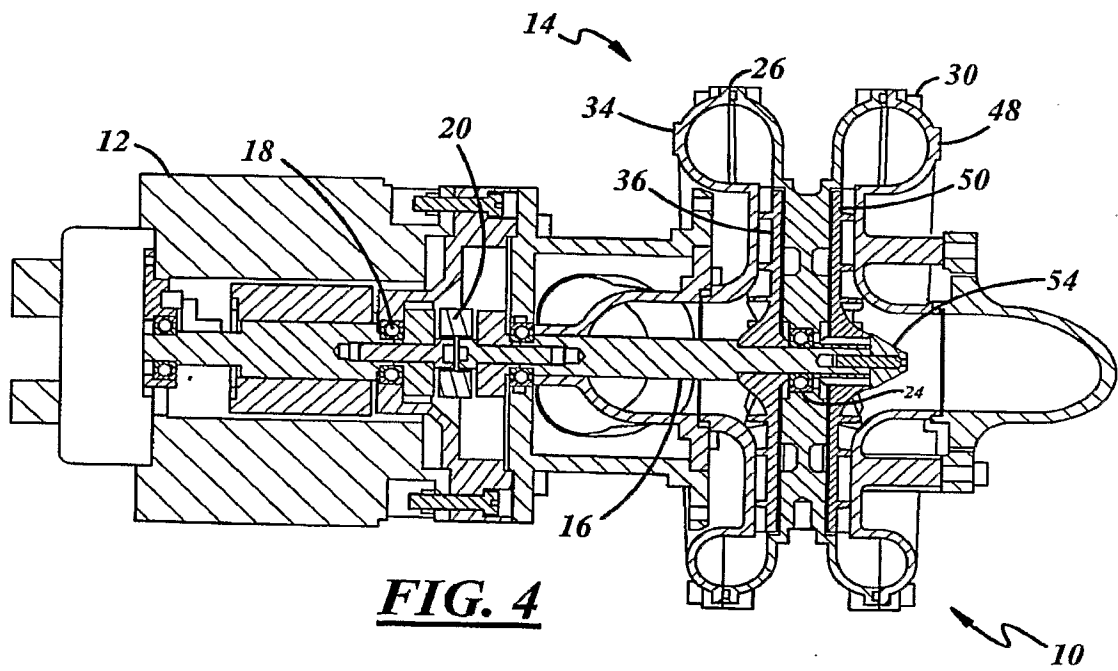
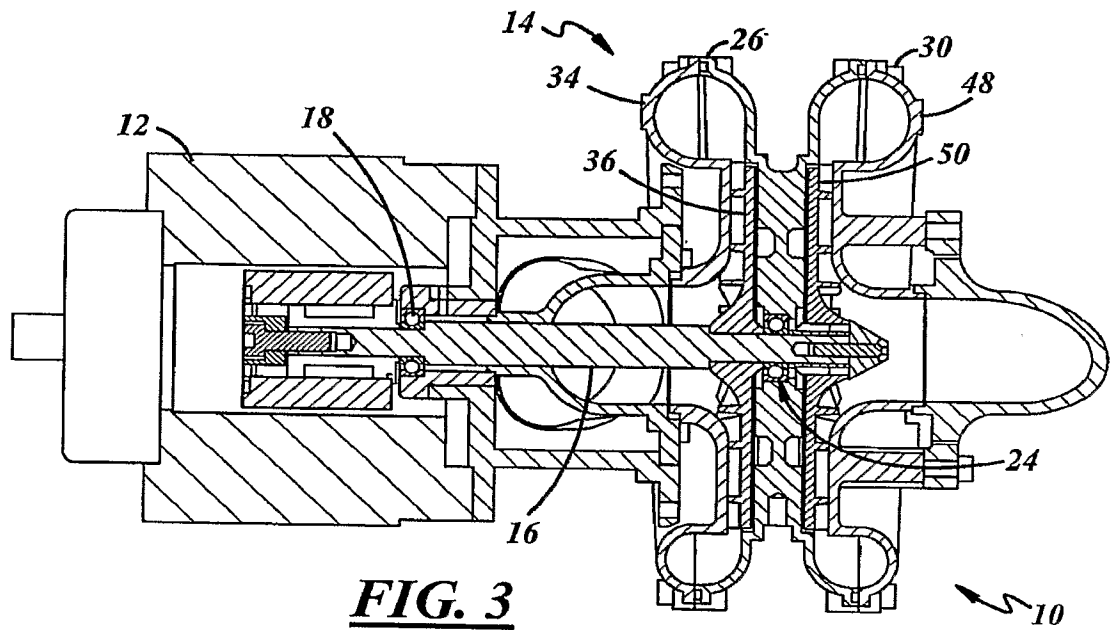


FIG. 2



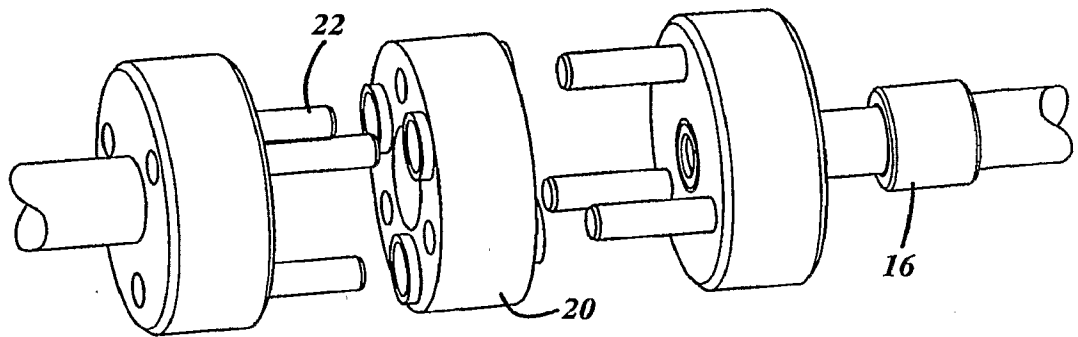


FIG. 5

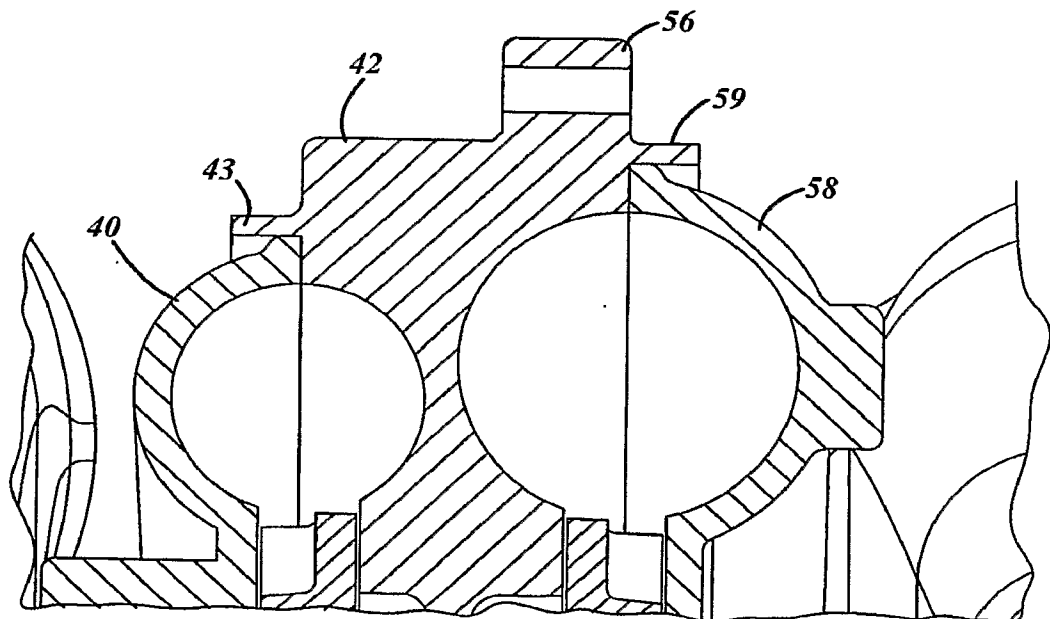
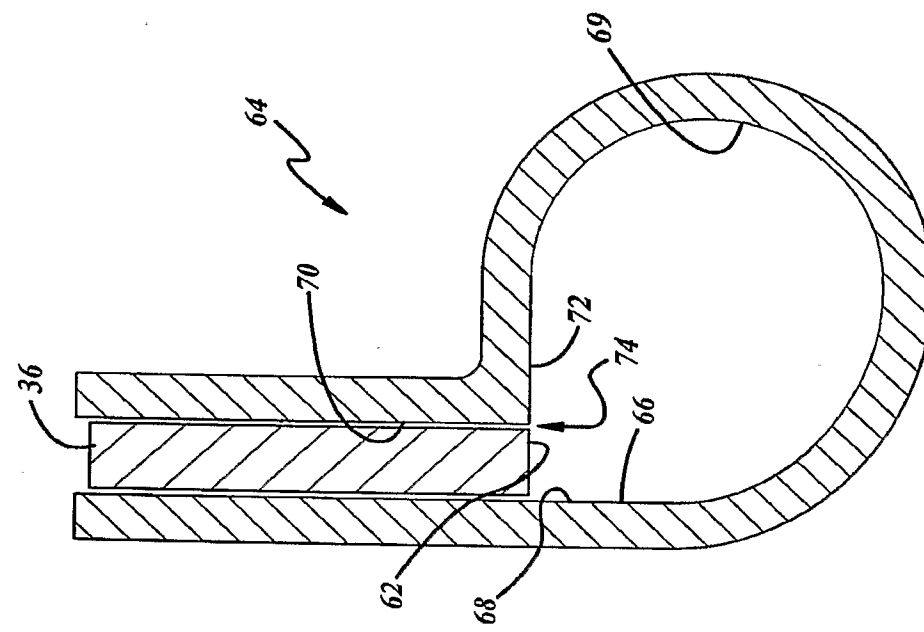


FIG. 6



(PRIOR ART)
FIG. 7A

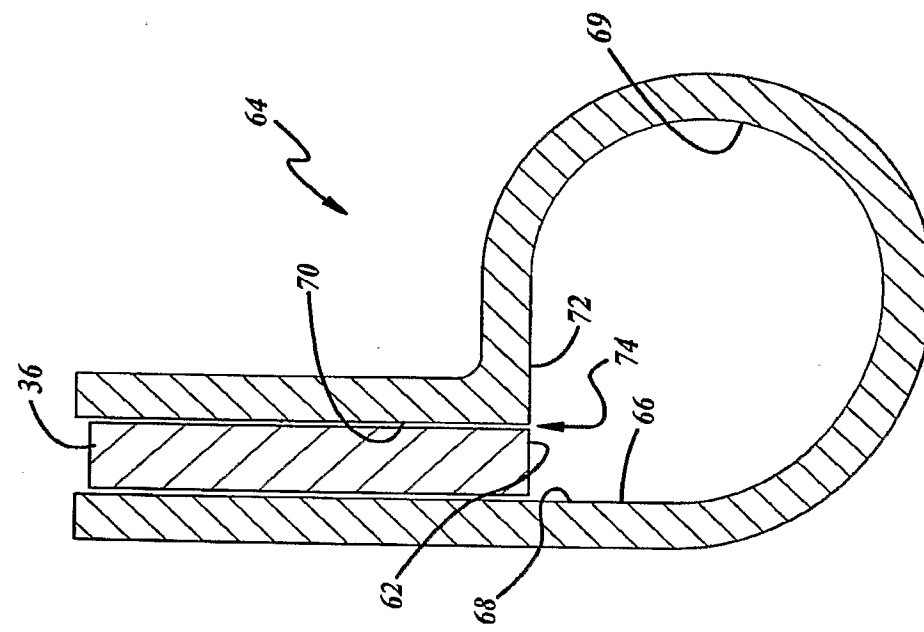


FIG. 7B