(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 June 2012 (28.06.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/087907 A2

(51) International Patent Classification:
F02B 37/02 (2006.01) ***F01D 9/02*** (2006.01)
F02B 67/10 (2006.01) ***F01D 25/24*** (2006.01)
F02F 1/24 (2006.01) ***F01D 25/26*** (2006.01)
F01N 13/10 (2010.01) ***F01D 17/10*** (2006.01)
F01N 3/04 (2006.01) ***F01D 25/16*** (2006.01)
F02B 39/00 (2006.01)

(21) International Application Number:
PCT/US2011/065791

(22) International Filing Date:
19 December 2011 (19.12.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/426,092 22 December 2010 (22.12.2010) US

(71) Applicant *(for all designated States except US)*: **HONEYWELL INTERNATIONAL, INC.** [US/US]; 101 Columbia Road, POB 2245, Morristown, NJ 07962-2245 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **SERRES, Nicolas** [FR/FR]; 71 Rue Neuve Grange, F-88000 Epinal, Vosges (FR). **LOMBARD, Alain** [FR/FR]; 26 Rue Du Centre, F-88150 Chavelot, Vosges (FR). **MARQUES, Manuel** [FR/FR]; 2, rue de l'Avenir, Z.I. INOVA 3000, F-88155 Thaon-Les-Vosges (FR). **LAISSUS, Jean-Jacques** [US/FR]; 2, rue de l'Avenir, Z.I. INOVA 3000, F-88155 Thaon-Les-Vosges (FR).

(74) Agents: **HILL, Donald, M., Jr.** et al.; Alston & Bird LLP, Bank of America Plaza, 101 South Tryon Street, Suite 4000, Charlotte, NC 28280-4000 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE,

[Continued on next page]

(54) Title: TURBOCHARGER AND ENGINE CYLINDER HEAD ASSEMBLY

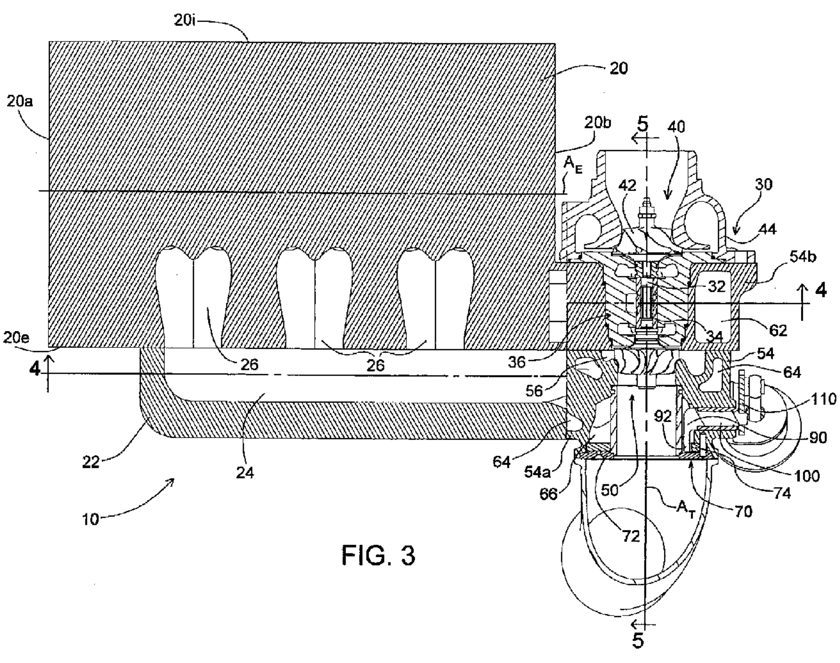

FIG. 3

(57) Abstract: An engine cylinder head and turbocharger assembly includes a turbocharger having a turbine housing, wherein part of the turbine housing is integrated into a casting of the engine cylinder head. The turbocharger is arranged with respect to the engine cylinder head such that the rotational axis of the turbocharger is transverse to the engine axis along which the engine cylinders are spaced. A compressor housing of the turbocharger is oriented toward an air intake side of the engine cylinder head, and the turbine housing is oriented toward an exhaust side of the engine cylinder head.

WO 2012/087907 A2

DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

TURBOCHARGER AND ENGINE CYLINDER HEAD ASSEMBLY

BACKGROUND OF THE INVENTION

The present disclosure relates to exhaust gas-driven turbochargers, and particularly relates to turbocharger and engine cylinder head assemblies.

On next-generation gasoline engines, the tendency is toward integrating the exhaust manifold into the cylinder head. This provides some advantages in performance because the exhaust manifold pipes and their associated volumes can be reduced, and because the engine can be operated with slightly less enrichment at full load and high engine speed by virtue of exhaust gas cooling performed by the engine water coolant passing around the exhaust manifold. Thus, the trend in gasoline engine development appears to be toward making all such engines turbocharged, such that the turbo system will become a necessary part of the engine.

BRIEF SUMMARY OF THE DISCLOSURE

A possible next step beyond exhaust manifold integration is complete turbocharger integration into the engine cylinder head. However, a turbocharger includes sub-assemblies or parts that are very complex to fully integrate (for example the bearing system, which has to be balanced once assembled, or the turbine and compressor housings, which are complex in configuration and sensitive to design), and this may make it impractical to provide a cost-effective cylinder head casting that integrates the turbocharger. Furthermore, modifying the turbocharger (e.g., the A/R ratio) at development time could be a problem if the turbocharger were completely integrated in the cylinder head casting, as such modification would require modifying the cylinder head molds.

The present disclosure addresses issues such as those noted above.

The engine cylinder head and turbocharger assembly described in the present disclosure employs partial integration of the turbocharger in the cylinder head while allowing turbocharger design modifications that do not impact the cylinder head configuration. Additionally, the assembly results in an advantageous positioning and orientation of the turbocharger relative to the cylinder head.

In accordance with one embodiment described herein, the engine cylinder head and turbocharger assembly comprises: an engine cylinder head for an internal combustion engine having a plurality of cylinders spaced apart along an engine axis, the engine cylinder head comprising a casting and having an intake side on one side of the engine axis and an exhaust side on an opposite side of the engine axis; and a turbocharger comprising a compressor wheel mounted within a compressor housing and a turbine wheel mounted within a turbine housing and connected to the compressor wheel by a shaft that extends along a turbocharger axis about which the shaft rotates, the turbocharger further comprising a center housing assembly connected between the compressor housing and the turbine housing, the center housing assembly containing bearings for the shaft, the turbine housing defining a volute that surrounds the turbine wheel and receives exhaust gas from the engine and a nozzle that directs exhaust gas from the volute into the turbine wheel, the turbine housing further defining an axial bore through which exhaust gas that has passed through the turbine wheel is discharged from the turbine housing.

At least part of the turbine housing is an integral portion of the casting of the engine cylinder head, and the turbocharger is mounted to the engine cylinder head with the turbocharger axis oriented transverse to the engine axis and with the compressor housing oriented toward the intake side and the turbine housing oriented toward the exhaust side of the engine cylinder head.

In one embodiment, the turbine housing comprises a first turbine housing portion and a second turbine housing portion formed separately from the first turbine housing portion. The first turbine housing portion defines the volute and one wall of the nozzle and the second turbine housing portion defines an opposite wall of the nozzle. The second turbine housing portion is an integral portion of the casting of the engine cylinder head. This arrangement allows modifications to the turbocharger (e.g., the A/R ratio) to be made without having to change the casting of the cylinder head.

The cylinder head and turbocharger assembly can also include an exhaust manifold cap comprising a casting formed separately from the casting of the engine cylinder head and mounted to the exhaust side of the engine cylinder head. The exhaust manifold cap defines an internal space that collects exhaust gas from the cylinders of the engine via exhaust gas passages defined in the engine cylinder head. In one embodiment, the first turbine housing portion is an integral part of the casting of the exhaust manifold cap. Accordingly, if modifications to the turbocharger design (e.g., the A/R ratio) have to be made, only the relatively small and simple manifold cap casting need be altered, while the substantially more-complex cylinder head casting can remain the same.

The exhaust manifold cap can further define a coolant passage arranged to receive engine coolant from a corresponding passage in the engine cylinder head and circulate the coolant through the exhaust manifold cap, and the first turbine housing portion can define a coolant passage arranged to receive the coolant from the coolant passage in the exhaust manifold cap and circulate the coolant through the first turbine housing portion.

In one embodiment, the center housing comprises a single part formed by casting that integrates a backplate for the compressor and a backplate for the turbine. Additionally, the center housing and the second turbine housing portion are cooperatively configured such that the center housing is insertable into the second turbine housing portion in a direction parallel to the turbocharger axis. O-rings are engaged between the center housing and the second turbine housing portion to seal the interfaces therebetween. Optionally, the center housing, the shaft, the compressor wheel, and the turbine wheel form a cartridge that is insertable into the second turbine housing portion in the direction parallel to the turbocharger axis. In this embodiment, the compressor housing is formed separately from the second turbine housing portion and is secured to one side of the second turbine housing portion, and the first turbine housing portion is formed separately from the second turbine housing portion and is secured to the other side of the second turbine housing portion. This arrangement is particularly advantageous in that all of the complex and performance-sensitive parts of the turbocharger are included in the cartridge that is a self-contained unit separate from the cylinder head casting and its integral second turbine housing portion. Accordingly, design modifications on the turbocharger cartridge can be performed with complete freedom without impacting the design of the cylinder head casting.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

Having thus described the disclosure in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

FIG. 1 is a perspective view of an engine cylinder head and turbocharger assembly in accordance with one embodiment of the present invention;

FIG. 2 is a side view of the engine cylinder head and turbocharger assembly of FIG. 1;

FIG. 3 is a cross-sectional view of the engine cylinder head and turbocharger assembly along line 3-3 in FIG. 1;

FIG. 4 is a cross-sectional view of the engine cylinder head and turbocharger assembly along line 4-4 in FIG. 3;

FIG. 5 is a cross-sectional view of the engine cylinder head and turbocharger assembly along line 5-5 in FIG. 3;

FIG. 6 is a cross-sectional view of the center housing of the turbocharger;

FIG. 7 is a perspective view of an engine cylinder head and turbocharger assembly in accordance with another embodiment of the present invention;

FIG. 8 is a front view of the assembly of FIG. 7, partly in section to show internal details of the exhaust manifold and integral turbine housing; and

FIG. 9 is a perspective view of the engine cylinder head and integral exhaust manifold and turbine housing used in the assembly of FIG. 7, partly sectioned to show internal details of the exhaust manifold and turbine housing.

DETAILED DESCRIPTION OF THE DRAWINGS

The present disclosure now will be described more fully hereinafter with reference to the accompanying drawings in which some but not all embodiments of the inventions are shown. Indeed, these inventions may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

An engine cylinder head and turbocharger assembly **10** in accordance with one embodiment of the invention is depicted in FIGS. 1 through 5. The assembly **10** comprises an engine cylinder head **20** (illustrated only schematically) on which a turbocharger **30** is mounted. The engine cylinder head **20** comprises a casting that is configured to sit atop the engine block, above the engine cylinders. The head **20** typically houses components of the intake and exhaust valves for the cylinders and defines intake and exhaust passages through which intake air is delivered to the cylinders and exhaust gases are routed away from the cylinders, respectively. The drawings depict a cylinder head for a three-cylinder in-line engine, but the invention of course is applicable to any number and arrangement of cylinders.

With respect to an engine axis $\mathbf{A}_E$ (FIG. 3) along which the engine cylinders are spaced, the head **20** has a first end **20a** (at which typically the transmissions for the intake and exhaust valves are located) and an opposite second end **20b**. The head **20** also has an intake side **20i** and an exhaust side **20e**. An intake manifold (not shown) typically is mounted to (or integrated into) the intake side **20i** of the head **20** for delivering intake air to the cylinders via the intake passages in the head.

The assembly **10** also includes an exhaust manifold **22** that defines an internal space **24** for receiving and collecting exhaust gases from the engine cylinders via exhaust gas passages **26** defined in the head **20**. As further described below, the exhaust gases collected in the manifold space **24** are delivered to the turbocharger **30**. In the illustrated embodiment, the exhaust manifold **22** is a “cap” comprising a casting that is formed separately from the casting of the head **20**. The exhaust manifold cap **22** is fastened to the exhaust side **20e** of the head **20**, such as by threaded fasteners. Alternatively, the manifold **22** could be integral with the head **20**, as further described below.

The turbocharger **30** is located at the second end **20b** of the head **20**. The turbocharger **30** comprises a compressor **40** and a turbine **50**. The compressor **40** includes a compressor wheel **42** surrounded by a compressor housing **44**. The turbine **50** includes a turbine wheel **52** surrounded by a turbine housing **54**. The compressor wheel **42** and turbine wheel **52** are affixed to opposite ends of a shaft **32** that rotates about a turbocharger axis $\mathbf{A_T}$. The shaft **32** is held in bearings **34** disposed within a center housing **36** located between the compressor housing **44** and the turbine housing **54**. The turbocharger **30** is oriented with its axis $\mathbf{A_T}$ transverse to the engine axis $\mathbf{A_E}$. In a typical engine installation in a vehicle, where the engine cylinders have their axes oriented generally vertically, the turbocharger axis $\mathbf{A_T}$ is substantially horizontal.

Additionally, the turbocharger **30** is positioned such that the compressor **40** is oriented toward the intake side **20i** of the head **20**, and the turbine **50** is oriented toward the exhaust side **20e** of the head, as best seen in FIG. 3. This has the advantage that thermal separation between the hot exhaust side **20e** of the head and the compressor **40** is increased relative to a more-conventional positioning of the turbocharger that would place the turbocharger adjacent the exhaust side **20e** with its axis $\mathbf{A_T}$ parallel to the engine axis. Such increased thermal isolation in turn should result in less heating of the intake air by the hot exhaust side of the cylinder head, which is beneficial for engine performance.

The turbine housing **54** can be made up of two separately formed turbine housing portions. A first turbine housing portion **54a** defines a volute **56** that receives exhaust gas from the space **24** in the exhaust gas manifold **22**. The volute **56** in the illustrated embodiment is open on the side of the first turbine housing portion **54a** that faces the compressor housing **44**, and the open side of the volute is closed by the second turbine housing portion **54b** that is fastened to the first turbine housing portion **54a** (e.g., by threaded fasteners). A nozzle **58** leading from the volute **56** into the turbine wheel **52** is formed between the first turbine housing portion **54a** and the second turbine housing portion **54b**.

In the illustrated embodiment, the center housing **36** comprises a single part (e.g., formed by casting) that integrates the backplate for the compressor **40** and the backplate for the turbine **50** and also accommodates the bearings **34** and defines oil passages for feeding oil to the bearings and draining oil from the bearings for recirculation to the engine oil system.

Furthermore, in the illustrated embodiment, the center housing **36** and the second turbine housing portion **54b** are cooperatively configured such that the center housing **36** is insertable into the second turbine housing portion **54b** in a direction parallel to the turbocharger axis $\mathbf{A_T}$ (in the right-to-left direction in FIG. 5). Suitable O-rings **60** are engaged between the center housing **36** and the second turbine housing portion **54b** to seal the interfaces therebetween. The center housing **36** and the rotor assembly (i.e., shaft **32**, compressor wheel **42**, and turbine wheel **52**) form a "cartridge" (also known as a center housing rotating assembly or CHRA) that is thus inserted into the second turbine housing portion **54b**. The compressor housing **44** is then secured to one side of the second turbine housing portion **54b** and the first turbine housing portion **54a** is secured to the other side of the second turbine housing portion.

With reference to FIG. 6, which shows a cross-section through the center housing **36** in isolation, in one embodiment the center housing **36** can be machined from a solid piece of cylindrical bar stock. The outlines of the bar stock are shown in heavy lines, and the center housing **36** machined from the bar stock is shown in narrower lines. The center housing **36** includes external surface features such as steps, one or more flanges, and the like. The center housing further includes a bearing bore **BB**, an oil inlet **OI**, oil cavities **OC**, oil drain passages **OD** leading generally downward and toward each other from the oil cavities, an oil outlet **OO** that connects with the oil drain passages, and a bearing pin passage **BP** through which a pin extends and engages the bearing assembly for immobilizing the bearing assembly in the bearing bore. In accordance with this embodiment, starting with the solid cylindrical bar stock, the center housing **36** is machined by machining the external surface features, followed by machining the bearing bore **BB**, machining the oil inlet **OI**, and machining the oil cavities **OC**. Next the oil drain passages **OD** and oil outlet **OO** are machined. Finally, the bearing pin passage **BP** is machined either through the same hole as the oil outlet or through a separate hole at a location circumferentially displaced from the oil outlet. This sequence of steps can be varied if desired.

Additionally, in the illustrated embodiment, the second turbine housing portion **54b** is an integral part of the casting of the engine cylinder head **20**, as best seen in FIGS. 1 and 3. That is, the head **20** and the second turbine housing portion **54b** are formed as an integral one-piece part by casting. Optionally, the second turbine housing portion **54b** defines one or more coolant passages **62** for receiving coolant from the cylinder head **20** and circulating the coolant through the second turbine housing portion. The integral formation of the head **20** and second turbine housing portion **54b** means that coolant can be passed between the head and the second turbine housing portion without the coolant having to cross any interfaces between these parts (and thus seals for sealing such interfaces are not required).

Furthermore, in the illustrated embodiment, the first turbine housing portion **54a** and the manifold cap **22** are formed as an integral one-piece part by casting, and that part is separately formed from the cylinder head casting. Optionally, the first turbine housing portion **54a** defines one or more coolant passages **64** for receiving coolant from coolant passages **28** in the manifold cap **22** and circulating the coolant through the first turbine housing portion. The integral formation of the manifold cap **22** and first turbine housing portion **54a** means that coolant can be passed between the cap and the first turbine housing portion without the coolant having to cross any interfaces between these parts (and thus seals for sealing such interfaces are not required).

With reference to FIGS. 3 and 5, the assembly **10** can also include a turbine bypass valve **70** integrated into the assembly in a novel and particularly efficient manner. The exhaust gas flow path that supplies exhaust gas from the manifold cap **22** to the turbine housing volute **56** is also open to a generally annular bypass passage **66** defined in the first turbine housing portion **54a**. The bypass passage **66** surrounds the axial bore **68** defined in the turbine housing. Exhaust gas that has passed through the turbine wheel **52** is exhausted from the turbine housing through the bore **68**. The bypass passage **66** provides an alternative pathway for exhaust gas to flow without first having to pass through the turbine wheel **52**. The bypass valve **70** is substantially as described in commonly owned co-pending U.S. Patent Application No. 12/771,434 filed on April 30, 2010, the entire disclosure of which is hereby incorporated herein by reference.

The bypass valve **70** is installed in the bypass passage **66** for regulating flow through the bypass passage. With primary reference to FIGS. 1, 3, and 5, the major components of the annular bypass valve **70** include a stationary valve seat **72** and a rotary valve member **74** in abutting engagement with the valve seat. The valve seat **72** and valve member **74** are arranged between the first turbine housing portion **54a** and a tubular inner member **55**. As shown, the inner member **55** is formed separately from the first turbine housing portion **54a** and is connected with an integral portion of the first turbine housing portion, but in other embodiments the inner member can be an integral part of the turbine housing. The first turbine housing portion **54a** and inner member **55** define an annular space between them for receiving the valve member **74** and the valve seat **72**. The valve member **74** is prevented from moving axially upstream by a shoulder defined by the first turbine housing portion **54a**, although during operation pressure of the exhaust gas urges the valve member **74** in the downstream direction. The valve member **74** is not constrained by the turbine housing but is free to rotate about its axis and to move axially against the valve seat **72**. The valve seat **72** is captured between the first turbine housing portion **54a** and an exhaust conduit **80** that is fastened to the first turbine housing portion **54a** and receives exhaust gas from the bore **68** of the turbine housing. Accordingly, the valve seat **72** is prevented from moving axially, radially, or rotationally. A radially outer edge portion of the upstream face of the valve seat **72** (i.e., the right-hand face in FIG. 5) abuts a shoulder defined by the first turbine housing portion **54a**, and the radially inner edge portion of the upstream face abuts a shoulder defined by the inner member **55**, thereby putting the valve seat in a precise axial location as dictated by these shoulders.

The valve seat **72** is a generally flat ring-shaped or annular member having a plurality of orifices **73** (FIG. 5) circumferentially spaced apart about a circumference of the valve seat, the orifices **73** extending generally axially between the upstream and downstream faces of the valve seat. The orifices **73** can be uniformly or non-uniformly spaced about the circumference of the valve seat.

The rotary valve member **74** is a generally flat ring-shaped or annular member having a plurality of orifices (not visible in the drawings) circumferentially spaced apart about a circumference of the valve seat, the orifices extending generally axially between the upstream and downstream faces of the valve member. The orifices can be uniformly or non-uniformly spaced about the circumference of the valve member. The number and spacing of the orifices in the valve member are the same as the number and spacing of the orifices **73** in the valve seat. The valve member **74** has a substantially circular cylindrical outer edge and a substantially circular cylindrical inner edge, the outer and inner edges being coaxial with respect to a central longitudinal axis of the valve member, which axis is also substantially coincident with a central longitudinal axis of the valve seat **72**. The first turbine housing portion **54a** and the inner member **55** both define substantially circular bearing surfaces for the outer and inner edges of the rotary valve member **74** and there are clearances therebetween, so that the valve member can be rotated in one direction or the opposite direction about its central longitudinal axis in order to vary a degree of alignment between the valve member orifices and the valve seat orifices **73**, as further described below.

With reference to FIG. 3, the valve member **74** is engaged by the distal end **92** of an L-shaped drive arm **90** that is rigidly affixed to a distal (radially inner) end of a rotary drive member **100**. The rotary drive member **100** penetrates substantially radially through the first turbine housing portion **54a** via a bore that connects with the generally annular bypass passage **66**. The proximal (radially outer) end of the rotary drive member **100** is located outside the first turbine housing portion **54a** and is rigidly affixed to a link **110**. The link **110** has a connecting member **112** (FIG. 1) that is offset from the rotation axis of the rotary drive member **100** and that can be coupled to an actuator rod **114** of an actuator **116** such that extension of the actuator rod **114** causes the link **110** to rotate the rotary drive member **100** in one direction and retraction of the actuator rod causes the link to rotate the rotary drive member in the opposite direction. As a result, the drive arm **90** affixed to the distal end of the rotary drive member **100** in turn causes the valve member **74** to be rotated in one direction or the opposite direction about its axis.

When the valve member **74** is positioned such that each of its orifices is located between two adjacent orifices **73** in the valve seat **72**, with no overlap therebetween, the bypass valve is closed, such that essentially no exhaust gas can pass through the bypass passage **66** (except perhaps for a very small leakage flow of no appreciable consequence).

In a “crack-open” position of the valve **70**, the valve member **74** is rotated a small amount such that there just begins to be some overlap between the orifices of the valve seat and valve member.

With further rotation of the valve member **74**, a greater degree of overlap exists between the orifices and the valve is partially open.

In a fully open position of the valve, there is the maximum possible overlap between the orifices in the valve seat and valve member.

With the described annular bypass valve **70**, exhaust gas pressure acts on the valve member **74** in a direction toward the fixed valve seat **72**, thereby tending to improve sealing between the valve member and valve seat. Furthermore, the gas pressure does not tend to open the valve, in contrast to the aforementioned swing and poppet style bypass valve arrangements in which gas pressure acts in a direction tending to open the valve and cause leakage. The improved sealing made possible by the valve **70** is thought to be significant because it can improve the transient response time of the turbocharger, by making better use of instantaneous engine pulses in the exhaust gas stream, especially at low engine speeds and gas flow rates where the pulse impact is most significant in regard to turbine efficiency.

A further advantage is that the valve **70** can achieve better controllability than is typically possible with swing or poppet valves, particularly at the crack-open point. In particular, the evolution of the shape and size of the flow passages through the valve as the valve member **74** is rotated can be tailored to the needs of a particular application simply by suitably configuring the sizes, angular locations (e.g., whether uniformly or non-uniformly spaced apart), and shapes of the orifices in the valve member and valve seat.

FIGS. 7 through 9 illustrate an alternative embodiment of the invention in which the cylinder head **20'**, manifold **22'**, and turbine housing **54'** can comprise an integral one-piece part made by casting. This embodiment retains the advantage that the center housing rotating assembly (i.e., the center housing **36** together with the shaft **32** and wheels **42** and **52**) can still be inserted as a unit into the turbine housing **54'**, but does not have the advantage of the previously described embodiment in which modifications to the A/R ratio of the turbine can be made without having to alter the cylinder head casting.

Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

WHAT IS CLAIMED IS:

1. An engine cylinder head and turbocharger assembly comprising:

an engine cylinder head for an internal combustion engine having a plurality of cylinders spaced apart along an engine axis, the engine cylinder head comprising a casting and having an intake side on one side of the engine axis and an exhaust side on an opposite side of the engine axis; and

a turbocharger comprising a compressor wheel mounted within a compressor housing and a turbine wheel mounted within a turbine housing and connected to the compressor wheel by a shaft that extends along a turbocharger axis about which the shaft rotates, the turbocharger further comprising a center housing connected between the compressor housing and the turbine housing, the center housing containing bearings for the shaft, the turbine housing defining a volute that surrounds the turbine wheel and receives exhaust gas from the engine and a nozzle that directs exhaust gas from the volute into the turbine wheel, the turbine housing further defining an axial bore through which exhaust gas that has passed through the turbine wheel is discharged from the turbine housing;

wherein at least part of the turbine housing is an integral portion of the casting of the engine cylinder head, and wherein the turbocharger is mounted to the engine cylinder head with the turbocharger axis oriented transverse to the engine axis and with the compressor housing oriented toward the intake side and the turbine housing oriented toward the exhaust side of the engine cylinder head.

2. The engine cylinder head and turbocharger assembly of claim 1, wherein the turbine housing comprises a first turbine housing portion and a second turbine housing portion formed separately from the first turbine housing portion, wherein the first turbine housing portion defines the volute and one wall of the nozzle and the second turbine housing portion defines an opposite wall of the nozzle, and wherein at least the second turbine housing portion is an integral portion of the casting of the engine cylinder head.

3. The engine cylinder head and turbocharger assembly of claim 2, further comprising an exhaust manifold cap comprising a casting formed separately from the casting of the engine cylinder head and mounted to the exhaust side of the engine cylinder head, the exhaust manifold cap defining an internal space that collects exhaust gas from the cylinders of the engine via exhaust gas passages defined in the engine cylinder head, and wherein the first turbine housing portion is an integral part of the casting of the exhaust manifold cap.

4. The engine cylinder head and turbocharger assembly of claim 3, wherein the exhaust manifold cap further defines a coolant passage arranged to receive engine coolant from a corresponding passage in the engine cylinder head and circulate the coolant through the exhaust manifold cap, and wherein the first turbine housing portion defines a coolant passage arranged to receive the coolant from the coolant passage in the exhaust manifold cap and circulate the coolant through the first turbine housing portion.

5. The engine cylinder head and turbocharger assembly of claim 1, wherein the turbine housing defines an annular bypass passage surrounding the bore and arranged to allow exhaust gas to bypass the turbine wheel, and the turbocharger further comprises:

an annular bypass valve disposed in the bypass passage, the bypass valve comprising a fixed annular valve seat and a rotary annular valve member arranged coaxially with the valve seat relative to an axis, the valve member being disposed against the valve seat and being rotatable about the axis for selectively varying a degree of alignment between respective orifices defined through each of the valve seat and valve member, ranging from no alignment defining a closed condition of the bypass valve, to at least partial alignment defining an open condition of the bypass valve.

6. The engine cylinder head and turbocharger assembly of claim 1, wherein the center housing comprises a single part formed by casting that integrates a backplate for the compressor and a backplate for the turbine.

7. The engine cylinder head and turbocharger assembly of claim 6, wherein the center housing and the second turbine housing portion are cooperatively configured such that the center housing is insertable into the second turbine housing portion in a direction parallel to the turbocharger axis.

8. The engine cylinder head and turbocharger assembly of claim 7, wherein O-rings are engaged between the center housing and the second turbine housing portion to seal the interfaces therebetween.

9. The engine cylinder head and turbocharger assembly of claim 7, wherein the center housing, the shaft, the compressor wheel, and the turbine wheel form a cartridge that is insertable into the second turbine housing portion in said direction parallel to the turbocharger axis.

10. The engine cylinder head and turbocharger assembly of claim 9, wherein the compressor housing is formed separately from the second turbine housing portion and is secured to one side of the second turbine housing portion, and the first turbine housing portion is formed separately from the second turbine housing portion and is secured to the other side of the second turbine housing portion.

11. The engine cylinder head and turbocharger assembly of claim 1, further comprising an exhaust manifold joined to the exhaust side of the engine cylinder head, the exhaust manifold defining an internal space that collects exhaust gas from the cylinders of the engine via exhaust gas passages defined in the engine cylinder head, and wherein the engine cylinder head, exhaust manifold, and turbine housing all are integrated into a one-piece part made by casting.

12. The engine cylinder head and turbocharger assembly of claim 11, wherein the center housing and the turbine housing are cooperatively configured such that the center housing is insertable into the turbine housing in a direction parallel to the turbocharger axis, and the center housing, the shaft, the compressor wheel, and the turbine wheel form a cartridge that is insertable into the turbine housing in said direction parallel to the turbocharger axis.

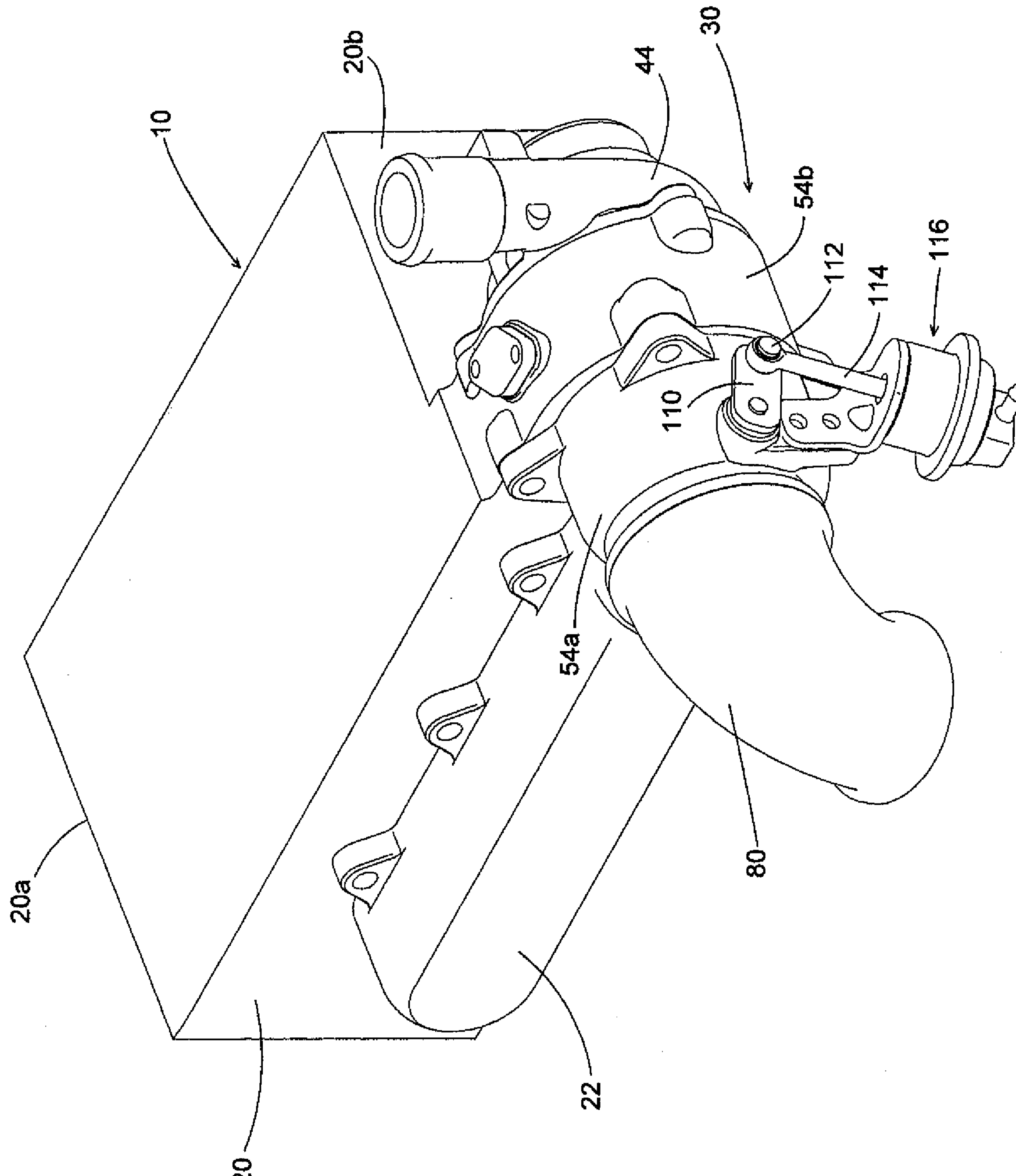

FIG. 1

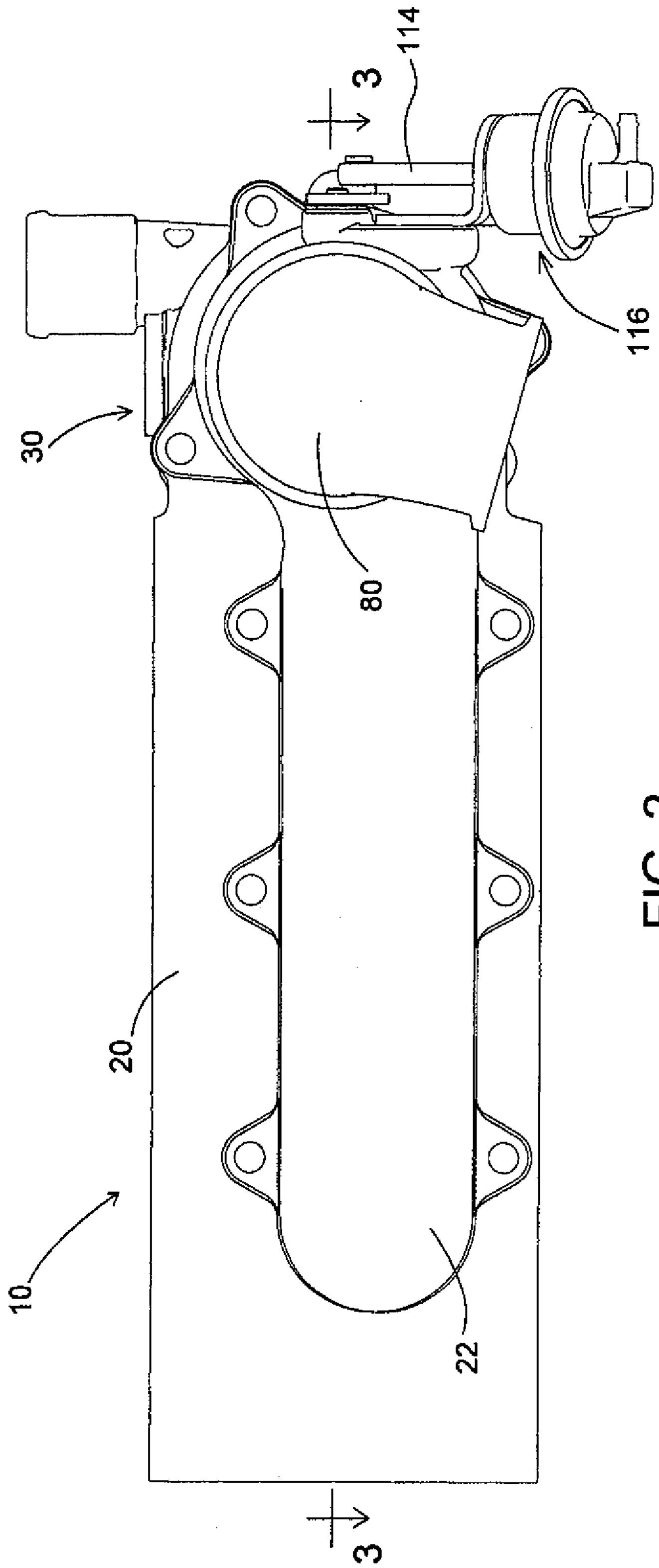

FIG. 2

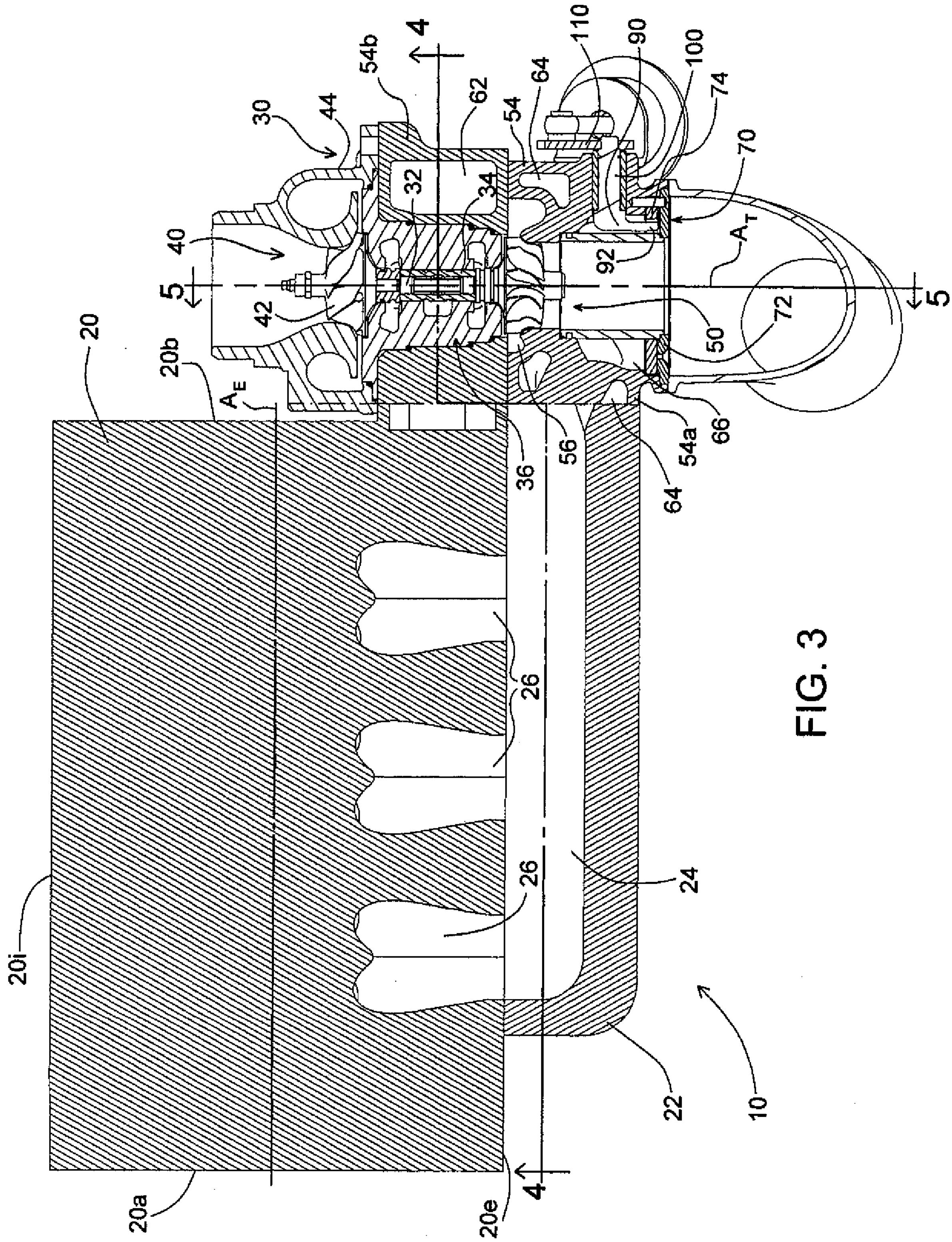
4
54b
62
54
64
110
90
100
74
70
30
44
32
34
40
5
42
92
A_T
50
72
5
20
20b
A_E
36
56
54a
66
64
26
26
26
24
20i
22
10
20a
20e
4

FIG. 3

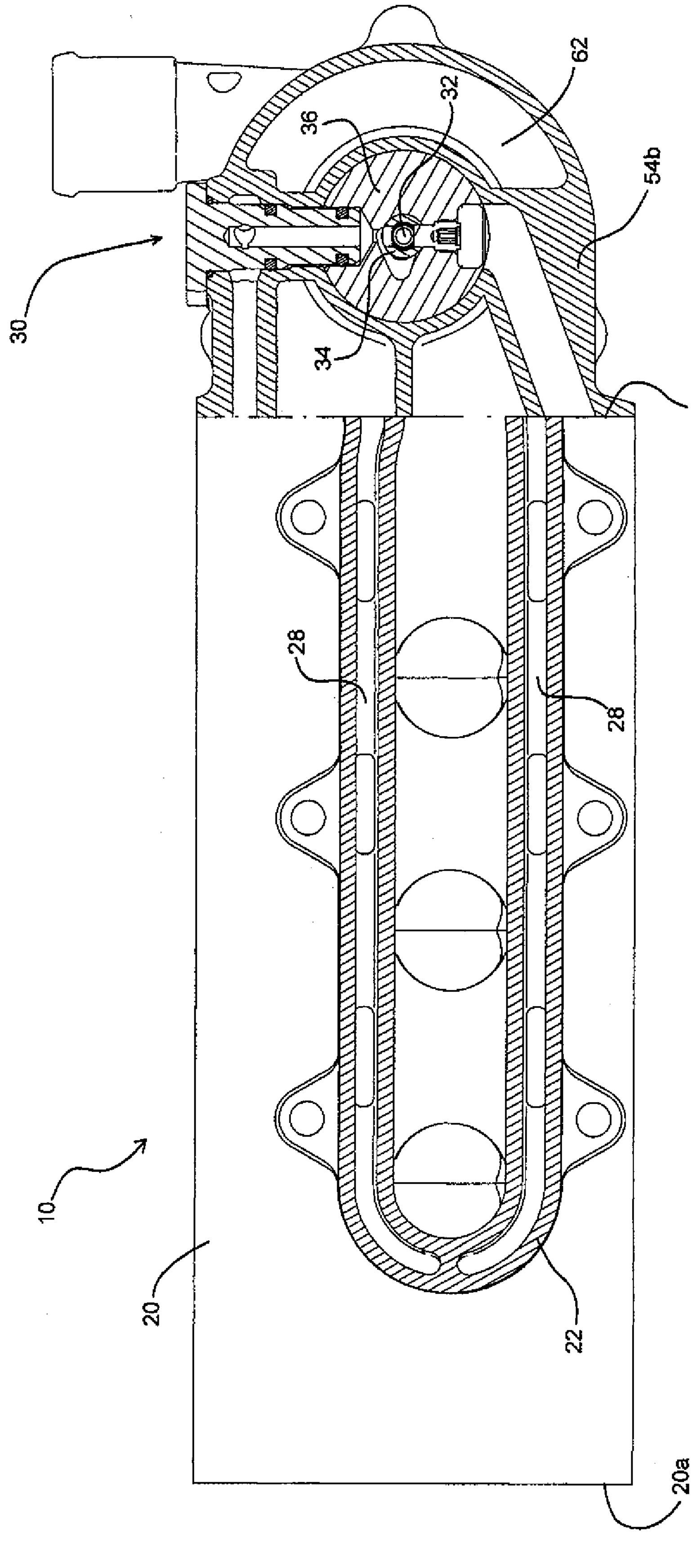

FIG. 4

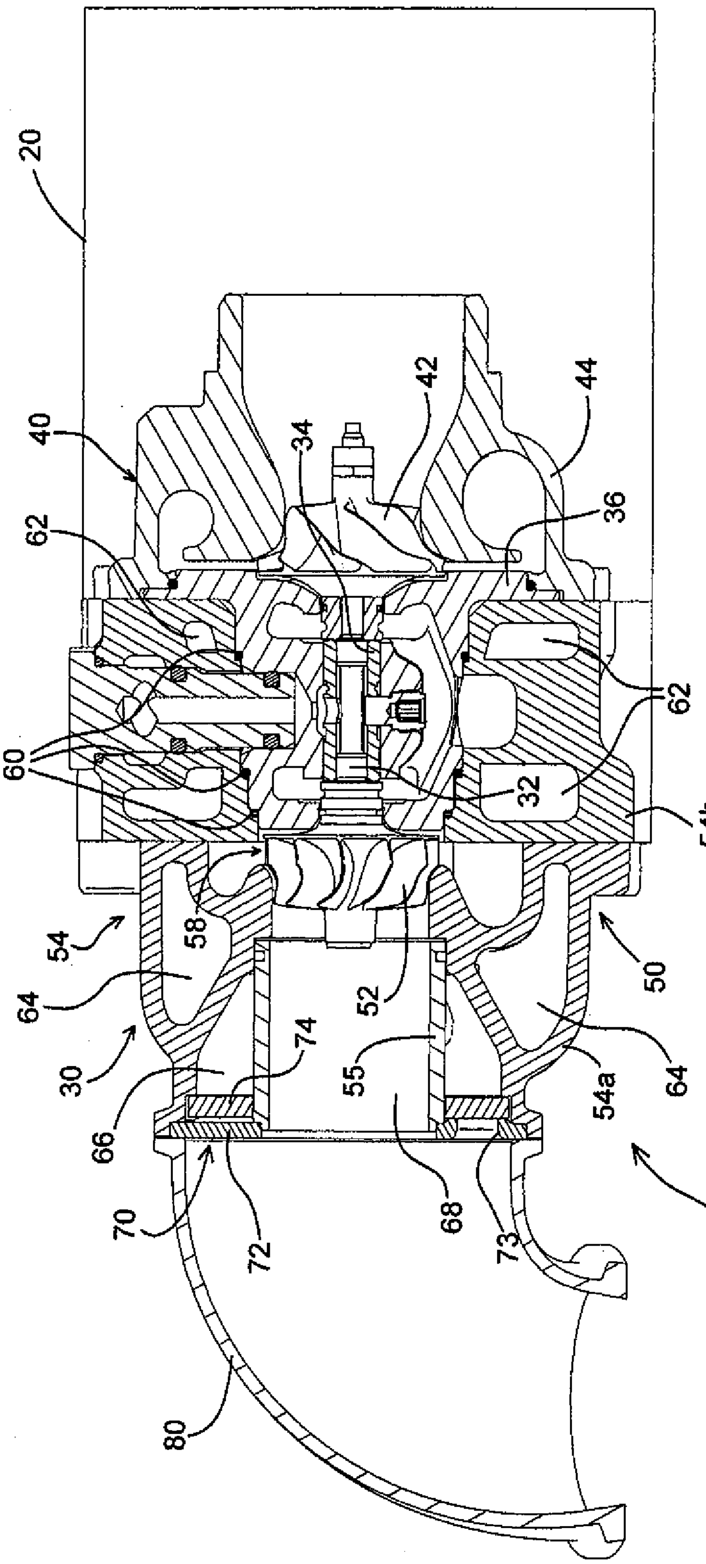
20
40
42
44
34
36
62
62
60
32
54b
58
54
50
64
52
64
30
74
55
54a
66
68
70
72
73
10
80

FIG. 5

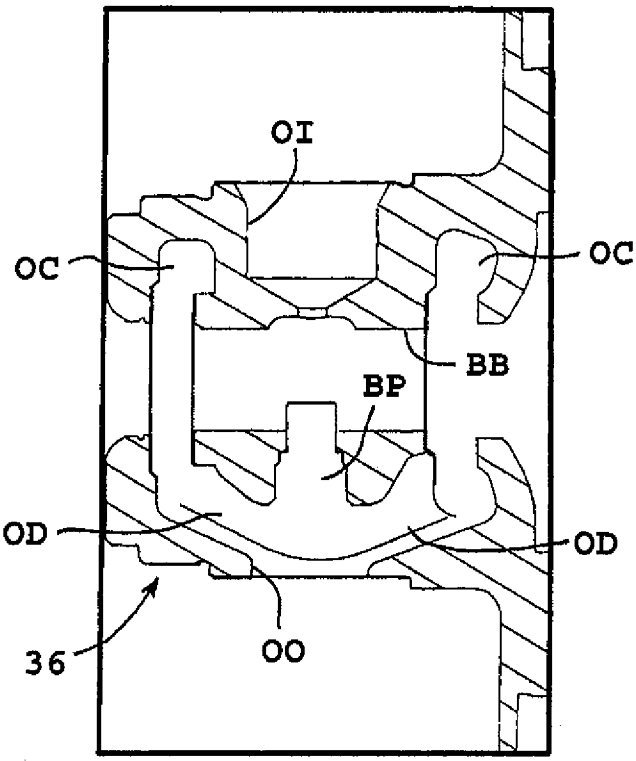

FIG. 6

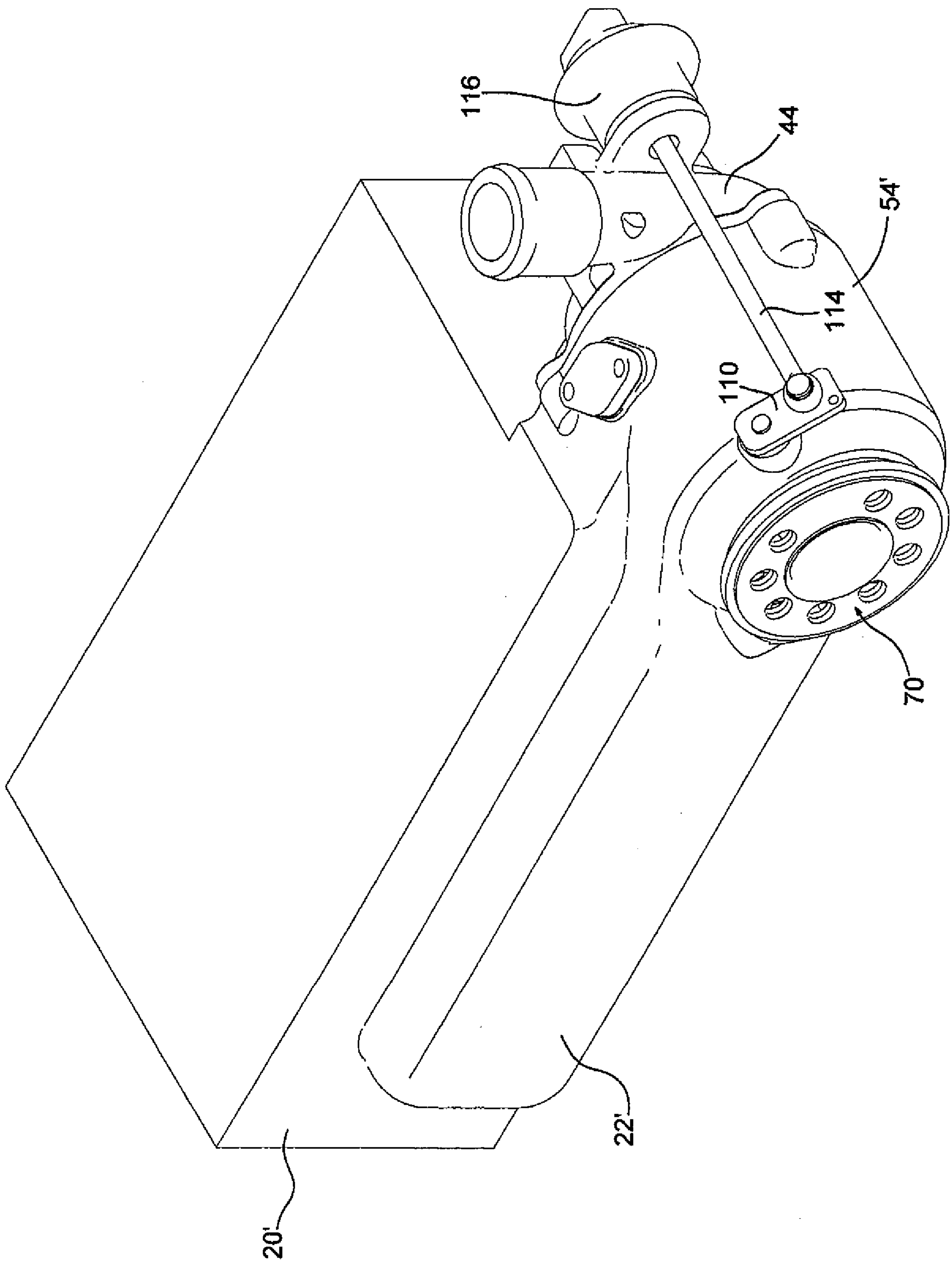

FIG. 7

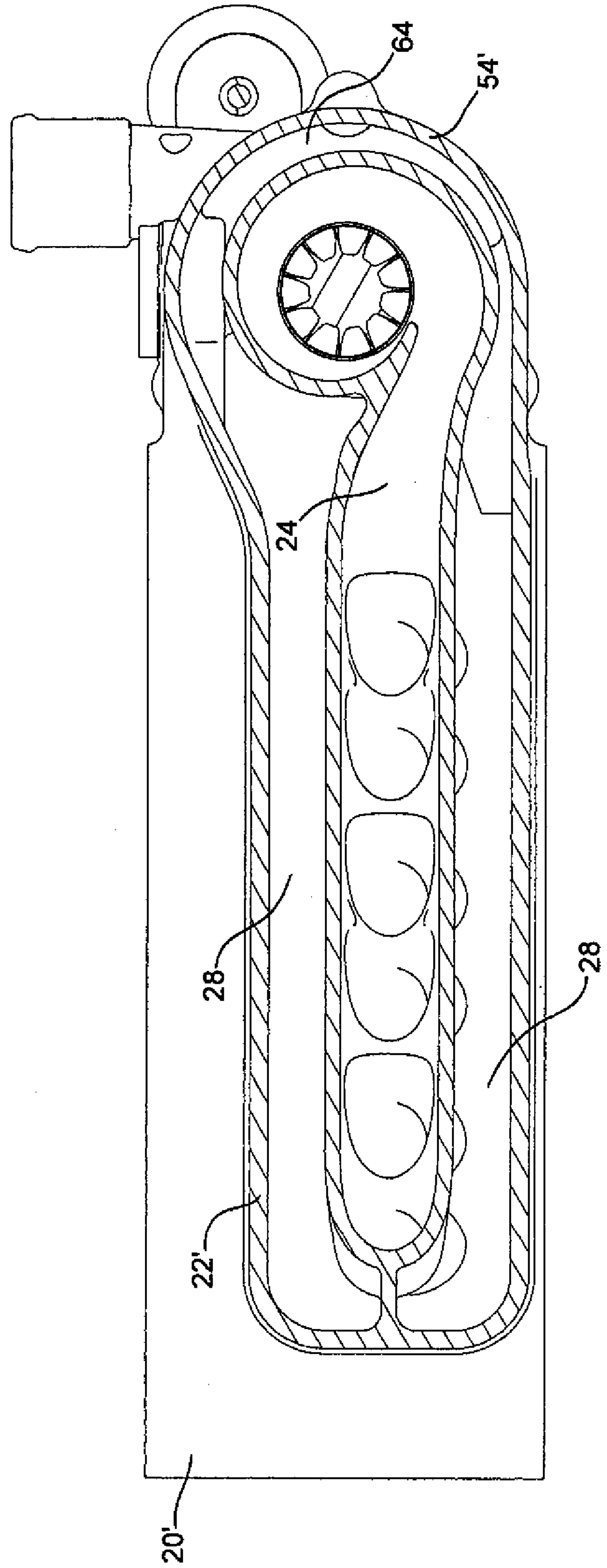

FIG. 8

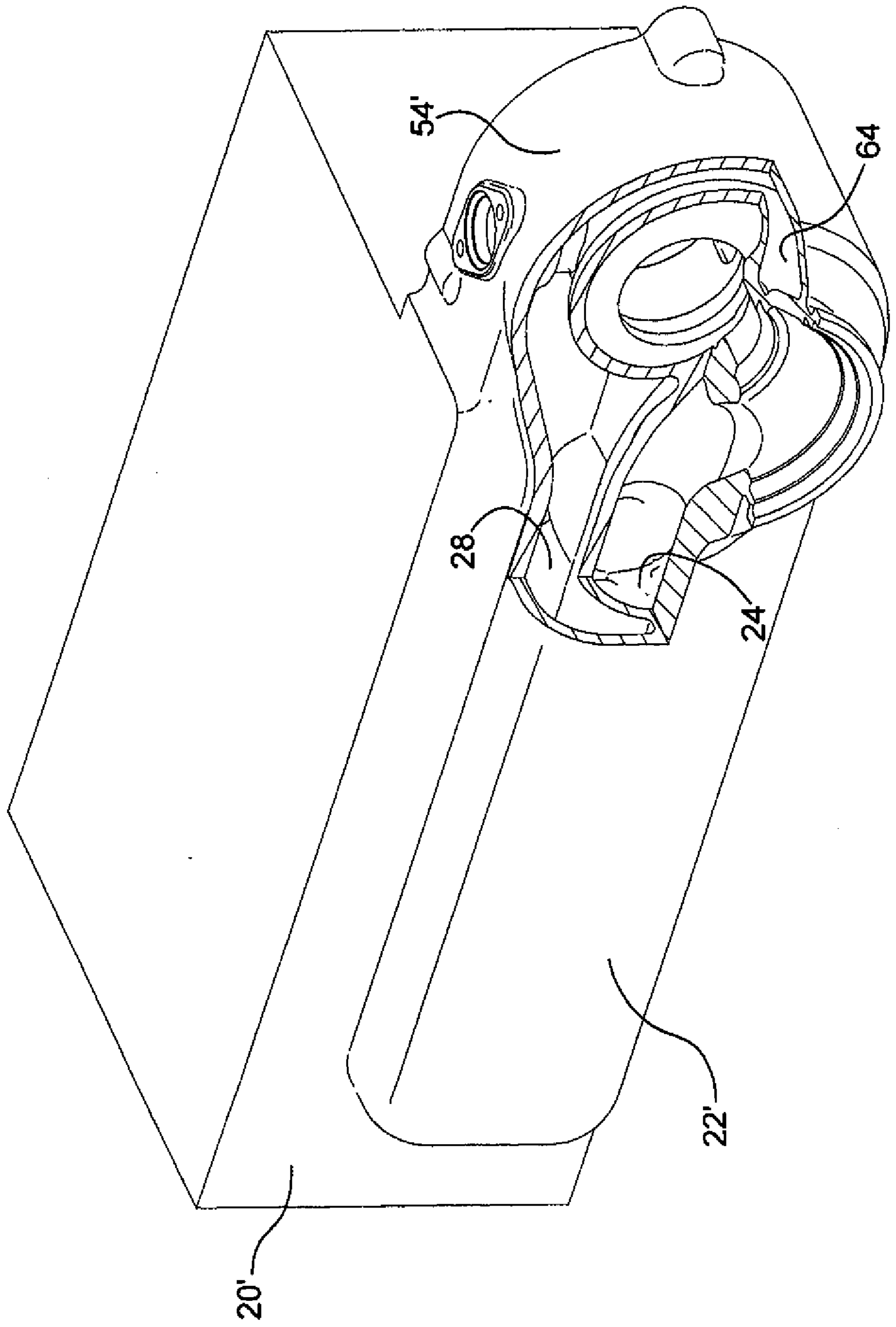

FIG. 9