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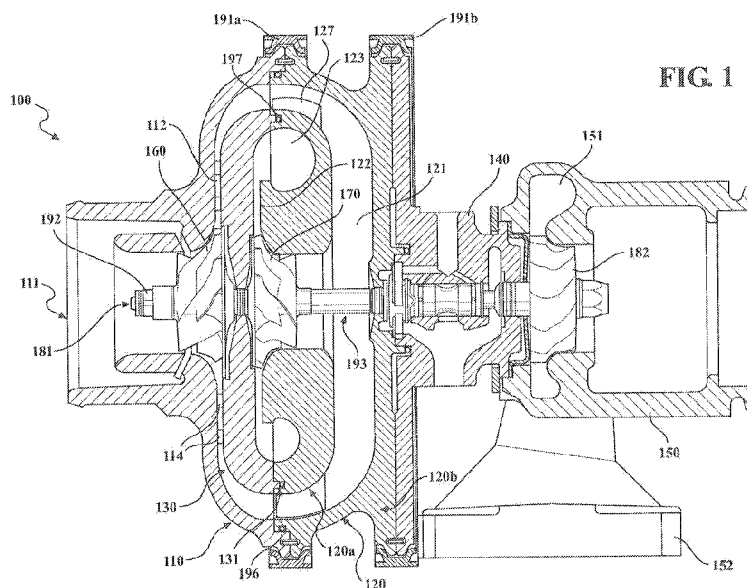
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(54) **Title:** TURBOCHARGER COMPRISING A MODULAR CONSTRUCTION COMPRESSOR HOUSING

**FIG. 1**

(57) **Abstract:** This disclosure provides a modular construction compressor housing (100, 200, 300) including an outer compressor housing (110, 210, 310) having an outer compressor wheel (160, 260, 360) disposed therein. The outer compressor housing (110, 210, 310) is fluidly connected to an inner compressor housing (120, 220, 320) also including an inner compressor wheel (170, 270, 370) disposed therein. A diffuser plate (130, 230) is positioned between the outer compressor housing (110, 210) and the inner compressor housing (120, 220).

TURBOCHARGER COMPRISING A MODULAR CONSTRUCTION COMPRESSOR
HOUSING**CROSS-REFERENCE TO RELATED APPLICATION**

5 This application claims priority to and all the benefits of U.S. Provisional Application No. 62/015,004 filed on June 20, 2015, and entitled "Modular Design Concept For Construction And Assembly Of Single And Multistage Turbocharger Compressors" which is incorporated herein by reference.

BACKGROUND**10 Field of the Disclosure**

 The present disclosure relates to turbochargers for an internal combustion engine. More particularly the disclosure relates to a method of modular construction and assembly of a turbocharger housing. The turbocharger housing is assembled from modules which are fastened to one another using V-clamps, circlips, bolts, clamp load force, or other suitable attachment
15 devices.

Description of Related Art

 A turbocharger is a type of forced induction system used with internal combustion engines. Turbochargers deliver compressed air to an engine intake, allowing more fuel to be
20 combusted, thereby boosting the horsepower of an engine without significantly increasing engine weight. Thus, turbochargers permit the use of smaller engines that develop the same amount of horsepower as larger, normally aspirated engines. Using a smaller engine in a vehicle has the desired effect of decreasing the mass of the vehicle, increasing performance, and enhancing fuel economy. Moreover, the use of turbochargers permits more complete combustion of the fuel
25 delivered to the engine, which contributes to the highly desirable goal of a cleaner environment.

 Turbochargers typically include a turbine housing connected to the exhaust manifold of the engine, a compressor housing connected to the intake manifold of the engine, and a bearing housing coupling the turbine and compressor housings together. A turbine wheel in the turbine housing is rotatably driven by an inflow of exhaust gas supplied from the exhaust manifold. A
30 shaft rotatably supported in the bearing housing connects the turbine wheel to a compressor impeller in the compressor housing so that rotation of the turbine wheel causes rotation of the compressor impeller. The shaft connecting the turbine wheel and the compressor impeller defines an axis of rotation. As the compressor impeller rotates, it increases the air mass flow rate, airflow density and air pressure delivered to the cylinders of the engine via the intake

manifold of the engine. The compressor housing, bearing housing, and turbine housing are frequently connected by bolts, although V-clamps or circlips as attaching devices may also be used.

In recent years, increasingly stringent emissions regulations have mandated a progressive
5 reduction in the level of oxides of nitrogen (NO_x) present in the exhaust gas of diesel engines. Since greater NO_x production occurs at high combustion temperatures, a common strategy among engine manufacturers in reducing NO_x levels, is to direct a portion of the exhaust gas back into the cylinders of the engine in a process known as Exhaust Gas Recirculation or EGR. The exhaust gas is combined with the oxygen-rich fresh air from the intake stage and does not
10 contribute to the combustion process. Instead, recirculated exhaust gas absorbs heat from the fresh air/fuel mix during combustion, lowering the engine combustion temperature and reducing NO_x production. In some cases, to further reduce the engine combustion temperature, the exhaust gas is cooled before being recirculated and combined with the oxygen-rich fresh air from the engine intake. Depending on the configuration and operating parameters of the engine, as
15 much as 30% of the engine intake may consist of recirculated exhaust gas.

Higher EGR rates increase the demand on the compressor side of the turbocharger without increasing the amount of exhaust gas available to power the turbine. This makes matching of a conventional turbocharger with an engine increasingly difficult as the compressor wheel must increase in size to provide the required volumetric flow and boost pressure, while the
20 turbine wheel must remain small to make optimal use of the exhaust gas. As such, a compromise in compressor wheel selection is required because larger compressor wheels operate more efficiently at lower rotational speeds but, differing compressor wheel sizes are not possible with a conventional single-stage turbocharger. Furthermore, increasing the diameter of the compressor wheel increases inertia of the wheel and has a detrimental effect on the transient
25 response of the turbocharger. The longer time-to-boost causes the engine to spend more time running in a less efficient state, increasing fuel consumption and exhaust emissions. One solution has been to use a two-stage turbocharger system; however, two-stage turbocharger systems are usually not preferred because they are complex, expensive and difficult to package in situations where space is limited around the engine.

30 Another solution has involved placing multiple, smaller compressor wheels on a common shaft driven by a single turbine wheel. This arrangement allows the turbocharger to operate at a higher speed and therefore with greater turbine efficiency, while the compressor wheels together provide the performance of a single, large wheel with less inertia and therefore a faster transient

response time. To achieve the desired volumetric flow and boost pressure, the compressor wheels can be arranged to operate in parallel as a single-stage compressor, in series as a multi-stage compressor, or as a combination of these.

SUMMARY

5 The present disclosure provides a turbocharger including a modular compressor in which the compressor housing is divided into multiple portions held together with attaching devices such as V-clamps, circlips, bolts, clamp force or other suitable attachment devices. This allows the compressor to be easily modified without having to create new complex castings. Accordingly, the modular design allows rapid turbocharger development for new applications
10 using modular plates.

BRIEF DESCRIPTION OF THE DRAWINGS

Advantages of the present disclosure will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

15 Figure 1 is a cross-sectional view of a two stage compressor turbocharger having modular construction.

Figure 2 is an exploded view of a two stage compressor having modular construction.

20 Figure 3 is a side view of the high pressure compressor housing.

Figure 4 is a cross-sectional view of a one stage compressor turbocharger having a modular construction with compressor wheels having dissimilar aerodynamic performance.

25 Figure 5 is a cross-sectional view of a one stage compressor turbocharger having a modular construction with compressor wheels having similar aerodynamic performance.

DETAILED DESCRIPTION

30 Figure 1 details a two-stage turbocharger having a modular construction compressor housing (100) comprising a low pressure stage including an outer compressor housing (110), a high pressure stage including an inner compressor housing (120), a bearing housing (140), and a turbine housing (150). The outer compressor housing (110) houses an outer compressor wheel (160) and the inner compressor housing (120) houses an inner compressor wheel (170). The
35 outer compressor wheel (160) and the inner compressor wheel (170) are retained on one end of a

shaft (181) by a nut (192). A turbine wheel (182) is positioned on an opposing end of the shaft (181) within an exhaust gas volute (151) of the turbine housing (150). The bearing housing (140) connects the inner compressor housing (120) to the turbine housing (150), and shaft (181) is rotatably supported within the bearing housing (140). Turbine housing (150) is fluidly
5 connected to an internal combustion engine (not shown) by an exhaust gas inlet passage (152).

As detailed in Figure 2, the two-stage turbocharger having a modular construction compressor housing (100) further includes a diffuser plate (130) disposed between the outer compressor wheel (160) and the inner compressor wheel (170). The inner compressor housing (120) further includes an inner volute (123), an inner air passage (121), a front flange (124) and a rear flange (125); the outer compressor housing (110) includes an outer flange (113); and the bearing housing (140) includes a bearing housing flange (141). The outer compressor housing (110) and the inner compressor housing (120) are held together at the outer compressor housing (110) outer flange (113) and the inner compressor housing (120) front flange (124) by a first
10 connection device (191a). The inner compressor housing (120) and the bearing housing (140) are held together at the inner compressor housing (120) rear flange (125) and the bearing housing flange (141) by a second connection device (191b). While a V-clamp is illustrated as the connection device for the modular compressor, circlips, bolts, clamp load force, or other similar attachment devices are known to work as well. The inner compressor housing (120) includes a
15 first inner compressor portion (120a) and a second inner compressor portion (120b). The first inner compressor portion (120a) of the inner compressor housing (120), which forms the inner volute (123), is connected to the second inner compressor portion (120b) of the inner compressor housing (120) forming the inner air passage (121) by one or more struts (127). While at least one strut (127) is detailed, more than one strut (127) has been found to work well. The diffuser
20 plate (130) is connected to the first inner compressor portion (120a) of the inner compressor housing (120) by a joining assembly (131) such as a tongue and groove connection or any other similar joining or connection means. An outer diffuser (112), associated with the outer compressor wheel (160), is formed by the outer compressor housing (110) and the diffuser plate (130). An inner diffuser (122), associated with the inner compressor wheel (170) and the inner
25 volute (123), is formed between the diffuser plate (130) and the inner compressor housing (120). In this arrangement, the inner compressor housing (120) is attached to one side of the bearing housing (140) and the turbine housing (150) is attached to an opposite side of the bearing housing (140).
30

The turbocharger, having two compressor stages, is assembled by mounting the inner compressor housing (120) on the bearing housing (140) and securing the rear flange (125) to the bearing housing flange (141) using the second connection device (191b). A first O-ring (196) and a second O-ring (197) are inserted in grooves (not labeled) formed, respectively, in the second inner compressor portion (120b) and the first inner compressor portion (120a) of the inner compressor housing (120). The first O-ring (196) and the second O-ring (197) aid with maintaining the pressure acquired from stage to stage. Specifically, the first O-ring (196) is positioned to maintain pressure with respect to mating surfaces (not labeled) formed between the inner compressor housing (120) and the outer compressor housing (110), and the second O-ring (197) is positioned to maintain pressure with respect to mating surfaces (not labeled) formed between the diffuser plate (130) and the inner compressor housing (120), (See Figure 1). A first spacer (193) and the inner compressor wheel (170) are mounted to the shaft (181) along with a second spacer (194) and interstage seals (195). The second spacer (194) may be a simple spacer or it may be a bearing of a type that does not require a continuous supply of lubricating oil, for example a roller bearing, a ball bearing, or a sliding contact bearing. The first (193) and second (194) spacer aid in supporting and maintaining the position of the shaft (181). Interstage seals (195) also assist with maintaining pressure across compressor stages. The diffuser plate (130) and the outer compressor wheel (160) are mounted to the shaft (181) and the outer compressor wheel (160) is secured by the nut (192). The diffuser plate (130) is positioned with respect to the inner compressor housing (120) by height controlled contact features (114) located on the outer compressor housing (110). The contact features (114) may be, for example, pads or bosses having a height that is controllable relative to the outer flange (113) of the outer compressor housing (110), or they may be separate components, such as stand-off bolts, pre-assembled to the outer compressor housing (110). Contact features (114) that are cast as an integral portion of the outer compressor housing (110) have been found to work well. The diffuser plate (130) is retained in position by a compressive load applied through the contact features (114) by the outer compressor housing (110) and the first connection device (191a). Anti-rotation pins, lugs or other similar means, may be used to ensure that the diffuser plate (130) is properly oriented with respect to the outer compressor housing (110) or the outer compressor housing (120). Interstage seals (195), particularly, maintain pressure here - across the outer compressor wheel (160) and the inner compressor wheel (170) at the diffuser plate (130) and the shaft (181). Finally, the outer compressor housing (110) is mounted, and the outer flange (113) is secured to the front flange (124) of the inner compressor housing (120) with the first connection device (191a).

In operation, exhaust gas is received through the exhaust gas inlet passage (152) to the exhaust volute (151) which then spins the turbine wheel (182). The turbine wheel (182) drives rotation of the outer compressor wheel (160) and the inner compressor wheel (170). Ambient air enters the modular construction compressor housing (100) via an air inlet (111) and is accelerated/compressed by the outer compressor wheel (160). The air passes through the outer diffuser (112) and enters the inner air passage (121). The compressed air from the outer compressor wheel (160) passes through the inner air passage (121) to the inner compressor wheel (170) where it is further accelerated/compressed. The air then passes through the inner diffuser (122) before entering the inner volute (123) and is delivered to the cylinders of the engine via the intake manifold of the engine (not shown).

The modular design disclosed allows for quick modification of the turbocharger. For example, in order to modify the shape of the outer diffuser (112), one can either change the outer compressor housing (110) or the diffuser plate (130) or possibly both. Similarly, the shape of the inner diffuser (122) may be changed by changing the diffuser plate (130). The aspect ratio of the turbocharger may be changed by changing the inner compressor housing (120). The trim of the turbocharger outer compressor wheel (160) may be changed by changing the outer compressor wheel (160), and either the outer compressor housing (110), or the diffuser plate (130) or both. The trim of the turbocharger inner compressor wheel (170) may be changed by changing the inner compressor wheel (170), the diffuser plate (130), the inner compressor housing (120), or any combination of these. The connection of the modular construction compressor housing (100) to the air intake of an internal combustion engine (not shown) may be changed by changing the inner compressor housing (120) without modifying the other components of the turbocharger.

Casting of the modular portions used in the modular compressor assembly is simple and less costly to produce as opposed to the traditional casting of a compressor housing. Accordingly, it is possible to assemble a set of modular portions of the compressor, which may be used to quickly assemble a wide variety of turbochargers.

Figure 3 shows a side view of the inner compressor housing (120), an external side of the inner volute (123), and the struts (127) that connect the first inner compressor portion (120a) of the inner compressor housing (120) to the second inner compressor portion (120b) of the inner compressor housing (120) (see also Figure 1).

An alternate embodiment, comprising a single-stage turbocharger, as shown in Figure 4, includes a modular construction compressor housing (200) having two compressor wheels – an outer compressor wheel (260) and an inner compressor wheel (270) disposed therein. The outer and inner compressor wheels (260, 270) are not aerodynamically similar in that the outer and inner compressor wheels (260, 270) rotate in opposing directions and do not provide the same volumetric flow and boost pressure.

The modular construction compressor housing (200) includes an outer compressor housing (210), an inner compressor housing (220), a bearing housing (240), and a turbine housing (250). The outer compressor housing (210) includes a first outer compressor portion (210a) and a second outer compressor portion (210b). The first outer compressor portion (210a) forms an outer volute (216). The first outer compressor portion (210a) and the second outer compressor portion (210b) forms an outer air passage (215). The inner compressor housing (220) includes a first inner compressor portion (220a) and a second inner compressor portion (220b). The first inner compressor portion (220a) forms an inner volute (223) and an inner air passage (228). The outer air passage (215) and the inner air passage (228) are fluidly connected to an air inlet (211) and the inner compressor wheel (270). A diffuser plate (230) is disposed between the first outer compressor portion (210a) of the outer compressor housing (210) and the first inner compressor portion (220a) of the inner compressor housing (220). The first outer compressor portion (210a) of the outer compressor housing (210) and the diffuser plate (230) forms the first diffuser (212). The first diffuser (212) is associated with the outer volute (216) and the outer compressor wheel (260). The first inner compressor portion (220a) of the inner compressor housing (220) and the diffuser plate (230) forms a second diffuser (222). The second diffuser (222) is associated with the inner volute (223) and the inner compressor wheel (270).

The modular construction compressor housing (200) is assembled by mounting the inner compressor housing (220) on the bearing housing (240) about a shaft (281) and securing a rear flange (225) of the inner compressor housing (220) to a bearing flange (241) of the bearing housing (240) using a first connection device (291b). While a V-clamp is illustrated as the connection device for the modular compressor, circlips, bolts, clamp load force, or other similar attachment devices are known to work as well. A first spacer (293) and the inner compressor wheel (270) are mounted on the shaft (281). Similar to the assembly shown in Figure 2, a first O-ring (296) (shown in Figure 4), second spacers (not shown in Figure 4) and interstage seals (not shown in Figure 4) may then be mounted on the shaft (281). The second spacers (not shown) may be a simple spacer or may be a bearing of a type that does not require a continuous

supply of lubricating oil, for example a roller bearing, a ball bearing, or a sliding contact bearing. The diffuser plate (230) and the outer compressor wheel (260) are mounted to the inner compressor housing (220) and the shaft (281), respectively, and are secured by a nut (292). Finally, the outer compressor housing (210) is mounted and an outer flange (213) of the outer
5 compressor housing (210) is secured to a front flange (224) of the inner compressor housing (220) with a second connection device (291a). The diffuser plate (230) is maintained in position with the inner compressor housing (220) by making contact with the first outer compressor portion (210a) of the outer compressor housing (210) and is retained in position by a compressive load applied by the outer compressor housing (210) and the second connection
10 device (291a). Anti-rotation pins, lugs or other similar means, may be used to ensure that the diffuser plate (230) is properly oriented with respect to the outer compressor housing (210) or the inner compressor housing (220).

15 In operation, the outer (260) and inner (270) compressor wheels are driven by the rotation of a turbine wheel (282) which is contained in the turbine housing (250) and receives exhaust gas from an exhaust gas inlet (252) via an exhaust gas volute (251). Compressed air from the inner compressor wheel (270) and the outer compressor wheel (260) is combined after passing through the inner volute (223) and the outer volute (216), respectively, before entering the air intake of
20 the engine (not shown).

Another alternate embodiment single-stage turbocharger, as shown in Figure 5, includes a modular construction compressor housing (300) having two compressor wheels – an outer compressor wheel (360) and an inner compressor wheel (370) disposed therein. The outer and
25 inner compressor wheels (360, 370) are aerodynamically similar in that the outer and inner and compressor wheels (360, 370) rotate in opposing directions and, otherwise, provide the same volumetric flow and boost pressure.

The turbocharger (300) includes an outer compressor housing (310), an inner compressor
30 housing (320), a bearing housing (340), and a turbine housing (350). The outer compressor housing (310) includes a first outer compressor portion (310a) and a second outer compressor (310b). The first outer compressor portion (310a) and the second outer compressor (310b) forms an outer air passage (315). The inner compressor housing (320) includes a first inner compressor portion (320a) and a second inner compressor portion (320b). The first inner compressor portion
35 (320a) forms an inner volute (323). The first inner compressor portion (320a) and the second

inner compressor portion (320b) forms an inner air passage (328). The outer air passage (315) and the inner air passage (328) are fluidly connected to an air inlet (311), the outer compressor wheel (360) and the inner compressor wheel (370). The inner volute (323) is common to both the inner compressor wheel (370) and the outer compressor wheel (360). An inner diffuser (322) is formed by the first inner compressor portion (320a) of the inner compressor housing (320) and the first outer compressor portion (310a) of the outer compressor housing (310).

The modular construction compressor housing (300) is assembled by mounting the inner compressor housing (320) about a shaft (381) on the bearing housing (340) and securing a rear flange (325) of the inner compressor housing (320) to a bearing flange (341) of the bearing housing (340) using a first connection device (391b). While a V-clamp is illustrated as the connection device for the modular compressor, circlips, bolts, clamp load force, or other similar attachment devices are known to work as well. A first spacer (293), the inner compressor wheel (370), and the outer compressor wheel (360) are mounted on the shaft (381) and secured by a nut (392). Similar to the assembly shown in Figure 2, a first O-ring (396) (shown in Figure 5) and additional spacers or seals may also be used. The second spacer (not shown) may be a simple spacer or may be a bearing of a type that does not require a continuous supply of lubricating oil, for example a roller bearing, a ball bearing, or a sliding contact bearing. Finally the outer compressor housing (310) is mounted to the inner compressor housing (320) and an outer flange (313) of the outer compressor housing (310) is secured to a flange (324) of the inner compressor housing (320) with a second connection device (391a).

In operation, the outer (360) and inner (370) compressor wheels are driven by the rotation of a turbine wheel (382) which is contained in the turbine housing (350) and receives exhaust gas from an exhaust gas inlet (352) via an exhaust gas volute (351). Compressed air from the inner compressor wheel (370) and the outer compressor wheel (360) is combined in the inner diffuser (322) and inner volute (323) before entering the air intake of the engine (not shown).

We claim:

1. A turbocharger comprising:

a modular construction compressor housing (100, 200) including an outer compressor housing (110, 210) having an outer compressor wheel (160, 260) disposed therein, an inner compressor housing (120, 220) having an inner compressor wheel (170, 270) disposed therein and including a first inner compressor portion (120a, 220a) configured to form an inner volute (123, 223), and a diffuser plate (130, 230) disposed between the outer compressor housing (110, 210) and the inner compressor housing (120, 220);

a bearing housing (140, 240);

a turbine housing (150, 250) having a turbine wheel (181, 282) disposed therein;

a turbocharger shaft (181, 281) extending through the modular construction compressor housing (100, 200), the bearing housing (140, 240) and the turbine housing (150, 250);

the outer compressor wheel (160, 260) and the inner compressor wheel (170, 270) retained on one end of the turbocharger shaft (181, 281) via a nut (192, 292), the turbine wheel (182, 282) mounted on an opposing end of the turbocharger shaft (181, 281);

the outer compressor housing (110, 210) is configured to be fluidly connected to the inner compressor housing (120, 220) by a first connection device (191a, 291a); and

the inner compressor housing (120, 220) is configured to be fluidly connected to the bearing housing (140, 240) by a second connection device (191b, 291b).

2. The turbocharger according to claim 1 wherein the outer compressor housing (210) includes a first outer compressor portion (210a) configured to form an outer volute (216) and the diffuser plate (230) is configured to be disposed between the first outer compressor portion (210a) of the outer compressor housing (210) and the first inner compressor portion (220a) of the inner compressor housing (220).

3. The turbocharger according to claim 2 wherein the outer compressor housing (210) further includes an outer flange (213), the inner compressor housing (220) further includes a front flange (224) and a rear flange (225), and the bearing housing (240) comprises a bearing flange (241).

4. The turbocharger according to claim 3 wherein the outer compressor housing (210) is configured to be connected to the inner compressor housing (220) by the first connection device (291a) being configured to secure the outer flange (213) of the outer compressor housing (210) to the front flange (224) of the inner compressor housing (220); and

the inner compressor housing (220) is configured to be connected to the bearing housing (240) by the second connection device (291b) being configured to secure the rear flange (225) of the inner compressor housing (220) to the bearing flange (241).

- 5 5. The turbocharger according to claim 2 wherein the diffuser plate(230) and the first outer compressor portion (210a) of the outer compressor housing (210) forms an outer diffuser (212) configured to be fluidly connected to the outer compressor wheel (260) and the outer volute (216).
- 10 6. The turbocharger according to claim 5 wherein the diffuser plate (230) and the first inner compressor portion (220a) of the inner compressor housing (220) forms an inner diffuser (222) configured to be fluidly connected to the inner compressor wheel (270) and the inner volute (223).
- 15 7. The turbocharger of claim 1 wherein the inner compressor housing (120) further includes a first inner compressor portion (120a) connected to a second inner compressor portion (120b) of the inner compressor housing (120) by at least one strut (127) such that the second inner compressor portion (120b) forms an inner air passage (121).
8. The turbocharger according to claim 7 wherein the diffuser plate (130) and the outer compressor housing (110) forms an outer diffuser (112) configured to be fluidly connected to the outer compressor wheel (160).
- 20 9. The turbocharger according to claim 8 wherein the diffuser plate (130) and the first inner compressor portion (120a) of the inner compressor housing (120) forms an inner diffuser (122) configured to be fluidly connected to the inner compressor wheel (170), the inner volute (123) and the inner air passage (121).
- 25 10. The turbocharger according to claim 9 wherein the diffuser plate (130) is connected to the first inner compressor portion (120a) of the inner compressor housing (120) by a joining assembly (131).
11. The turbocharger according to claim 10 wherein the outer compressor housing (110) includes contact features (114) configured to position the diffuser plate (130) with respect to the first inner compressor portion (120a) of the inner compressor housing (120).

12. The turbocharger according to claim 11 wherein contact features (114) are selected from the group consisting of height controllable components, pads, bosses, separate components, stand-off bolts, pre-assembled and integral cast components.

13. The turbocharger according to claim 6 wherein the outer compressor wheel (260) and the inner compressor wheel (270) are not aerodynamically similar in that the outer compressor wheel (260) and inner compressor wheels (270) rotate in opposing directions and do not provide similar volumetric flow and boost pressure.

14. A turbocharger comprising:

a modular construction compressor housing (300) including an outer compressor housing (310) having a first outer compressor portion (310a) and an outer compressor wheel (360) disposed therein, an inner compressor housing (320) including a first inner compressor portion (320a) configured to form an inner volute (323) and a having an inner compressor wheel (370) disposed therein and an inner diffuser (322) formed between the first outer compressor portion (310a) of the outer compressor housing (310) and the first inner compressor portion (320a) of the inner compressor housing (320);

a bearing housing (340);

a turbine housing (350) having a turbine wheel (382) disposed therein;

a turbocharger shaft (381) extending through the modular construction compressor housing (300), the bearing housing (340) and the turbine housing (350);

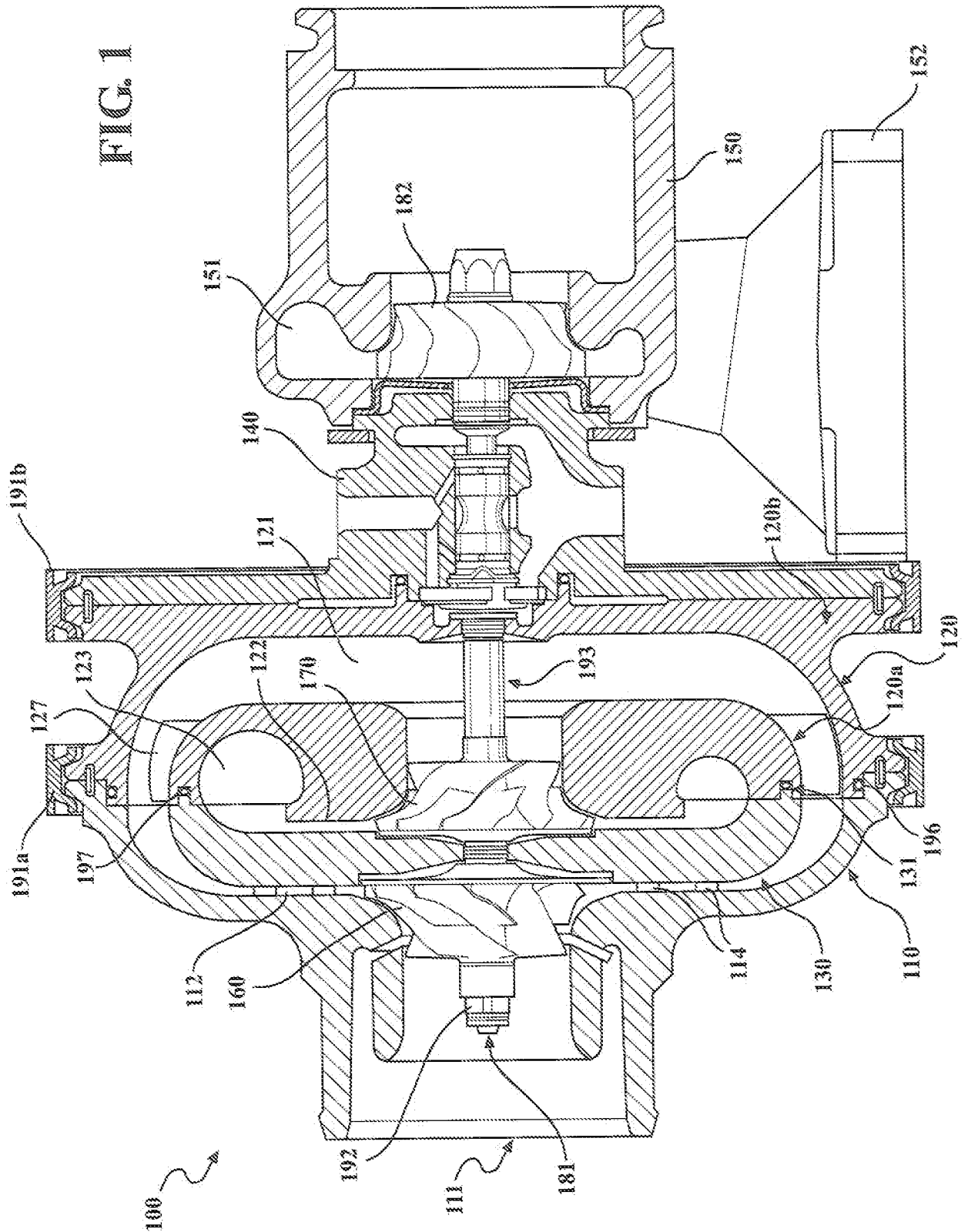
the outer compressor wheel (360) and the inner compressor wheel (370) retained on one end of the turbocharger shaft (381) via a nut (392), the turbine wheel (382) mounted on an opposing end of the turbocharger shaft (382);

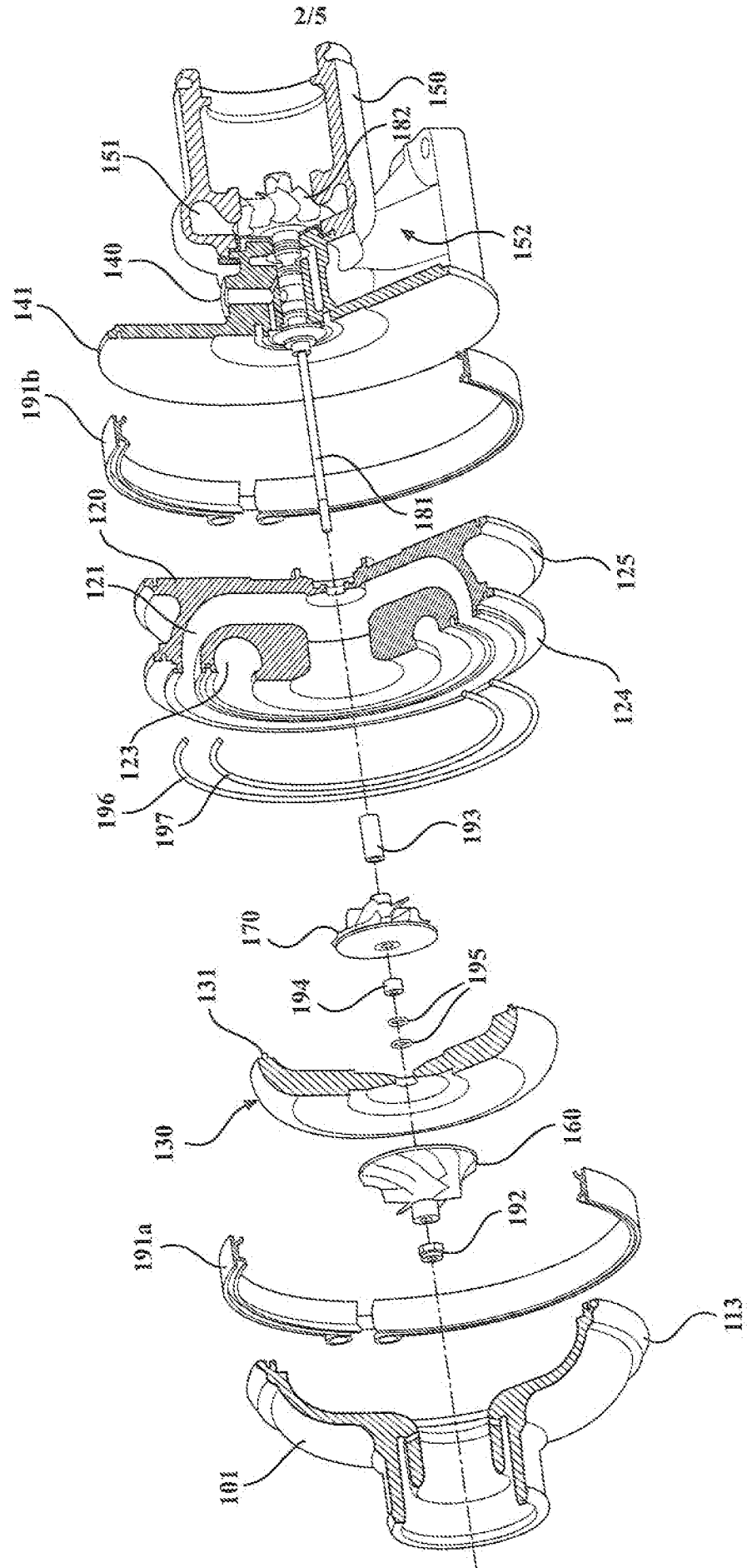
the outer compressor housing (310) is configured to be fluidly connected to the inner compressor housing (320) by a first connection device (391a); and

the inner compressor housing (320) is configured to be fluidly connected to the bearing housing (340) by a second connection device (391b).

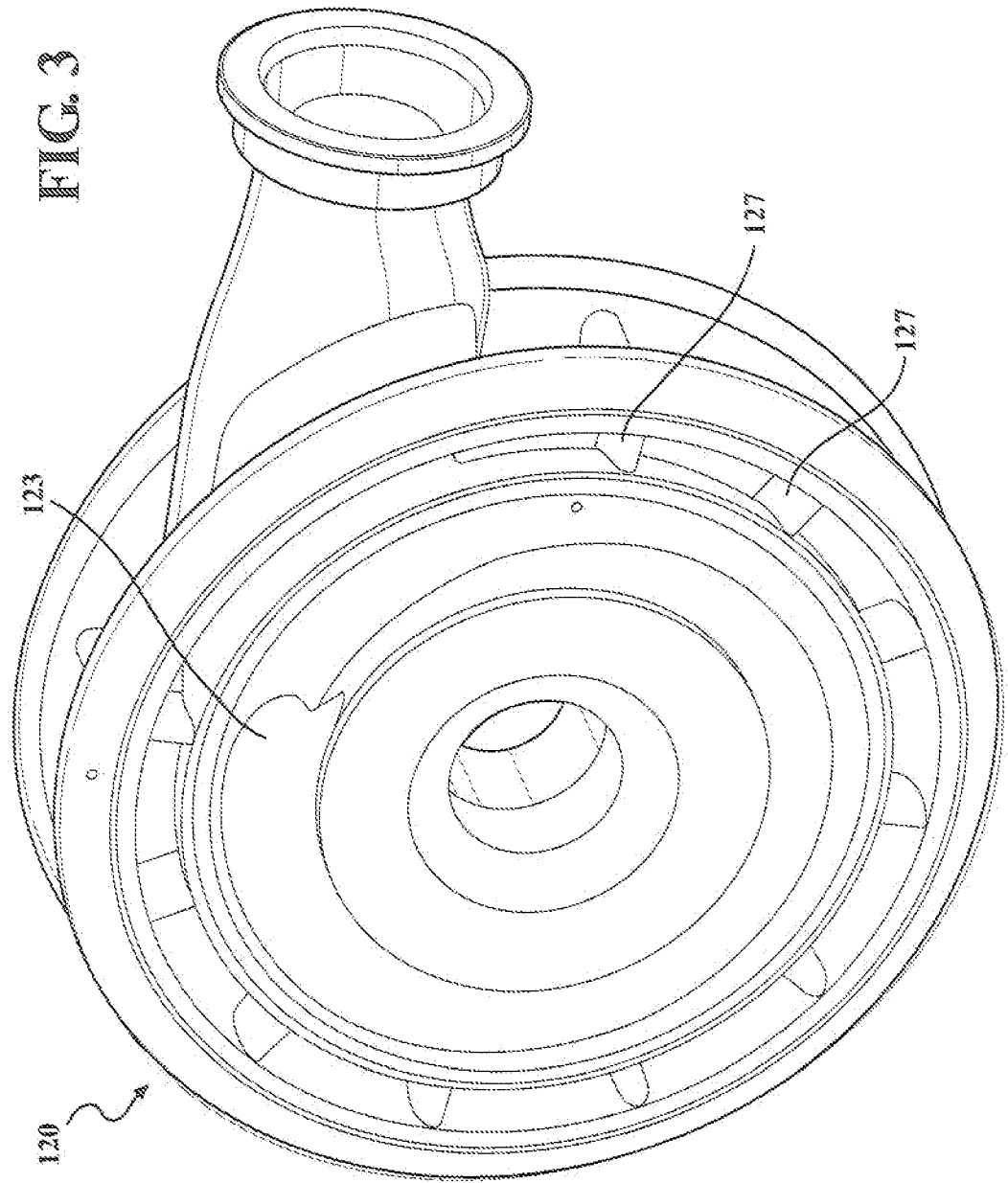
15. The turbocharger according to claim 14 wherein the outer compressor wheel (360) and the inner compressor wheel (370) are aerodynamically similar in that the outer compressor wheel (360) and the inner compressor wheel (370) rotate in opposing directions and provide similar volumetric flow and boost pressure.

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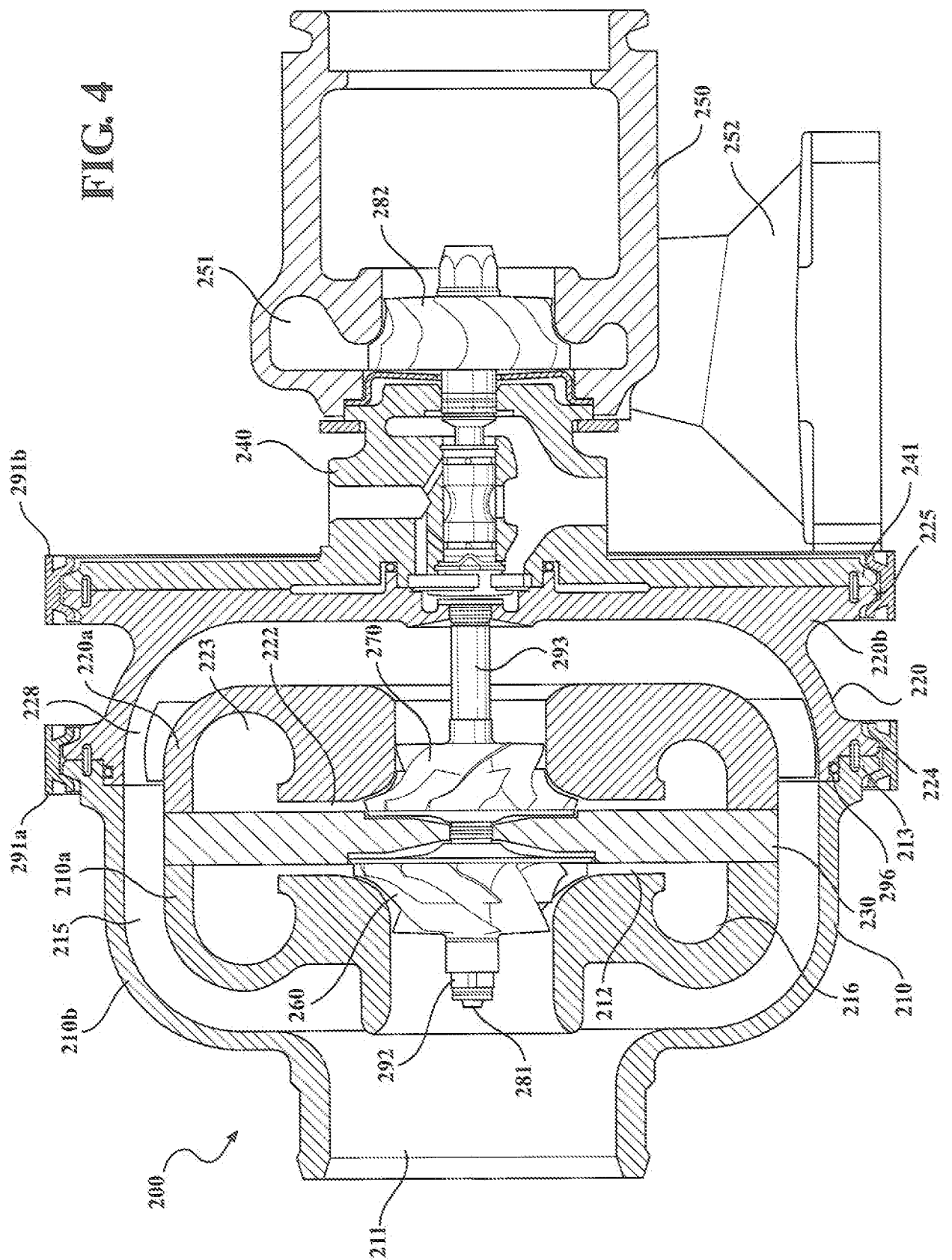




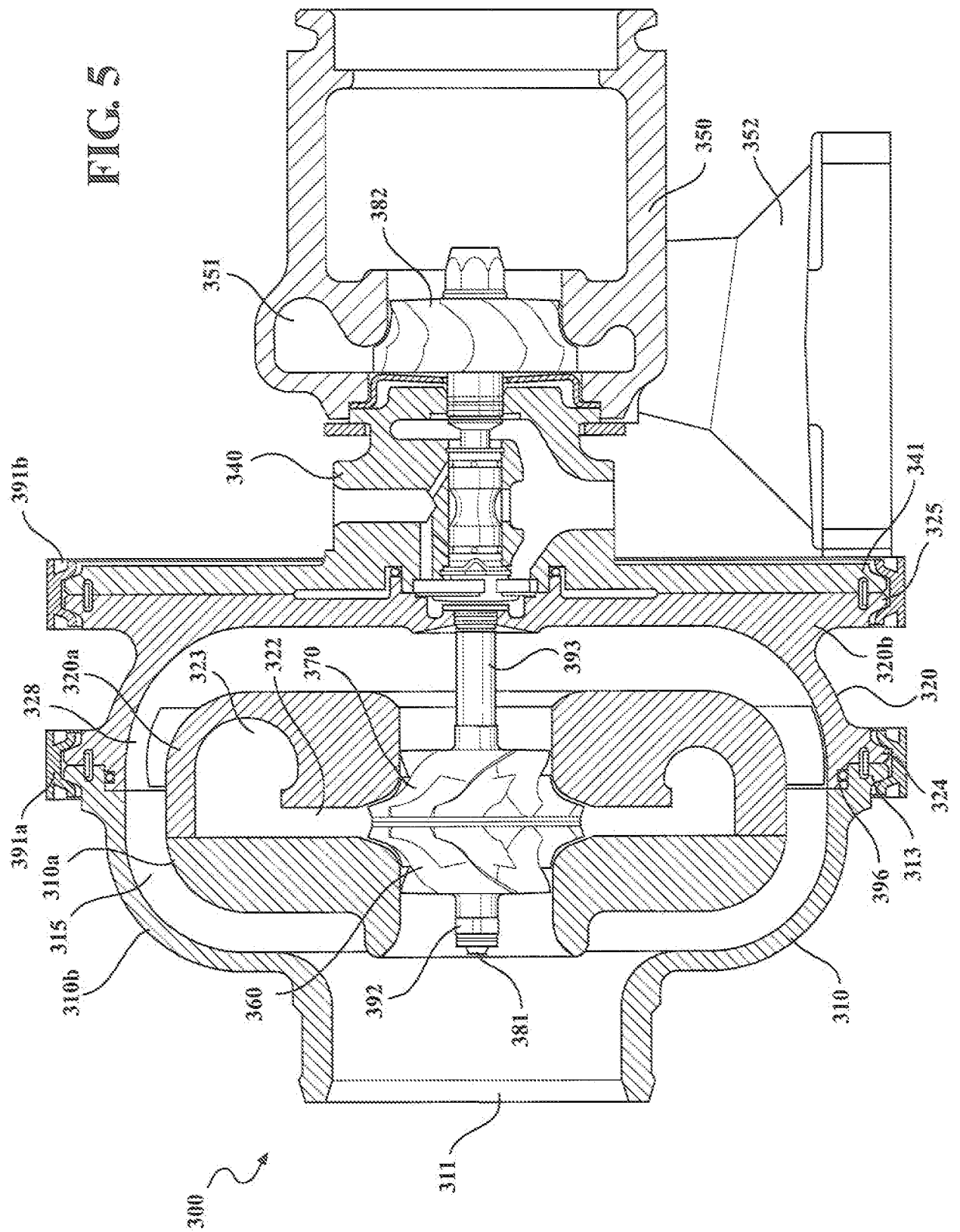
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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/034100

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02C6/12 F02B37/013
ADD.

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)
F02C F02B

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 practicable, search terms used)

EP0-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	US 2006/198727 A1 (ARNOLD STEVEN D [US] ET AL) 7 September 2006 (2006-09-07) paragraphs [0028] - [0033]; figure 1 -----	1-15
X	US 7 014 418 B1 (ARNOLD STEVE DON [US] ET AL) 21 March 2006 (2006-03-21) column 2, line 48 - column 4, line 52; figure 1 -----	1-15
X	US 6 834 501 B1 (VRBAS GARY [US] ET AL) 28 December 2004 (2004-12-28) column 2, line 35 - column 3, line 65; figure 1 -----	1,14
X	US 6 062 028 A (ARNOLD STEVEN DON [US] ET AL) 16 May 2000 (2000-05-16) column 3, line 37 - column 4, line 2; figure 2 ----- -/--	1-15

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"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

7 September 2015

Date of mailing of the international search report

14/09/2015

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/034100

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 8 453 445 B2 (LOTTERMAN JEFFREY A [CZ] ET AL) 4 June 2013 (2013-06-04) column 2, lines 24-41; figure 2 -----	1-15

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