US008905735B2

(12) **United States Patent**
Holtzapple et al.

(10) **Patent No.: US 8,905,735 B2**
(45) **Date of Patent: *Dec. 9, 2014**

(54) **GEROTOR APPARATUS FOR A QUASI-ISOTHERMAL BRAYTON CYCLE ENGINE**

(75) Inventors: **Mark T. Holtzapple**, College Station, TX (US); **Andrew Rabroker**, College Station, TX (US); **Michael Kyle Ross**, Bryan, TX (US); **Steven D. Atmur**, Clifton Park, NY (US); **Gary P. Noyes**, Houston, TX (US)

(73) Assignees: **The Texas A&M University System**, College Station, TX (US); **StarRotor Corportion**, College Station, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 150 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **12/749,032**

(22) Filed: **Mar. 29, 2010**

(65) **Prior Publication Data**

US 2010/0247360 A1 Sep. 30, 2010

Related U.S. Application Data

(63) Continuation of application No. 11/256,364, filed on Oct. 21, 2005, now Pat. No. 7,695,260.

(60) Provisional application No. 60/621,221, filed on Oct. 22, 2004.

(51) **Int. Cl.**

F01C 19/00	(2006.01)
F03C 2/00	(2006.01)
F01C 19/02	(2006.01)
F01C 21/06	(2006.01)
F01C 20/14	(2006.01)
F01C 1/10	(2006.01)

(52) **U.S. Cl.**

CPC ***F01C 1/103*** (2013.01); ***F01C 19/02*** (2013.01); ***F01C 21/06*** (2013.01); ***F01C 20/14*** (2013.01)

USPC **418/104**; 418/19; 418/171; 418/190

(58) **Field of Classification Search**

USPC 418/104, 140, 142, 166–171, 189, 190, 418/61.3, 178, 152, 19, 21, 26

See application file for complete search history.

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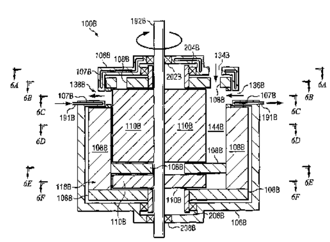
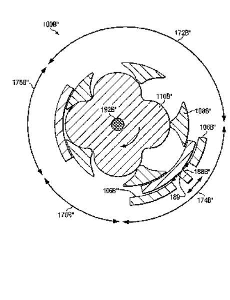
Primary Examiner — Theresa Trieu

(57) **ABSTRACT**

According to one embodiment of the invention, an engine system comprises a housing, an outer gerotor, an inner gerotor, a tip inlet port, a face inlet port, and a tip outlet port. The housing has a first sidewall, a second sidewall, a first endwall, and a second endwall. The outer gerotor is at least partially disposed in the housing and at least partially defines an outer gerotor chamber. The inner gerotor is at least partially disposed within the outer gerotor chamber. The tip inlet port is formed in the first sidewall and allows fluid to enter the outer gerotor chamber. The face inlet port is formed in the first endwall and allows fluid to enter the outer gerotor chamber. The tip outlet port is formed in the second sidewall and allows fluid to exit the outer gerotor chamber.

28 Claims, 24 Drawing Sheets





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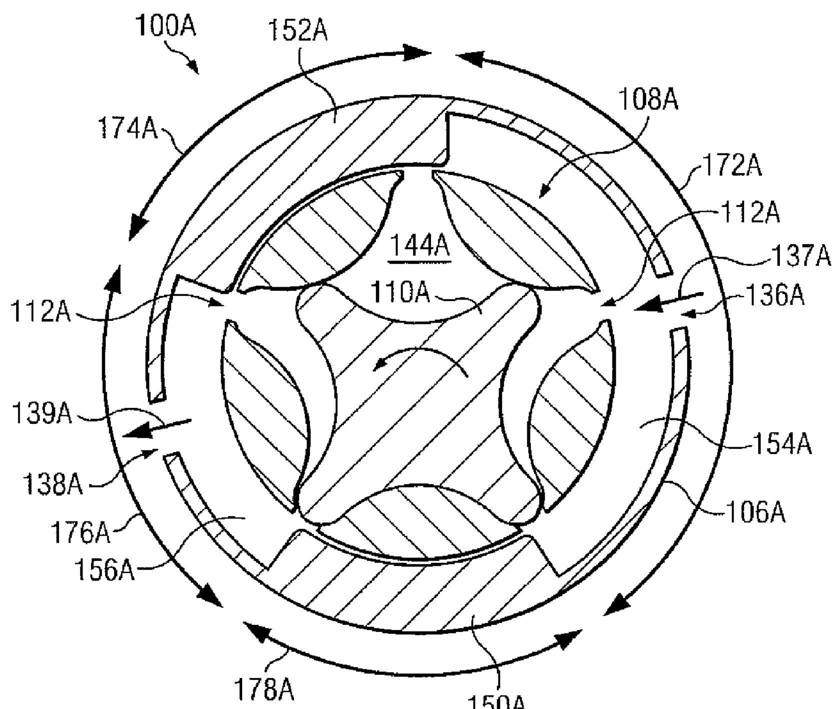
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150A

FIG. 1

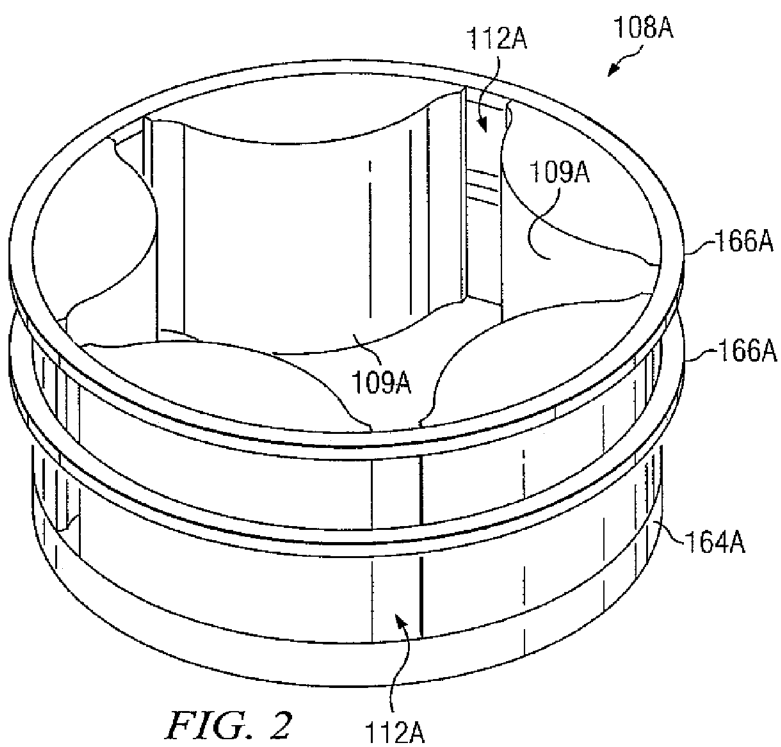
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FIG. 2

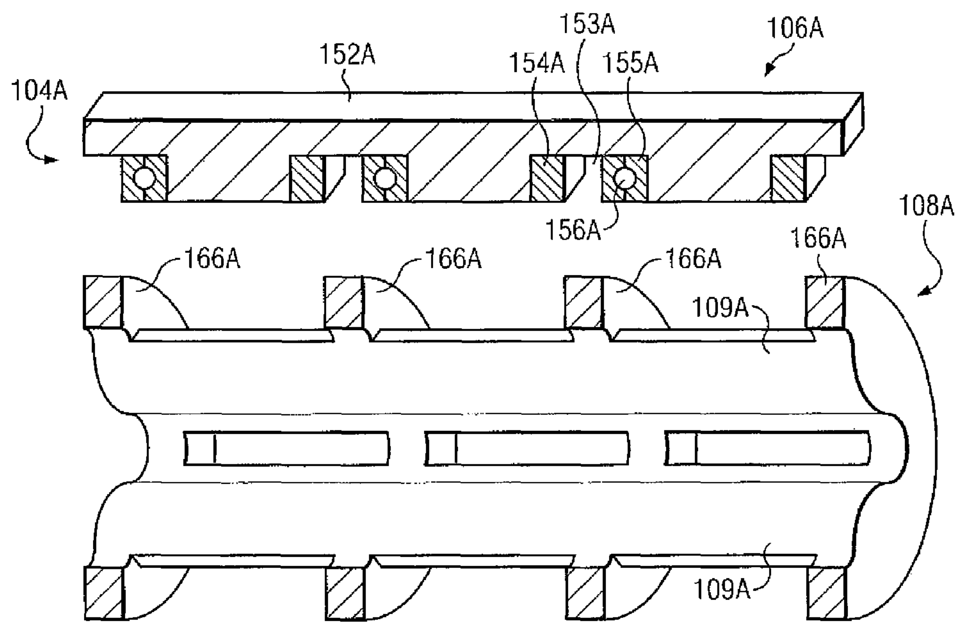


FIG. 3

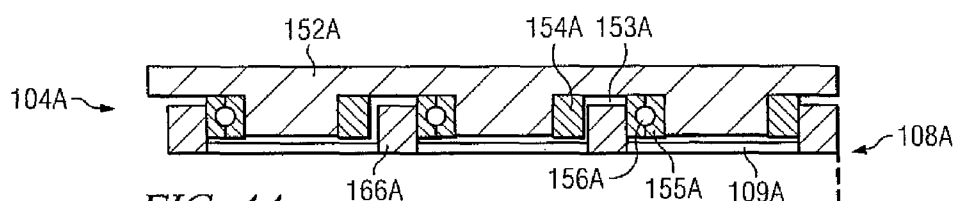


FIG. 4A

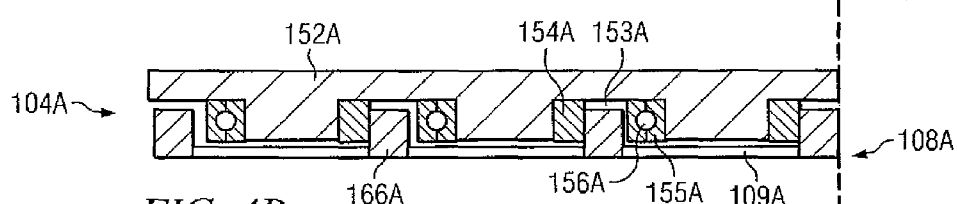


FIG. 4B

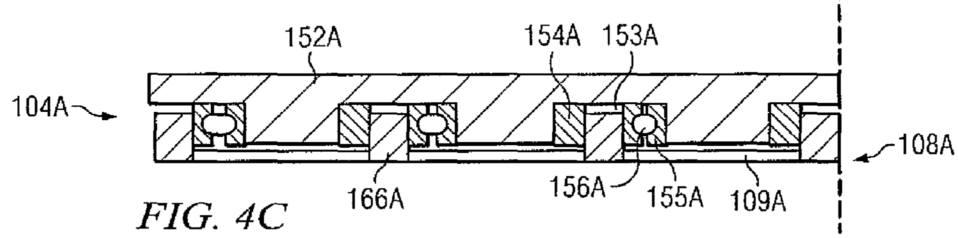
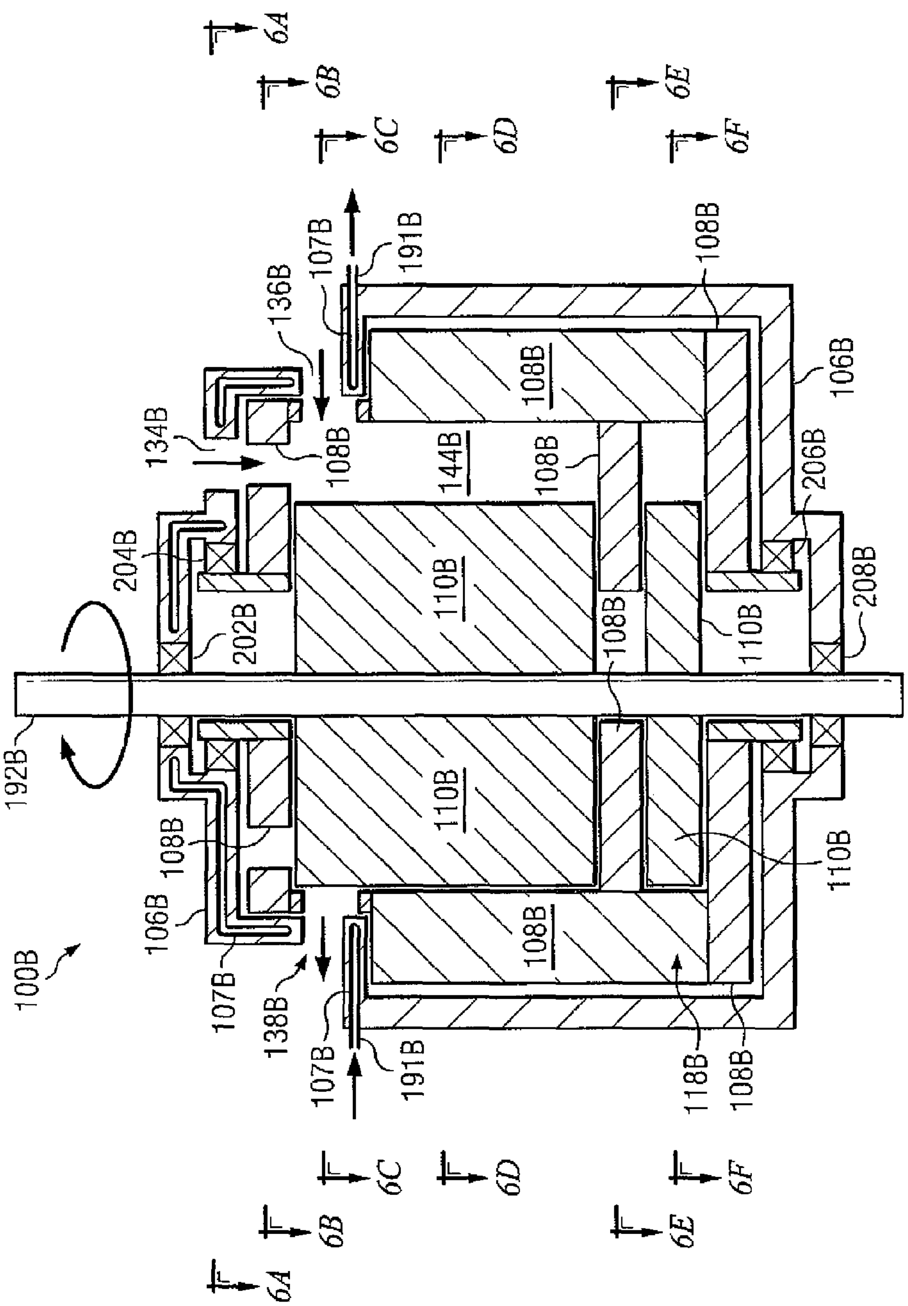


FIG. 4C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6F
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144B
191B
192B
202B
204B
206B
208B

FIG. 5

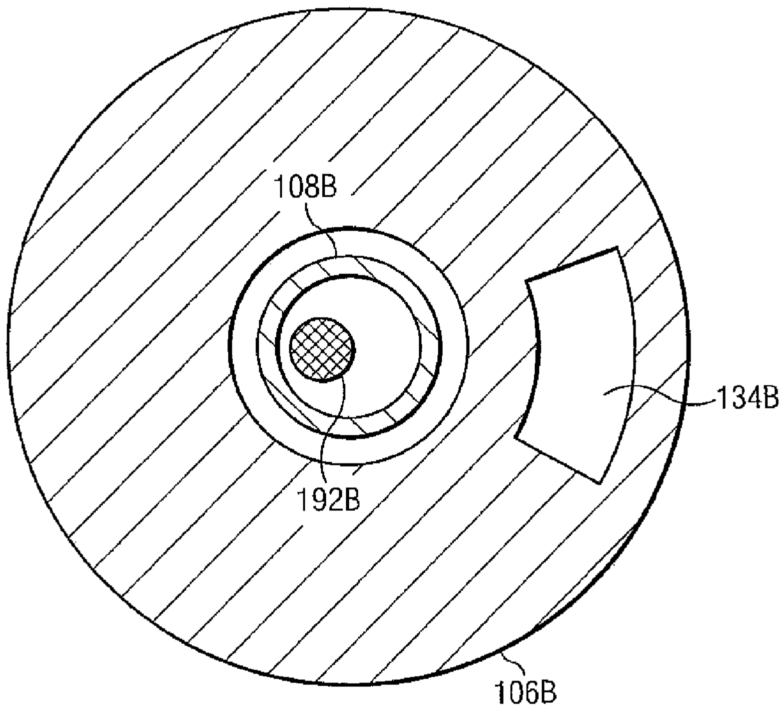


FIG. 6A

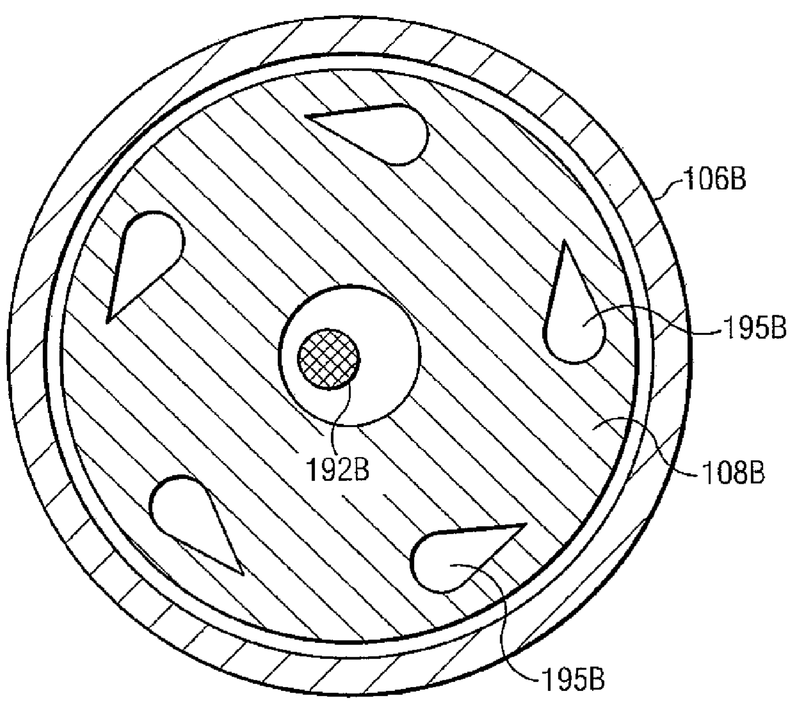


FIG. 6B

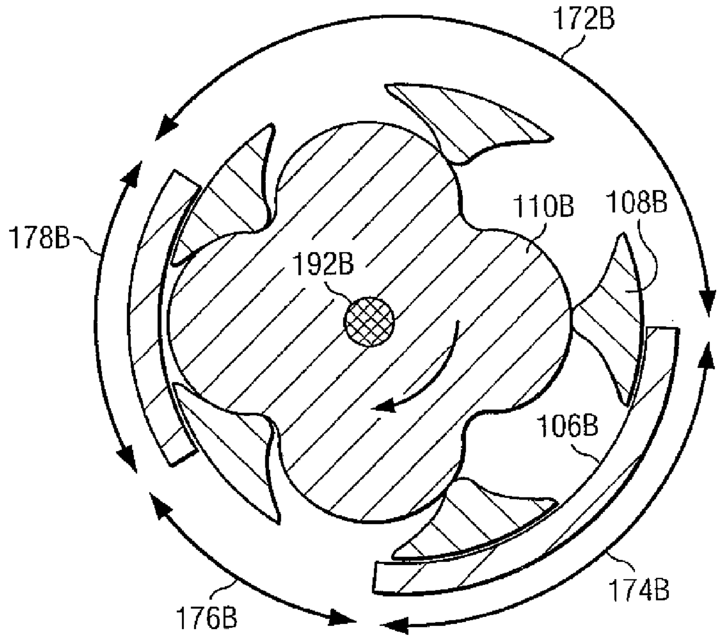


FIG. 6C

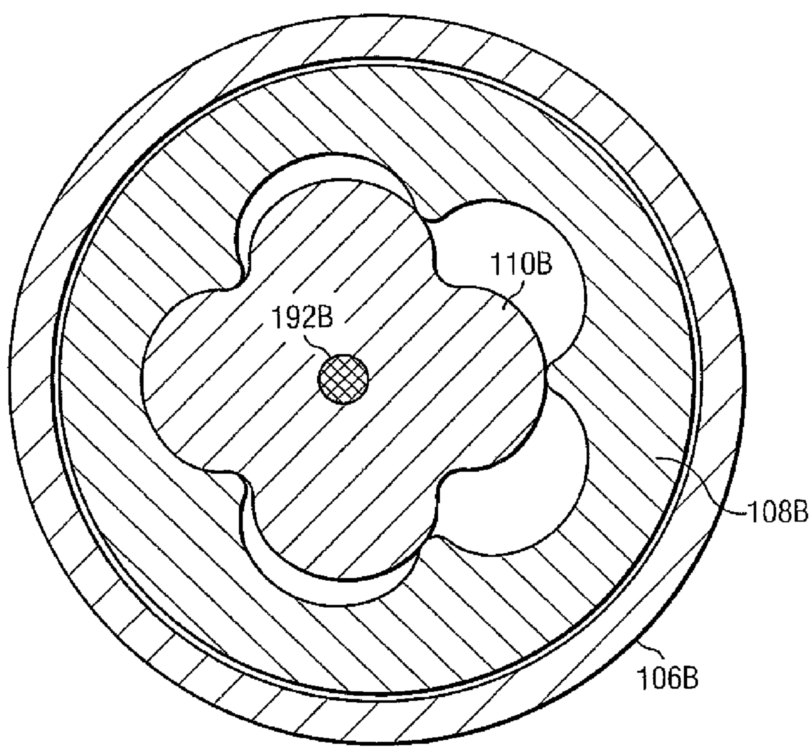


FIG. 6D

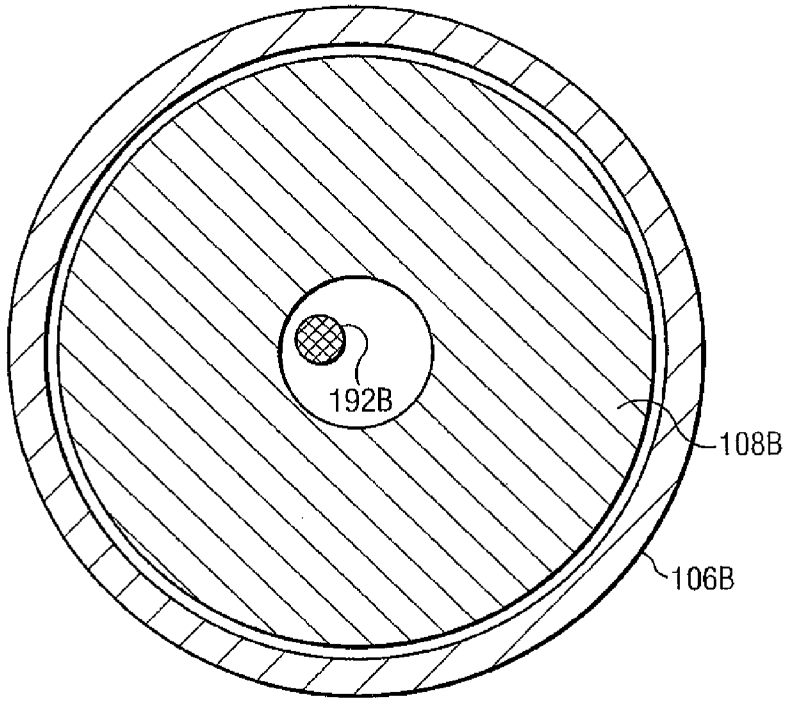


FIG. 6E

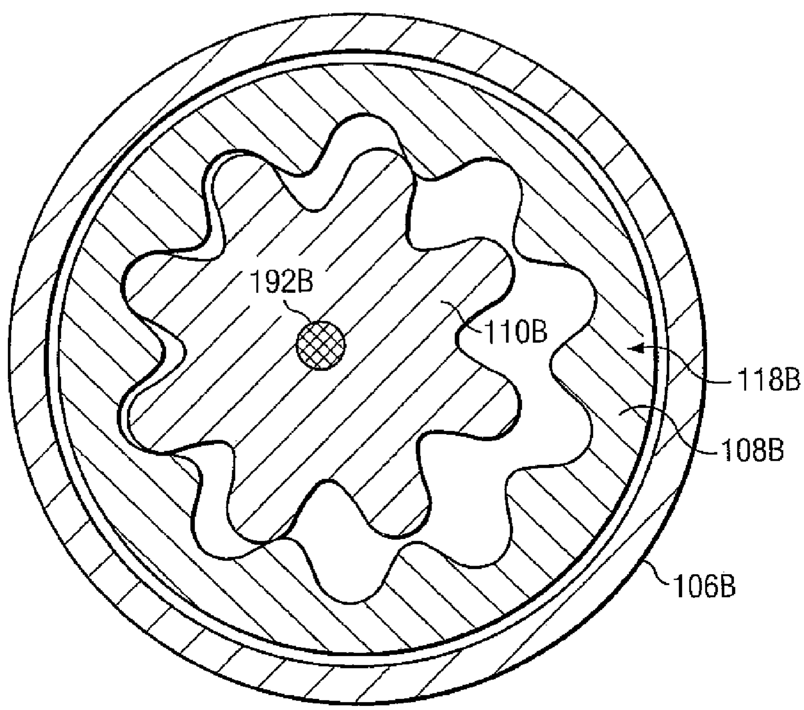
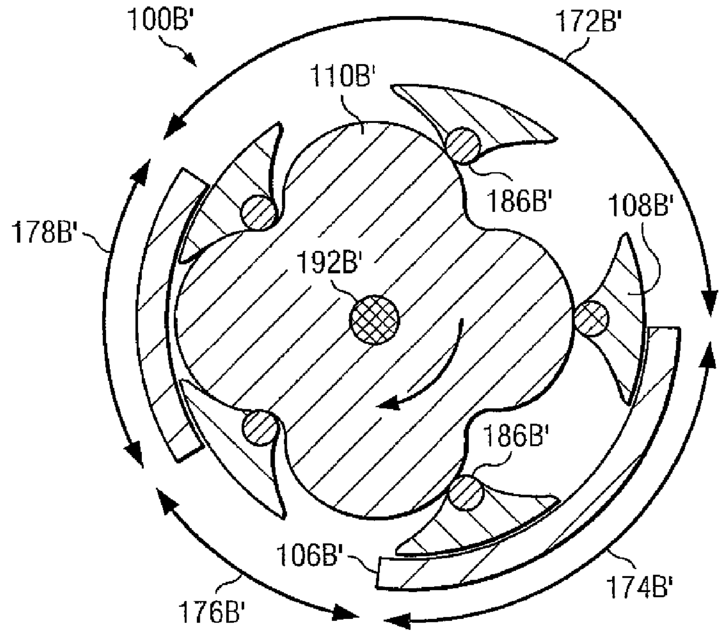


FIG. 6F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186B'
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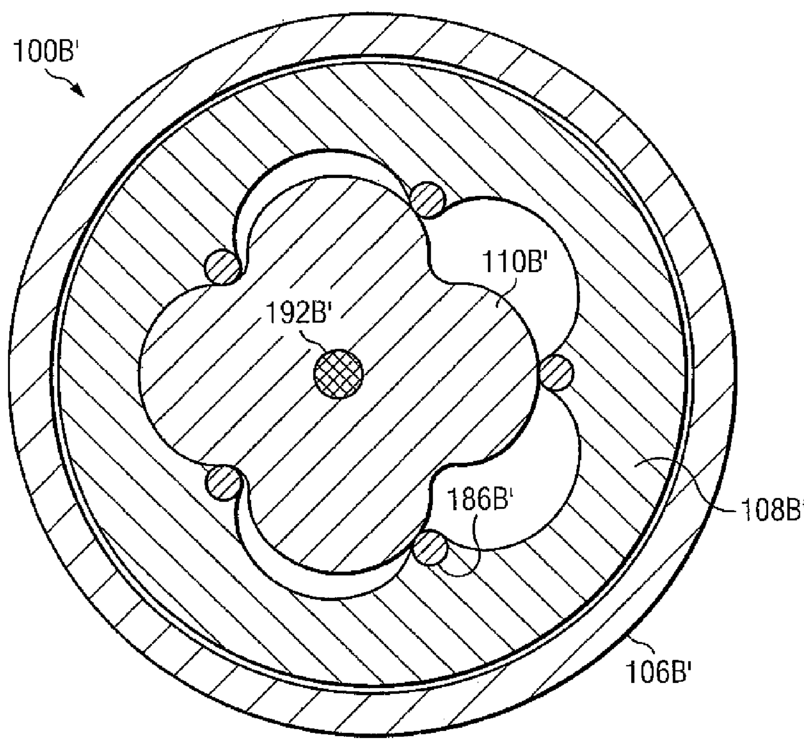
178B'
192B'
186B'
106B'
174B'
176B'

FIG. 7A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106B'

FIG. 7B

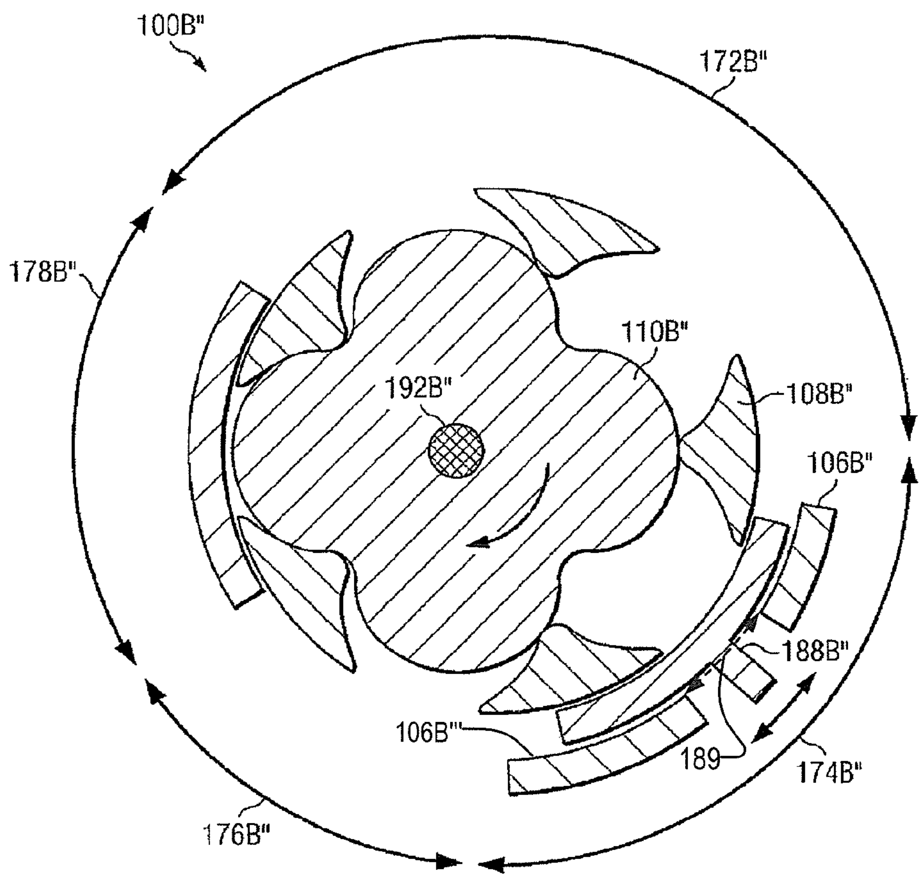
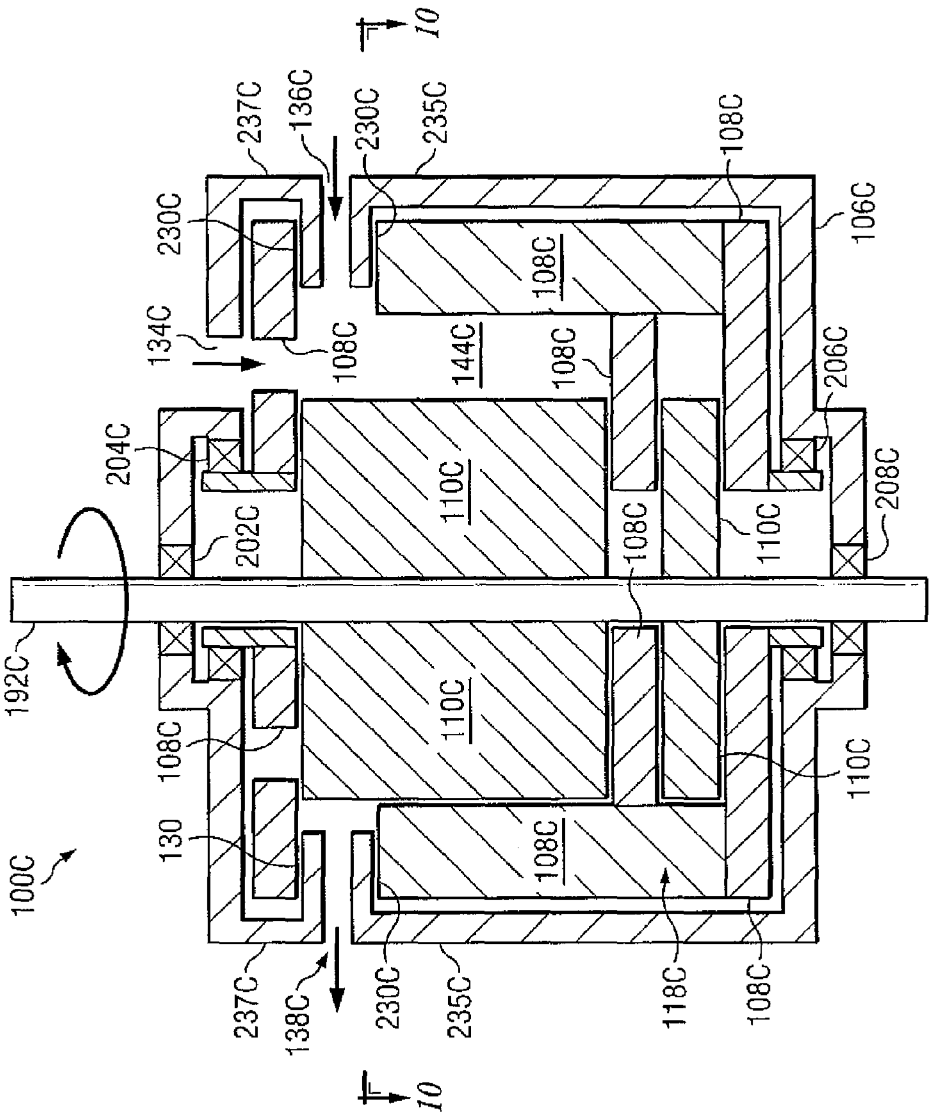


FIG. 8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136C
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235C
108C
230C
106C
134C
108C
144C
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206C
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208C
202C
108C
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130
100C
237C
138C
230C
235C
118C
108C
10

FIG. 9

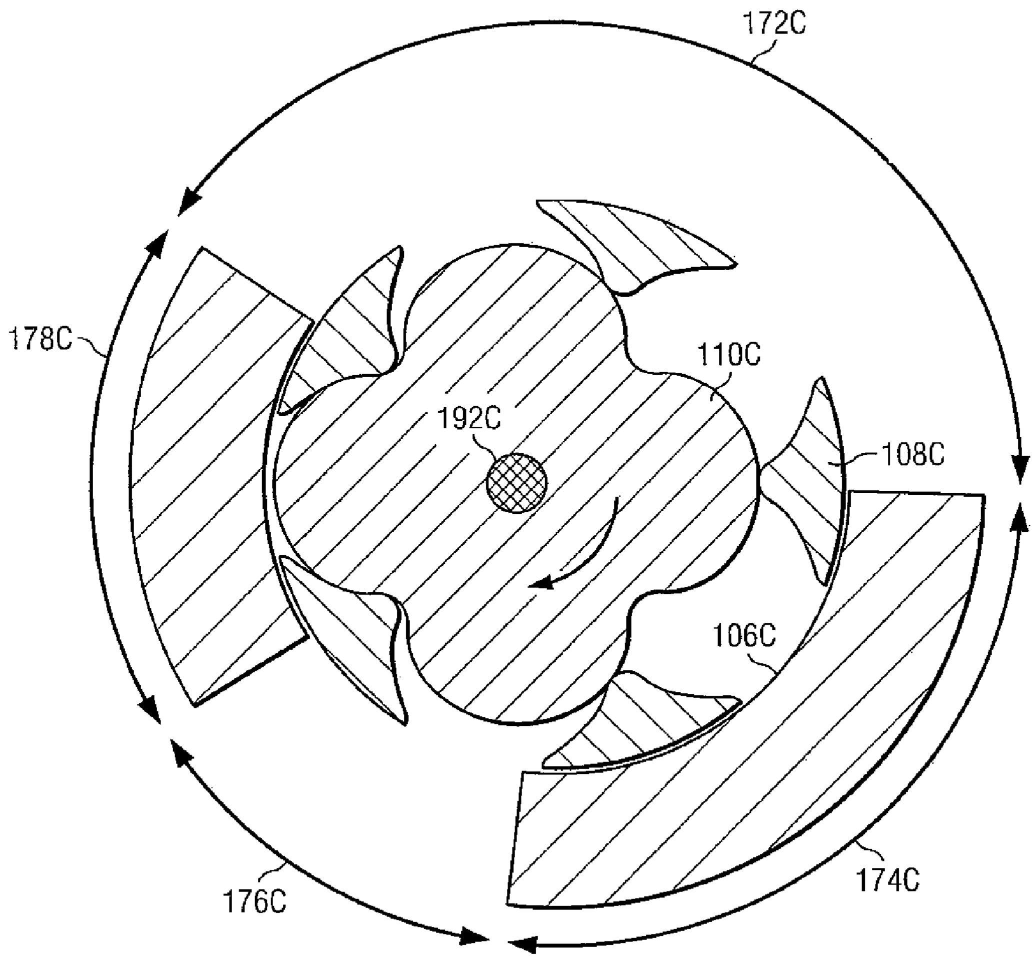
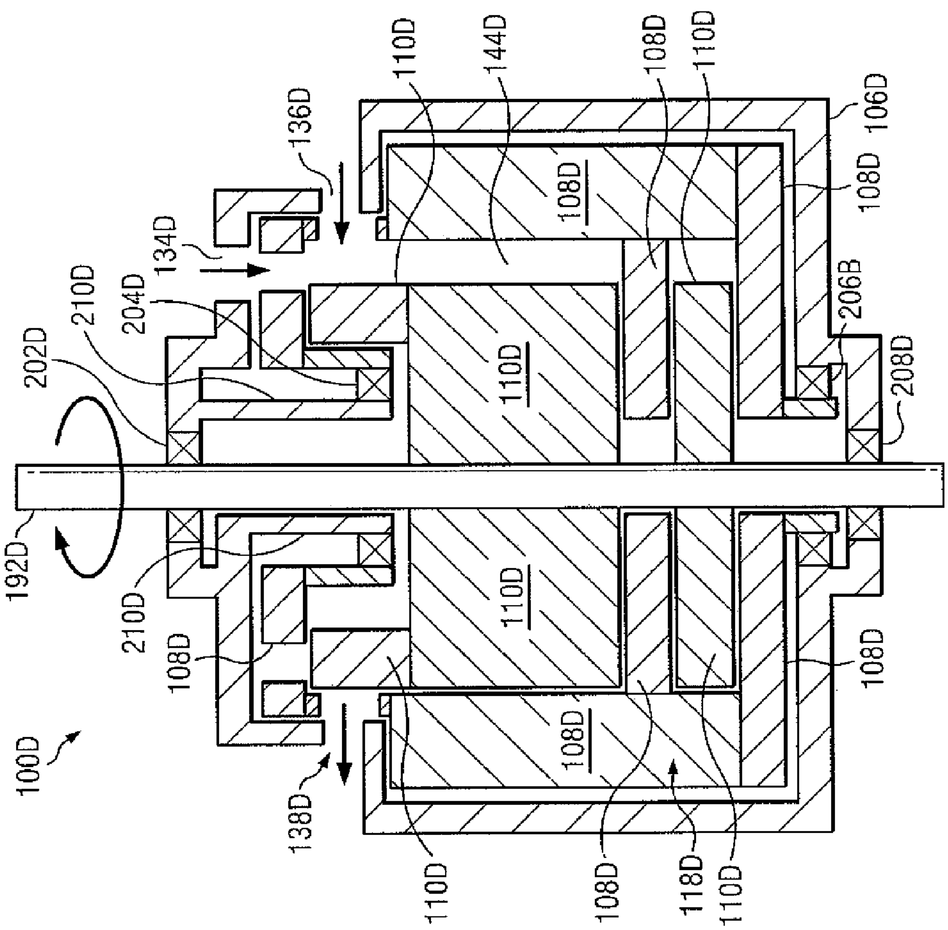


FIG. 10



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138D
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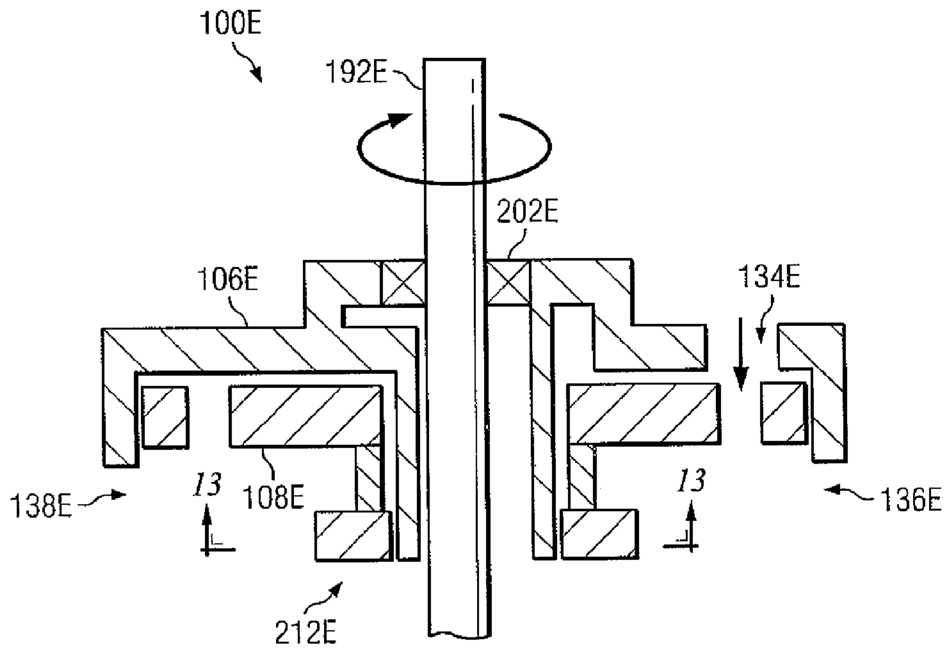
118D
110D

FIG. 11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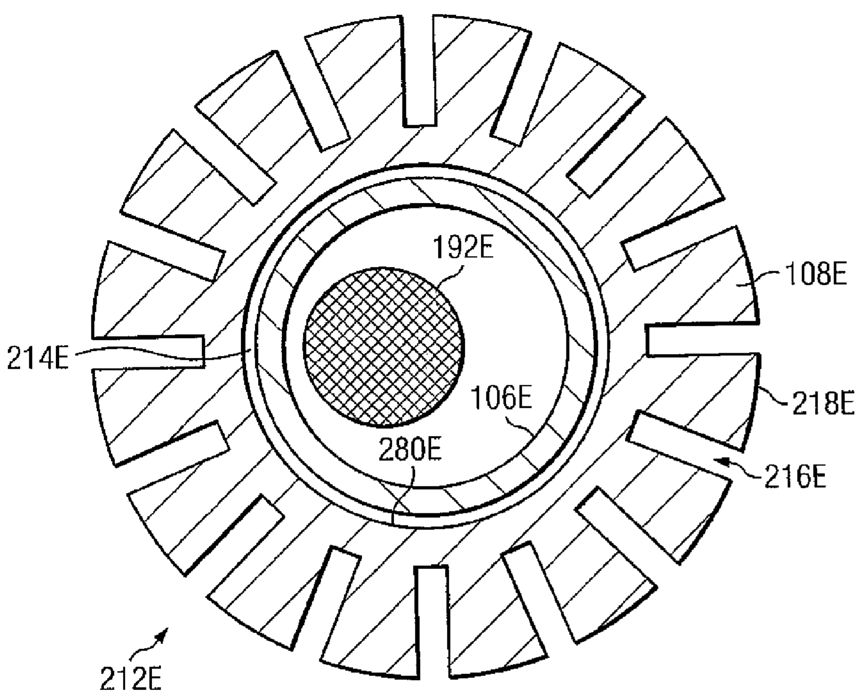
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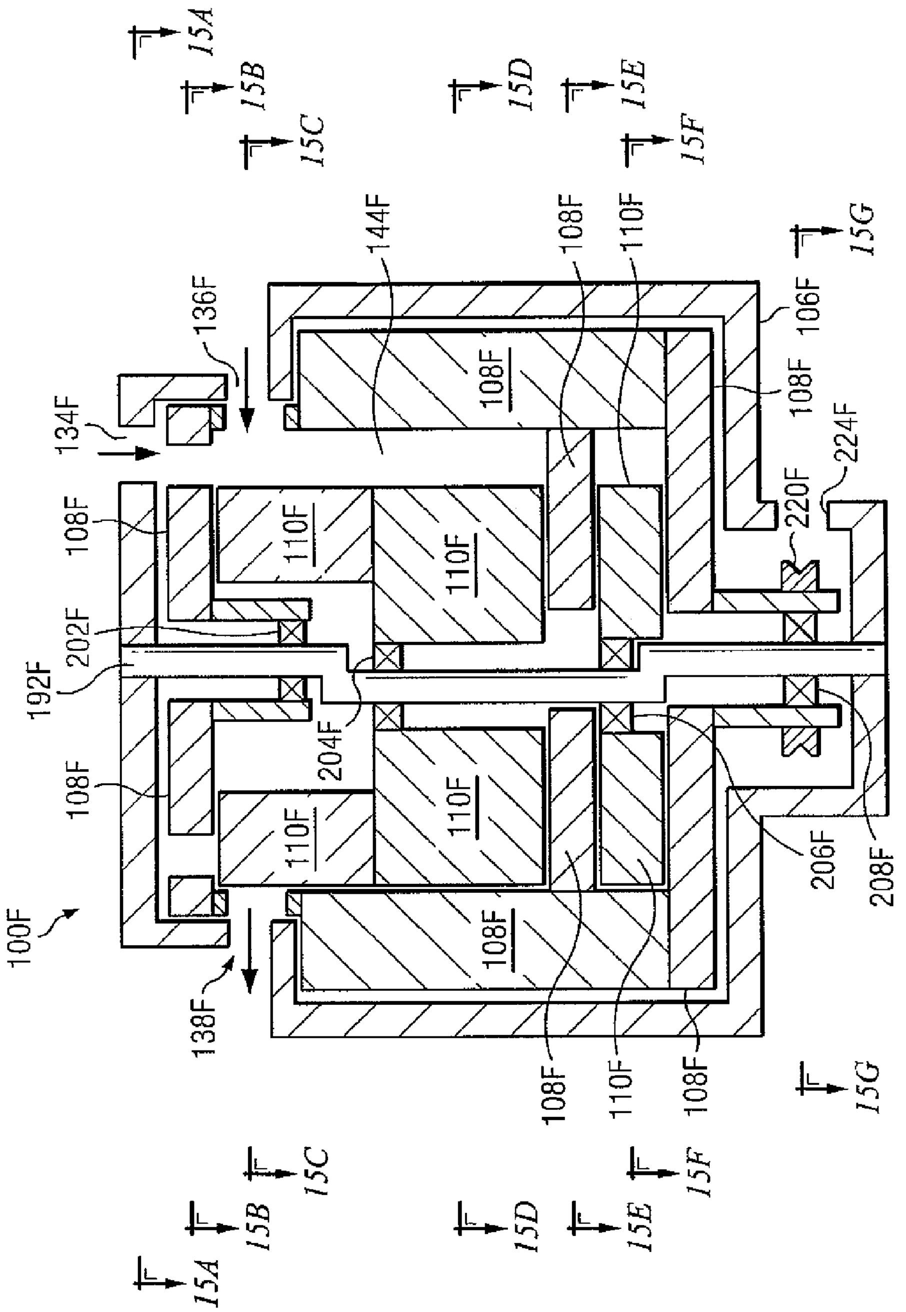
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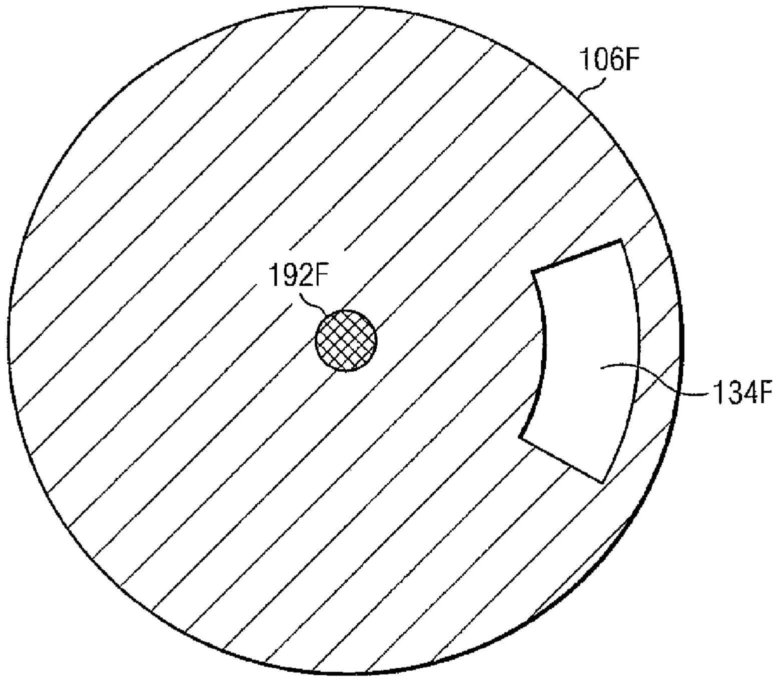
FIG. 14



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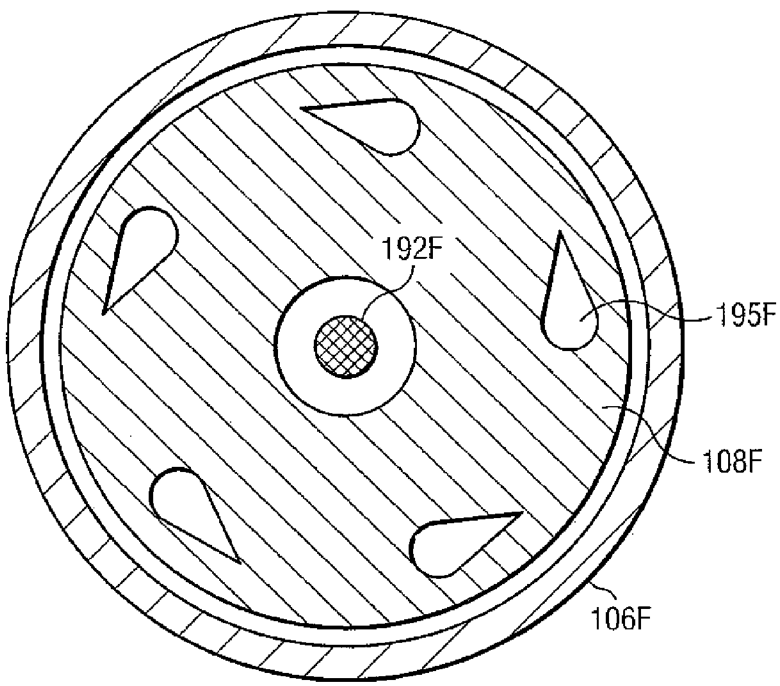

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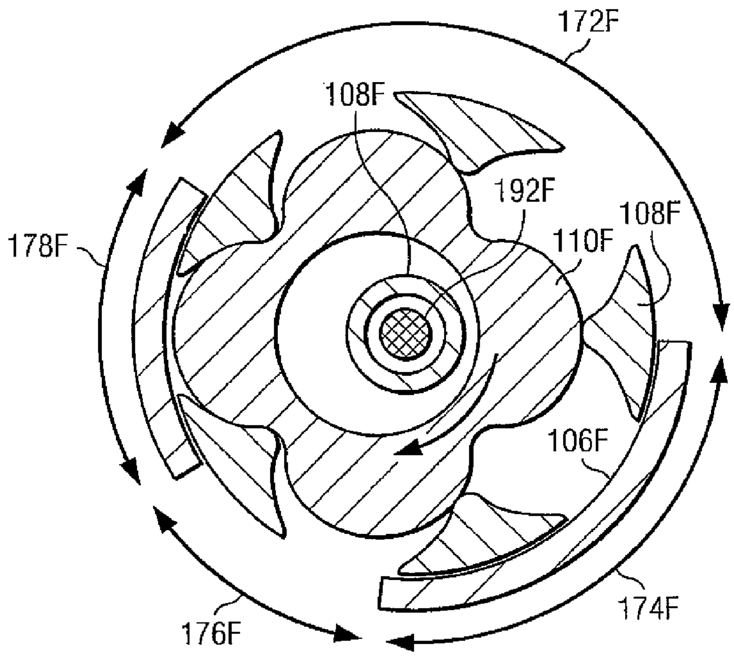

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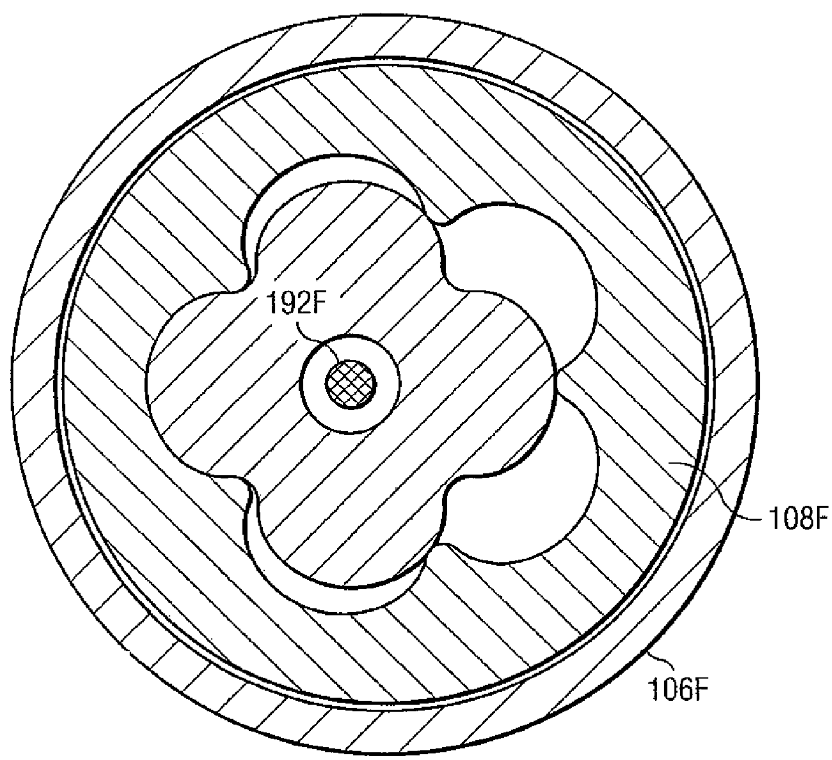

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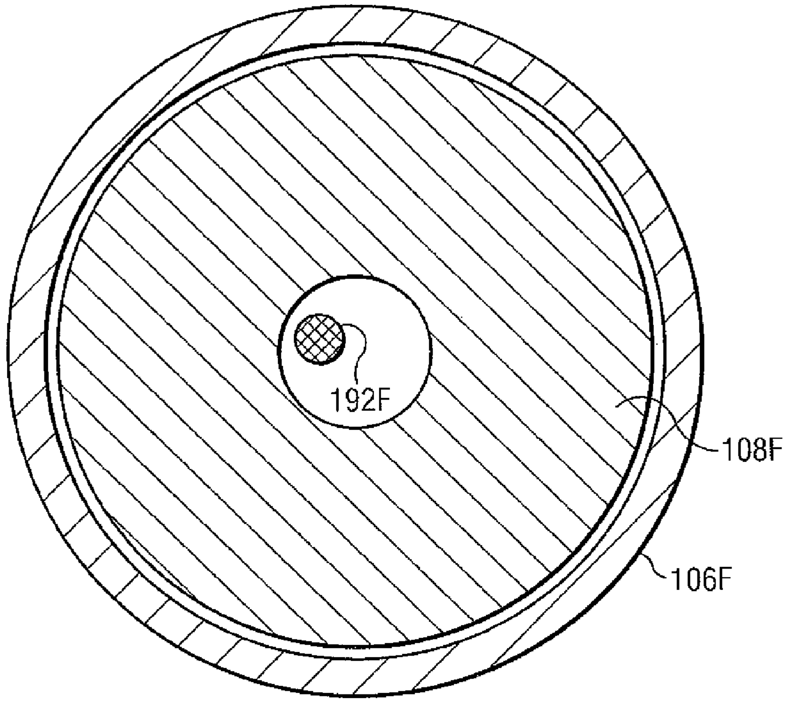
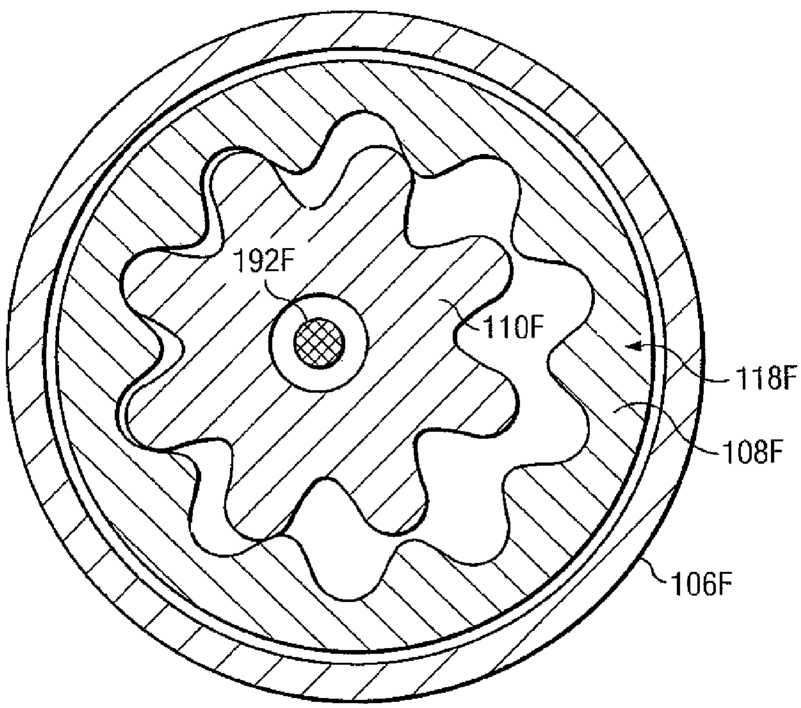


FIG. 15E



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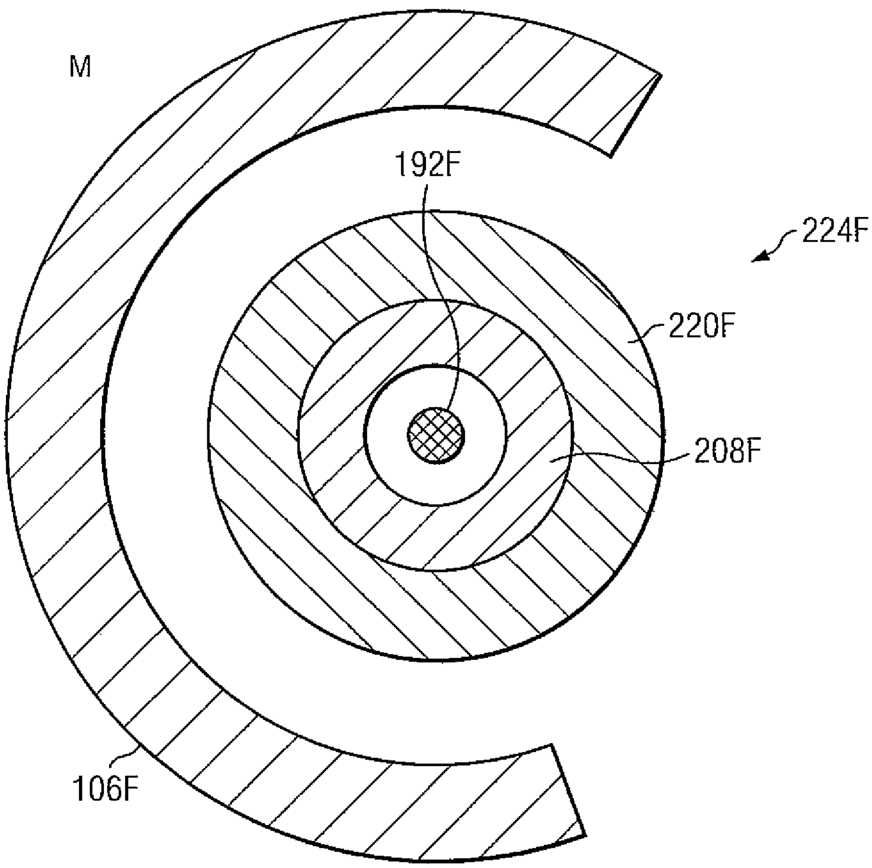

FIG. 15G

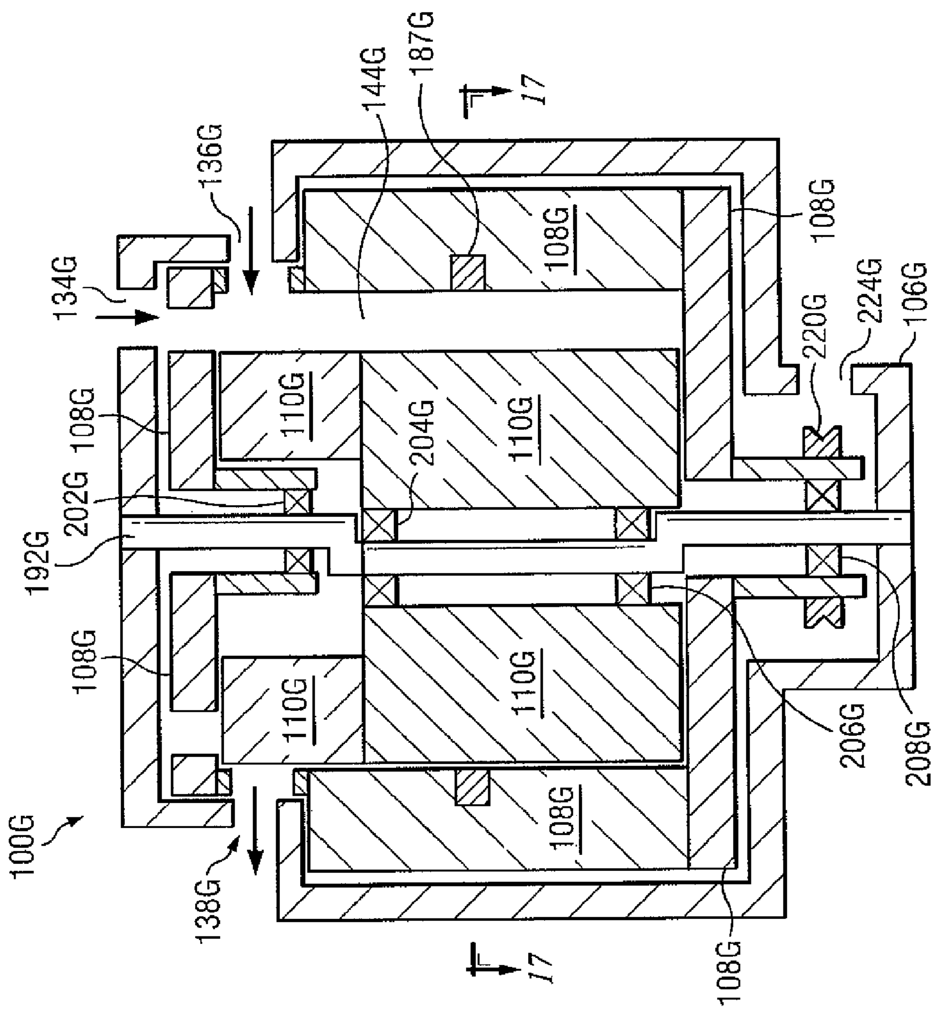
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FIG. 16

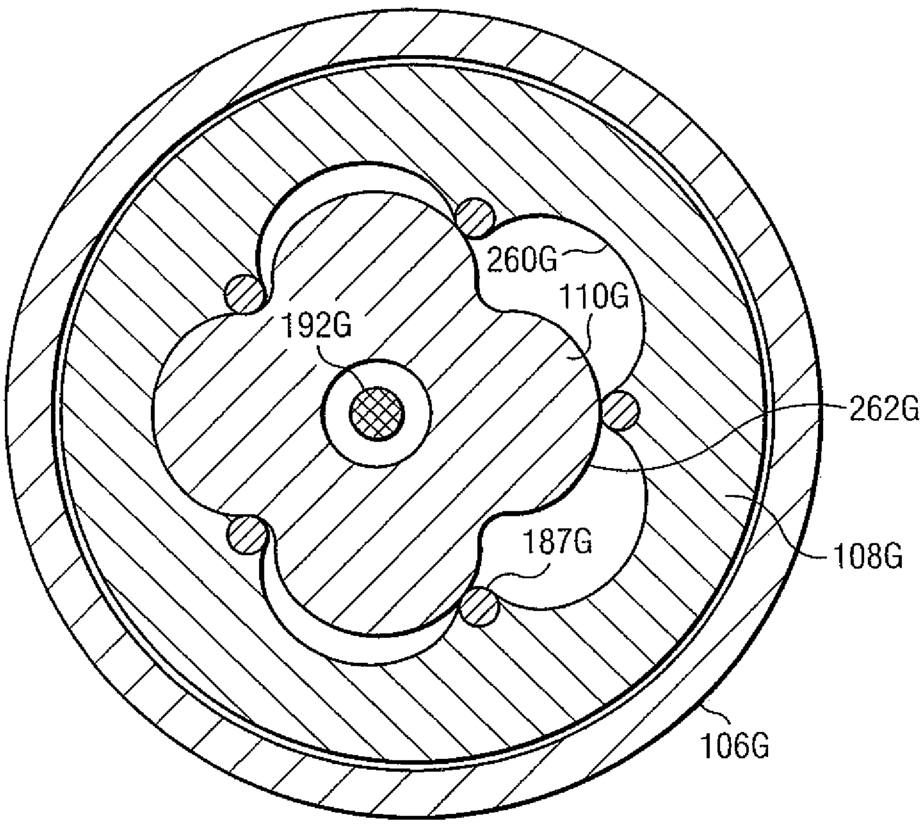
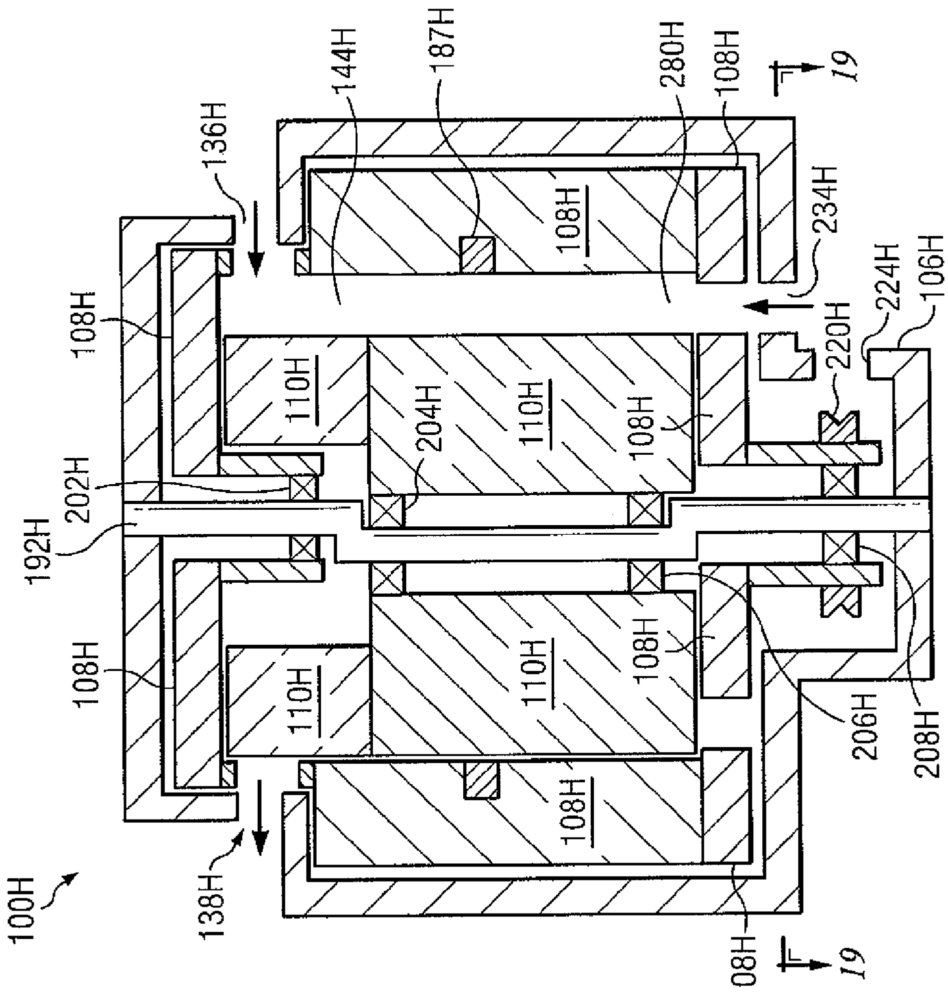


FIG. 17



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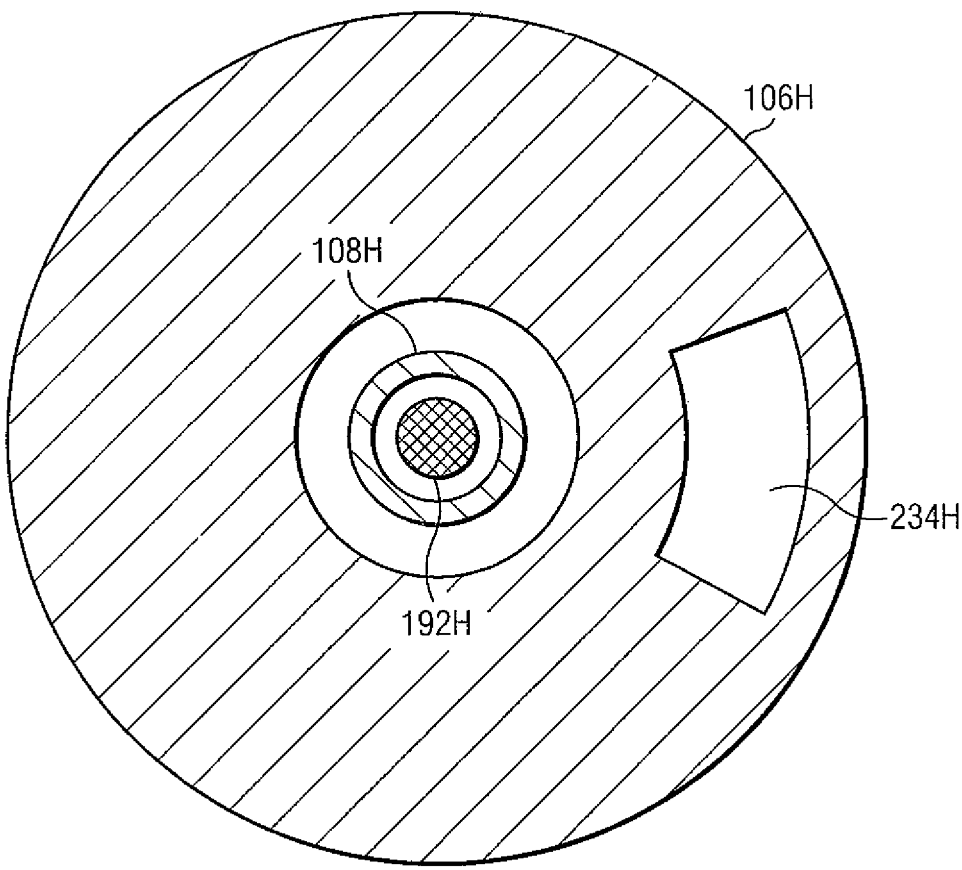
208H
220H
224H
234H
106H
19

FIG. 18



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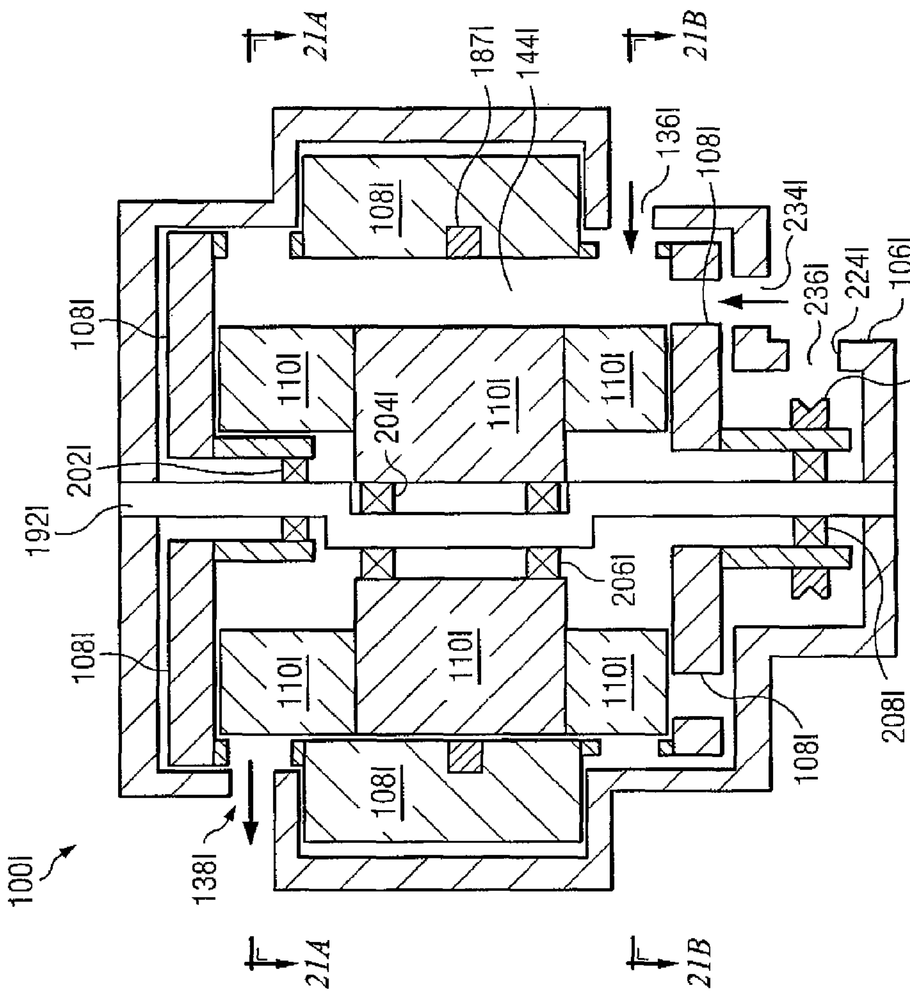
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208I
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21A
21B

FIG. 20

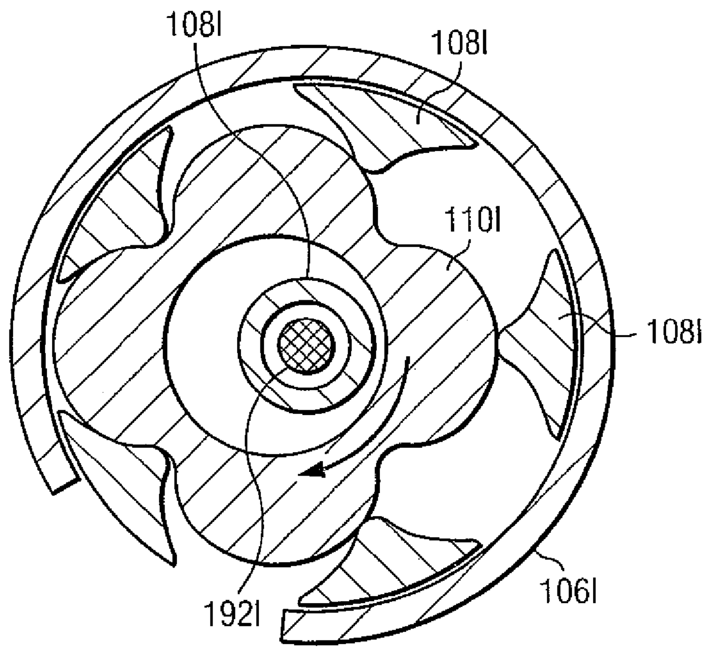


FIG. 21A

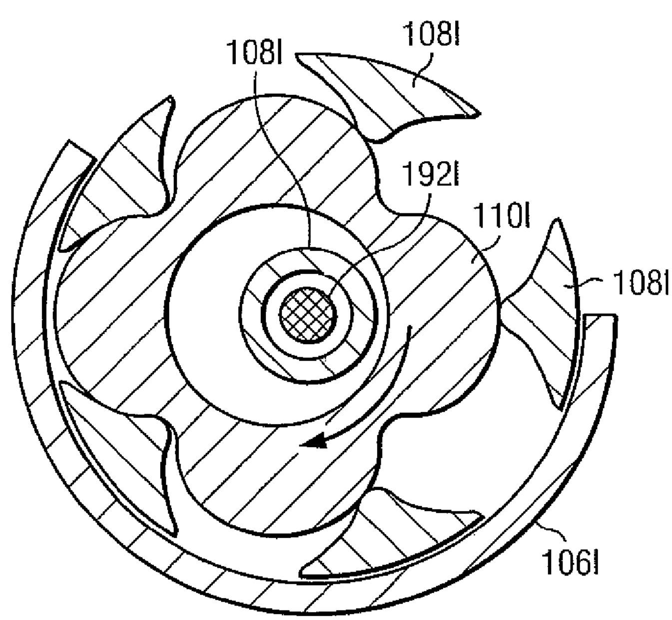
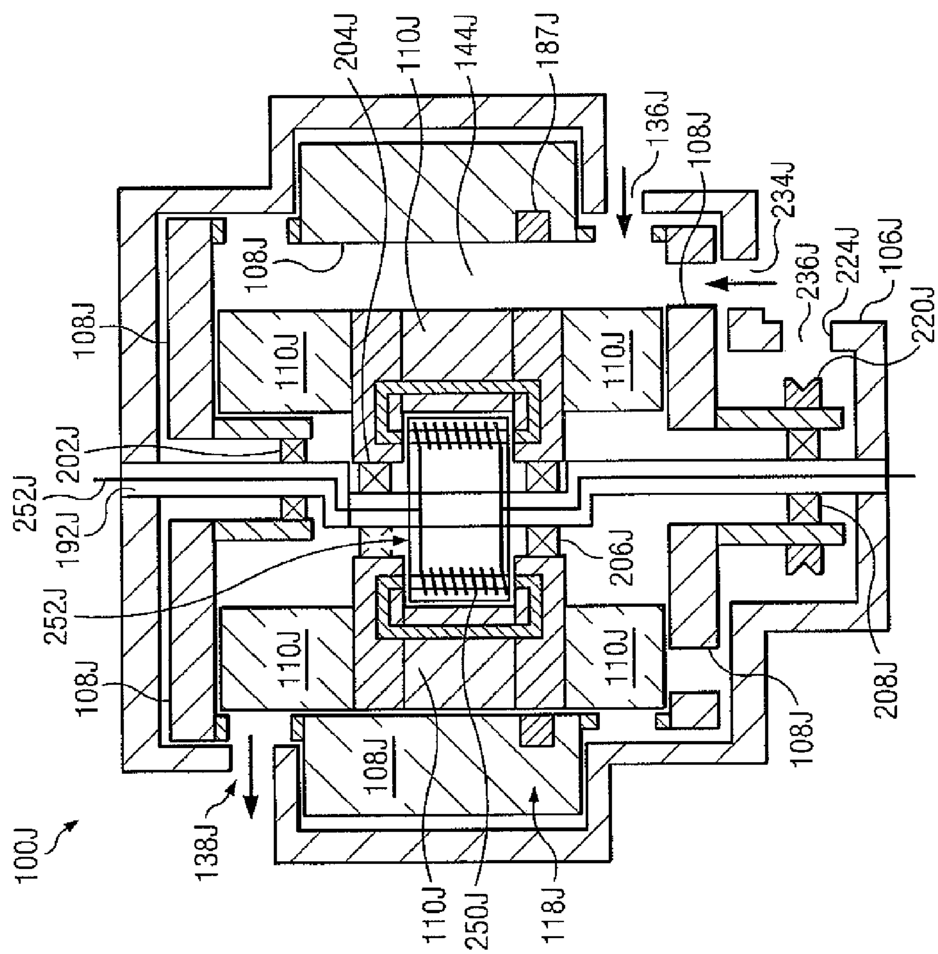


FIG. 21B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234J
236J
224J
106J
220J
206J
208J

FIG. 22

GEROTOR APPARATUS FOR A QUASI-ISOTHERMAL BRAYTON CYCLE ENGINE

RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 11/256,364 filed Oct. 21, 2005 and entitled "Gerotor Apparatus for a Quasi-Isothermal Brayton Cycle Engine," which claims benefit under 35 U.S.C. §119(e) of U.S. Provisional Application Ser. No. 60/621,221, entitled "Quasi-Isothermal Brayton Cycle Engine," filed on Oct. 22, 2004.

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a gerotor apparatus that functions as a compressor or expander. The gerotor apparatus may be applied generally to Brayton cycle engines and, more particularly, to a quasi-isothermal Brayton cycle engine.

BACKGROUND OF THE INVENTION

For mobile applications, such as an automobile or truck, it is generally desirable to use a heat engine that has the following characteristics: internal combustion to reduce the need for heat exchangers; complete expansion for improved efficiency; isothermal compression and expansion; high power density; high-temperature expansion for high efficiency; ability to efficiently "throttle" the engine for part-load conditions; high turn-down ratio (i.e., the ability to operate at widely ranging speeds and torques); low pollution; uses standard components with which the automotive industry is familiar; multifuel capability; and regenerative braking. There are currently several types of heat engines, each with their own characteristics and cycles. These heat engines include the Otto Cycle engine, the Diesel Cycle engine, the Rankine Cycle engine, the Stirling Cycle engine, the Erickson Cycle engine, the Carnot Cycle engine, and the Brayton Cycle engine. A brief description of each engine is provided below.

The Otto Cycle engine is an inexpensive, internal combustion, low-compression engine with a fairly low efficiency. This engine is widely used to power automobiles.

The Diesel Cycle engine is a moderately expensive, internal combustion, high-compression engine with a high efficiency that is widely used to power trucks and trains.

The Rankine Cycle engine is an external combustion engine that is generally used in electric power plants. Water is the most common working fluid.

The Erickson Cycle engine uses isothermal compression and expansion with constant-pressure heat transfer. It may be implemented as either an external or internal combustion cycle. In practice, a perfect Erickson cycle is difficult to achieve because isothermal expansion and compression are not readily attained in large, industrial equipment.

The Carnot Cycle engine uses isothermal compression and expansion and adiabatic compression and expansion. The Carnot Cycle may be implemented as either an external or internal combustion cycle. It features low power density, mechanical complexity, and difficult-to-achieve constant-temperature compressor and expander.

The Stirling Cycle engine uses isothermal compression and expansion with constant-volume heat transfer. It is almost always implemented as an external combustion cycle. It has a higher power density than the Carnot cycle, but it is difficult to perform the heat exchange, and it is difficult to achieve constant-temperature compression and expansion.

The Stirling, Erickson, and Carnot cycles are as efficient as nature allows because heat is delivered at a uniformly high temperature, T_{hot}, during the isothermal expansion, and rejected at a uniformly low temperature, T_{cold}, during the isothermal compression. The maximum efficiency, of these three cycles is:

$$\eta_{max} = 1 - \frac{T_{cold}}{T_{hot}}$$

This efficiency is attainable only if the engine is "reversible," meaning that the engine is frictionless, and that there are no temperature or pressure gradients. In practice, real engines have "irreversibilities," or losses, associated with friction and temperature/pressure gradients.

The Brayton Cycle engine is an internal combustion engine that is generally implemented with turbines and is generally used to power aircraft and some electric power plants. The Brayton cycle features very high power density, normally does not use a heat exchanger, and has a lower efficiency than the other cycles. When a regenerator is added to the Brayton cycle, however, the cycle efficiency increases. Traditionally, the Brayton cycle is implemented using axial-flow, multi-stage compressors and expanders. These devices are generally suitable for aviation in which aircraft operate at fairly constant speeds; they are generally not suitable for most transportation applications, such as automobiles, buses, trucks, and trains, which must operate over widely varying speeds.

The Otto cycle, the Diesel cycle, the Brayton cycle, and the Rankine cycle all have efficiencies less than the maximum because they do not use isothermal compression and expansion steps. Further, the Otto and Diesel cycle engines lose efficiency because they do not completely expand high-pressure gases, and simply throttle the waste gases to the atmosphere.

Reducing the size and complexity, as well as the cost, of Brayton cycle engines is important. In addition, improving the efficiency of Brayton cycle engines and/or their components is important. Manufacturers of Brayton cycle engines are continually searching for better and more economical ways of producing Brayton cycle engines.

SUMMARY OF THE INVENTION

According to one embodiment of the invention, an engine system comprises a housing, an outer gerotor, an inner gerotor, a tip inlet port, a face inlet port, and a tip outlet port. The housing has a first sidewall, a second sidewall, a first endwall, and a second endwall. The outer gerotor is at least partially disposed in the housing and at least partially defines an outer gerotor chamber. The inner gerotor is at least partially disposed within the outer gerotor chamber. The tip inlet port is formed in the first sidewall and allows fluid to enter the outer gerotor chamber. The face inlet port is formed in the first endwall and allows fluid to enter the outer gerotor chamber. The tip outlet port is formed in the second sidewall and allows fluid to exit the outer gerotor chamber.

Certain embodiments of the invention may provide numerous technical advantages. For example, a technical advantage of one embodiment may include the capability to enhance fluid intake into an outer chamber. Other technical advantages of other embodiments may include the capability to reduce dead volume in an engine system. Yet other technical advantages of other embodiments may include the capability to allow selective passage of fluid through a face inlet port. Still yet other technical advantages of other embodiments may include the capability to manipulate and/or regulate temperature in a housing. Still yet other technical advantages of other embodiments may include the capability to abrade tips of an outer gerotor. Still yet other technical advantages of other embodiments may include the capability to adjust a compression or expansion ratio in an outer gerotor chamber. Still yet other technical advantages of other embodiments may include the capability to create symmetries in ports to balance pressures developed by leaks. Still yet other technical advantages of other embodiments may include the capability to move a thermal datum into substantially the same plane as a seal between a housing and one of an inner or outer gerotor. Still yet other technical advantages of other embodiments may include the capability to create a journal bearing between a housing and one of an inner or outer gerotor. Still yet other technical advantages of other embodiments may include the capability to utilize a motor imbedded in one of an inner or outer gerotor.

Although specific advantages have been enumerated above, various embodiments may include all, some, or none of the enumerated advantages. Additionally, other technical advantages may become readily apparent to one of ordinary skill in the art after review of the following figures and description.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of example embodiments of the present invention and its advantages, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a side cross-sectional view of an engine system, according to an embodiment of the invention;

FIG. **2** is a perspective view of the outer gerotor of FIG. **1**;

FIG. **3** is a sealing system for an outer gerotor and a housing, according to an embodiment of the invention;

FIGS. **4**A, **4**B, and **4**C illustrate an operation of the first seat, the second seat, and the tubing in the sealing system of FIG. **3**, according to an embodiment of the invention;

FIG. **5** is a side cross-section view of an engine system, according to another embodiment of the invention;

FIG. **6**A is a cross section taken along line **6**A-**6**A of FIG. **5**;

FIG. **6**B is a cross section taken along line **6**B-**6**B of FIG. **5**;

FIG. **6**C is a cross section taken along line **6**C-**6**C of FIG. **5**;

FIG. **6**D is a cross section taken along line **6**D-**6**D of FIG. **5**;

FIGS. **6**E and **6**F are cross sections respectively taken along line **6**E-**6**E and line **6**F-**6**F of FIG. **5**;

FIGS. **7**A and **7**B are top cross-sectional views of an engine system, according to another embodiment of the invention;

FIG. **8** is a top cross-sectional view of an engine system, according to another embodiment of the invention;

FIG. **9** is a side cross-sectional view of an engine system, according to another embodiment of the invention;

FIG. **10** is a cross-section, cut across either one of the line **10-10** of FIG. **9**;

FIG. **11** is a side cross-sectional view of an engine system, according to another embodiment of the invention;

FIG. **12** is a side cross-sectional view of an upper portion of an engine system, according to another embodiment of the invention;

FIG. **13** is a cross-section of FIG. **12** taken across line **13-13** of FIG. **12**;

FIG. **14** is a side cross-sectional view of an engine system, according to another embodiment of the invention;

FIG. **15**A is a cross section taken along line **15**A-**15**A of FIG. **14**;

FIG. **15**B is a cross section taken along line **15**B-**15**B of FIG. **14**;

FIG. **15**C is a cross section taken along line **15**C-**15**C of FIG. **14**;

FIG. **15**D is a cross section taken along line **15**D-**15**D of FIG. **14**;

FIGS. **15**E and **15**F are cross sections respectively taken along lines **15**E-**15**E and lines **15**F-**15**F of FIG. **14**;

FIG. **15**G is a cross section taken along line **15**G-**15**G of FIG. **14**;

FIG. **16** is a side cross-sectional view of an engine system, according to another embodiment of the invention;

FIG. **17** is a cross section taken along line **17-17** of FIG. **16**;

FIG. **18** is a side cross-sectional view of an engine system, according to another embodiment of the invention;

FIG. **19** is a cross section taken along lines **19-19** of FIG. **18**;

FIG. **20** is a side cross-sectional view of an engine system, according to another embodiment of the invention;

FIGS. **21**A and **21**B are cross sections respectively taken along line **21**A-**21**A and line **21**B-**21**B of FIG. **20**; and

FIG. **22** is a side cross-sectional view of an engine system **100**J, according to another embodiment of the invention.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

It should be understood at the outset that although example embodiments of the present invention are illustrated below, the present invention may be implemented using any number of techniques, whether currently known or in existence. The present invention should in no way be limited to the example embodiments, drawings, and techniques illustrated below, including the embodiments and implementation illustrated and described herein. Additionally, the drawings are not necessarily drawn to scale.

FIGS. **1** through **22** below illustrate example embodiments of engine systems within the teachings of the present invention. Although the detailed description will describe these engine systems as being used in the context of a gerotor compressor, some of the engine system may function equally as well as gerotor expanders and/or combinations of gerotor expanders and compressors. In addition, the present invention contemplates that the engine systems described below may be utilized in any suitable application; however, the engine systems described below are particularly suitable for a quasi-isothermal Brayton cycle engine, such as the one described in U.S. Pat. No. 6,336,317 B1 ("the '317 patent") issued Jan. 8, 2002. The '317 patent, which is herein incorporated by reference, describes the general operation of a gerotor compressor and/or a gerotor expander. Hence, the operation of some of the engine systems described below may not be described in detail. In addition, in some embodiments, the technology described herein may be utilized in conjunction with the technology described in U.S. patent application Ser. Nos. 10/359,487 and 10/359,488, both of which are herein incorporated by reference.

FIG. **1** is a side cross-sectional view of an engine system **100**A, according to an embodiment of the invention. The geometry of the engine system **100**A of FIG. **1** may be used as either an expander or a compressor. However, for purposes of illustration, the engine system **100**A of FIG. **1** will be described as a compressor.

The engine system **100**A in the embodiment of FIG. **1** includes a housing **106**A, an outer gerotor **108**A, and an inner gerotor **110**A. The housing **106**A includes a tip inlet port **136**A and a tip outlet port **138**A. The tip inlet port **136**A allows fluids (e.g., gasses, liquids, or liquid-gas mixtures) to enter into the engine system **100**A in the direction of arrow **137**A. The tip outlet port **138**A allows allow the fluids to exit the engine system **100**A in the direction of arrow **139**A.

The housing **106**A additionally includes a first barrier **150**A and a second barrier **152**A operable to prevent a flow of fluids around the outer perimeter of the engine system **100**A. The first and second barriers **150**A and **152**B at least partially define a perimeter fluid inlet area **154**A and a perimeter fluid outlet area **156**A. The shape, configuration and size of the first and second barriers **150**A and **152**A may be selected to achieve a desired shape, configuration and size of the perimeter fluid inlet area **154**A and the perimeter fluid outlet area **156**A to achieve a desired compression ratio or range of compression ratios of fluids passing through the engine system **100**A.

The outer gerotor **108**A includes one or more openings **112**A which allow fluids to enter into and exit from an outer gerotor chamber **144**A. The inner gerotor **110**A in this embodiment is rotating in a counter-clockwise direction. In other embodiments, the inner gerotor **110**A may rotate in a clock-wise direction. The engine system **100**A of this embodiment may be viewed as having an intake section **172**A, a compression section **174**A, an exhaust section **176**A, and a sealing section **178**A.

Although a general shape and configuration of the inner gerotor **110**A and the outer gerotor **108**A have been shown in the embodiment of FIG. **1**, a variety of other shape and configurations for the inner gerotor **110**A and the outer gerotor **108**A may be used in other embodiments.

If the engine system **100**A were utilized as an expander, the tip inlet port **136**A may become a tip outlet port and the tip outlet port **138**A may become a tip inlet port.

FIG. **2** is a perspective view of the outer gerotor **108**A of FIG. **1**. The outer gerotor **108**A includes the plurality of openings **112**A, described above in FIG. **1**, as well as a base seat **164**A and a plurality of support rings or strengthening bands **166**A. The outer gerotor **108**A includes a plurality of outer gerotor portions **109**A, which extend in a cantilevered manner from the base seat **164**A. The support rings or strengthening bands **166**A wrap around the plurality of outer gerotor portions to provide support to the outer gerotor portions **109**A of outer gerotor **108**A. As an illustrative example, as the outer gerotor **108**A begins to spin, centrifugal forces may tend to splay the outer gerotor portions **109**A outwardly from the cantilevered support of the base seat **164**A. Accordingly, the support rings or strengthening bands **166**A provide structural support to the outer gerotor portions **109**A to prevent such splaying.

The support rings or strengthening bands **166**A may be made of a plurality of materials, either similar or different than the material utilized in the outer gerotor **108**A. Examples of materials that may be utilized in the support rings or strengthening bands **166**A include graphite fibers, other high-strength, high-stiffness materials, or other suitable materials.

FIG. **3** is a sealing system **104**A for an outer gerotor **108**A and a housing **106**A, according to an embodiment of the invention. FIG. **3** shows a side cut-away view of an outer gerotor **108**A with a plurality of support rings or strengthening bands **166**A supporting outer gerotor portions **109**A.

The portion of the housing **106**A that sealingly interacts with the outer gerotor **108**A is the barriers **150**A or **152**A. For purposes of brevity, only barrier **152**A is shown. Barrier **152**A includes a plurality of grooves **153**A. Each of the plurality of grooves **153**A includes a first seat **154**A and a second seat **155**A. The second seat **155**A includes tubing **156**A disposed therein. Details of an operation of the first seat **154**A, the second seat **155**A, and the tubing **156**A are described below with reference to FIGS. **4**A, **4**B, and **4**C. The support rings or strengthening bands **166**A are operable to be disposed in and rotate within the grooves **153**A. In particular embodiments, the strengthening bands **166**A may abrade away the first seat **154**A and the second seat **156**A. In other embodiments, the strengthening bands **166**A may not abrade away the first seat **154**A and the second seat **156**A.

FIGS. **4**A, **4**B, and **4**C illustrate an operation of the first seat **154**A, the second seat **155**A, and the tubing **156**A in the sealing system **104**A, according to an embodiment of the invention. During operation, the temperature of the outer gerotor **108**A (including associated outer gerotor portions **109**) may increase for a variety of reasons (e.g., due to heat from compression), thereby causing the outer gerotor **108**A to expand leftward from a thermal datum **190**A. Accordingly, the sealing system **104**A in particular embodiments may be designed as an adjustable seal, which compensates for expansion of the outer gerotor **108**A.

Each the first seats **154**A and the second seats **155**A may be made of abradable material, which allows for tight clearances as the parts wear. The first seat **154**A in particular embodiments may simply include a solid strip of abradable material. The second seat **155**A in particular embodiments may include abradable material with tubing **156**A disposed therein. The tubing **156**A may be designed to expand when pressure is applied. A variety of different configurations my be utilized in allowing the center tubing **156** to expand, including, but not limited to an application of fluid, such as hydraulic fluid or other suitable fluid. Upon expanding, the second seat **155**A reduces the gap in the groove **153**A. Although tubing **156**A has only been shown in the second seat **155**A, in other embodiments the tubing may be on the first seat **154**A as well. In other embodiments, either one or both of the first seat **154**A and the second seat **156**A may be mechanically actuated to reduce the gap in the groove **153**A and allow a seating of the support rings or strengthening bands **166**A.

FIG. **4**A shows the outer gerotor **108**A in a cold state—before expansion. The gap in the grooves **156**A are open. FIG. **4**B shows the outer gerotor **108**A in a heated state—expanding leftward from the thermal datum **190**A. As the outer gerotor **108**A expands leftward, the support rings or strengthening bands **166**A may be pushed against the first seat **154**A. The gap in the grooves **156**A are still open. FIG. **4**C shows an application of pressure to the tubing **156**A, thereby reducing the gap in the groove **153**A and forcing the second seat **155**A up against the support rings or strengthening bands **166**A to create a seal. During this operation, the barrier **152**A may additionally expand, but only in a relatively small manner compared to the outer gerotor **108**A. As briefly referenced above, after the seal is created, the rotation of the support rings or strengthening bands **166**A through the grooves **153**A may cause the first seat **154**A and second seat **155**A to abrade away. Accordingly, in particular embodiments, the first seat **154**A and second seat **155**A may be replaced as needed.

FIG. **5** is a side cross-section view of an engine system **100**B, according to another embodiment of the invention. Although one specific configuration of an engine system **100**B is described in FIG. **5**, it should be expressly understood that engine system **100**B may utilize more, fewer, or different components parts, including but not limited the components from various configurations described herein with reference to other embodiments. The engine system **100**B of FIG. **5** may be designed as a compressor, expander, or both, depending on the embodiment or intended application. For purposes of illustration, the engine system **100**B will be described as a compressor.

The engine system **100**B in the embodiment of FIG. **5** includes a housing **106**B, an outer gerotor **108**B, an inner gerotor **110**B, a shaft **192**B, and a synchronizing mechanism **118**B. The outer gerotor **108**B is at least partially disposed within the housing **106**B and the inner gerotor **110**B is at least partially disposed within the outer gerotor **108**B. More particularly, the outer gerotor **108**B at least partially defines an outer gerotor chamber **144**B and the inner gerotor **110**B is at least partially disposed within the outer gerotor chamber **144**B.

The housing may include a tip inlet port **136**B, a face inlet port **132**B, and a tip outlet port **138**B. The tip inlet port **136**B and the face inlet port **132**B generally allow fluids, such as gasses, liquids, or liquid-gas mixtures, to enter the outer gerotor chamber **144**A. Likewise, the tip outlet port **138**B generally allow the fluids within outer gerotor chamber **144**A to exit from outer gerotor chamber **144**A. The combination of the two inlet ports, a tip inlet port **136**B and a face inlet port **132**B, may allow entry of additional fluids in the outer gerotor chamber **144**A. FIGS. **6**A and **6**B show further details of supplementing the tip inlet port **136**B with the face inlet port **132**B.

The tip inlet port **136**B, the face inlet port **132**B, and the tip outlet port **138**B may have any suitable shape and size. Depending on the particular use or the engine system **100**B, in some embodiments, the total area of the tip inlet port **136**B and the face inlet port **132**B may be different than the total area of the tip outlet port **138**B.

As shown in FIG. **5**, inner gerotor **110**B may be rigidly coupled to the shaft **192**B, which is rotatably coupled to a hollow cylindrical portion of housing **106**B by one or more bearings **202**B, **208**B, such as ring-shaped bearings. Accordingly, the shaft **192**B and the inner gerotor may rotate about a first axis. In some embodiments, the shaft **192**B may be a drive shaft operable to drive the inner gerotor **110**B.

The outer gerotor **110**B is rotatably coupled to the interior of the housing **106**B by one or more bearings **204**B, **206**B such as ring-shaped bearings. The outer gerotor **110**B may rotate about a second axis different than the first axis.

The synchronizing system **118**B may take on a variety of different configurations. Further details of one configuration for the synchronizing system **118**B are described below with reference to FIG. **6**F.

In operation, when the engine system **100**B of FIG. **5** starts spinning and becomes hot, components of the engine system **100**B may begin to change and/or expand, causing, among other things, disturbance of the seals (e.g., between the housing **106**B and the outer gerotor **108**B) in the engine system **100**B. Accordingly, the engine system **100**B of FIG. **5** may incorporate channels **107**B into the housing **106**B to regulate temperature. The regulation of temperature, among other things, helps to prevent warping due to uneven temperature distributions in the engine system **100**B.

In particular embodiments, the channels **107**B may be located at points where expansion would be expected to occur for both centrifugal and thermal reasons. The channels **107**B may receive any suitable type of fluid for temperature regulations. Such channels may have one or more fluid inlets **191**B and one or more fluid outlets **192**B. And, in some embodiments, electrical heating strips may be used at the location of the channels **107**B.

In particular embodiments, the channels **107**B or electrical heating strips may allows the housing **106**B to be heated prior to starting the engine system **100**B. The resulting thermal expansion lifts the housing **106**B away from the ports (e.g., tip inlet port **136**B and the tip outlet port **138**B), thereby preventing abrasion of sealing surfaces during start-up. Once the engine system **100**B is operating at steady state and the component parts are fully expanded due to heating, the temperature of the housing **106**B can be reduced, for example, through the channels **107**B, thereby closing gaps and allowing abradable seals to function. For example, the components (e.g., the outer gerotor **108**B) may be allowed to seat on an abradable seat.

Abradable seals utilized in the engine system **100**B (e.g., between the housing **106**B and the outer gerotor **108**B) may be constructed from a variety of materials such as Teflon polymers or molybdenum disulfide. Additionally, the surfaces may be made of a roughened metal. In such embodiments, the roughened metal may act like sand paper and abrades away the abradable material coating the other surface. To prevent galling between components parts, dissimilar metals may be used, such as aluminum and steel. In embodiments using a high-temperature expander, one surface may be a highly porous silicon carbide and the other a dense silicon carbide. Porous silicon carbide may be made from polymers containing silicon, carbon, and hydrogen, such as those sold by Starfire Systems, Inc.

FIG. **6**A is a cross section taken along lines **6**A-**6**A of FIG. **5**. FIG. **6**A shows the housing **106**B, the shaft **192**B, the outer gerotor **108**B, and the face inlet port **134**B though the housing **106**B.

FIG. **6**B is a cross section taken along lines **6**B-**6**B of FIG. **5**. FIG. **6**B shows the housing **106**B, the shaft **192**B, the outer gerotor **108**B and a plurality of gerotor chamber face inlet ports **195**B disposed in the outer gerotor **108**B. The gerotor chamber face inlet ports **195**B in this embodiment are shown with a tear drop shape. In other embodiments, the gerotor chamber face inlet ports **195**B may have other shapes. The shape and arrangement of the gerotor chamber face inlet ports **195**B may be selected so that the gerotor chamber face inlet ports **195**E are open during an intake portion of a cycle of the engine system **100**B and blocked during an exhaust portion of the cycle of the engine system **100**B. Such a configuration reduces dead volume because the inlet ports **195**B are only selectively open, allowing passage of fluids, when the inlet ports **195**B are adjacent the face inlet port **134**B. The shape, structure, and location of the gerotor chamber face inlet ports **195**B can be changed based upon the inner gerotor **110**B and outer gerotor **108**B utilized.

FIG. **6**C is a cross section taken along lines **6**C-**6**C of FIG. **5**. FIG. **6**C shows the housing **106**B, the shaft **192**B, the inner gerotor **110**B, and the outer gerotor **108**B. FIG. **6**C also shows portions of the engine system **100**B that may roughly correspond to an intake section **172**B, a compression section **174**B, an exhaust section **176**B, and a sealing section **178**B.

FIG. **6**D is a cross section taken along lines **6**D-**6**D of FIG. **5**. FIG. **6**C shows the housing **106**B, the shaft **192**B, the inner gerotor **110**B, and the outer gerotor **108**B. In FIG. **6**D, the outer gerotor **108**B is not interrupted by any ports. Accordingly, the outer gerotor **108**B can resist centrifugal forces without support rings or strengthening bands, for example, as described with reference to FIG. **2**.

FIGS. **6**E and **6**F are cross sections respectively taken along lines **6**E-**6**E and lines **6**F-**6**F of FIG. **5**. FIGS. **6**E and **6**F show the housing **106**B, the shaft **192**B, and the outer gerotor **108**B. FIG. **6**F also shows the inner gerotor **110**B and further details of the synchronizing mechanism **118**B. The synchronizing mechanism of FIG. **6**F is a trochoidal gear arrangement between the inner gerotor **110**B and the outer gerotor **108**B. The synchronizing mechanism in other embodiments may include involute gears, peg-and-track systems, or other suitable synchronizing systems.

FIGS. **7**A and **7**B are top cross-sectional views of an engine system **100**B', according to another embodiment of the invention. The cross sections of the engine system **100**B' of FIGS. **7**A and **7**B are similar to cross sections of the engine system **100**B of FIGS. **6**C and **6**D, showing shows a housing **106**B', a shaft **192**B', an inner gerotor **110**B', and an outer gerotor **108**B'. However, the outer gerotor **108**B' of engine system **100**B' also has an abradable tip **186**B' disposed thereon. The abradable tip **186**B' may be made of a softer material than the inner gerotor **110**B'. Accordingly, as the inner gerotor **110**B' rotates relative to the outer gerotor **108**B', the inner gerotor **110**B' abrades away the abradable tips **186**B', thereby preserving the inner gerotor **110**B'. The abradable tips **186**B' may be replaced during maintenance of the engine system **200**B'.

FIG. **8** is a top cross-sectional view of an engine system **100**B", according to another embodiment of the invention. The cross section of the engine system **100**B" of FIG. **8** is similar to cross section of the engine system **100**B of FIG. **6**C, showing a housing **106**B", a shaft **192**B", an inner gerotor **110**B', an outer gerotor **108**B" and portions of the engine system **100**B" that may roughly correspond to an intake section **172**B', a compression section **174**B", an exhaust section **176**B', and a sealing section **178**B'. However, the housing **106**B' of the engine system **100**B' also includes a slider **188**B". The slider **188**B" is a portion of the housing **106**B" that defines the compression ratio. The slider **188**B" may change the compression ratio by circumferentially sliding in either direction with respect to a circumferential wall **106**B' of the housing **106**B'. As seen, the slider **188**B" has a maximum length **189** of circumferential movement and maintains a radial distance between the slider **188**B'" and the circumferential wall **106**B'" over the maximum length **189** because both the slider **188**B" and the circumferential wall **106**B'" have the same circumferential configuration. Additionally, one of ordinary skill in the art reviewing this specification will recognize that each location along the maximum length **189** provides a different compression ratio. Any of a variety of different configurations may be utilized to enable the sliding of the slider **188**B" relative to the remainder of the housing **106**B".

FIG. **9** is a side cross-sectional view of an engine system **100**C, according to another embodiment of the invention. The engine system **100**C of FIG. **9** may include features similar to the engine system **100**B of FIG. **5**, including a housing **106**C, an outer gerotor **108**C, an inner gerotor **110**C, an outer gerotor chamber **144**C, a shaft **192**C, a synchronizing mechanism **118**C, a tip inlet port **136**C, a face inlet port **132**C, a tip outlet port **138**C and bearings **202**C, **204**C, **206**C, and **208**C. Similar to engine system **100**B, the engine system **100**C in various embodiments may include more, fewer, or different component parts, including but not limited the components from various configurations described herein with reference to other embodiments. Further, the engine system **100**C of FIG. **9** may be designed as a compressor, expander, or both, depending on the embodiment or intended application. For purposes of illustration, the engine system **100**C will be described as a compressor. The embodiment of the engine system **100**C of FIG. **9** differs from the embodiment of the engine system **100**B, described herein, in the configuration of the tip inlet port **136**C and the tip outlet port **138**C.

In operation, there may be some fluid (e.g., gas or liquid-gas mixtures) leakage in a gap **230**C between the housing **106**C and the outer gerotor **108**C at both the tip inlet port **136**C and the tip outlet port **138**C. As fluid leaks between the gaps **230**C, a pressure distribution may develop and act on the outer gerotor **108**C, forcing the outer gerotor **108**C to move away from the gap **230**C. Such movement, among other things, may create undesirable axial loading on the bearings (e.g., bearing **204**C and **206**C). Accordingly, the engine system **100**C of FIG. **9** may utilize symmetry in a top portion **237**C and a bottom portion **235**C of the tip inlet port **136**C and the tip outlet port **138**C to allow creation of similar forces in each gap **230**C that balance one another and thereby reduce potential negative effects, including the undesirable axial loading on the bearings. In other words, the similar forces created by the gaps **230**C work against one another to create a net force of substantially zero at the tip inlet port **136**C and the tip outlet port **138**C. In the embodiment of FIG. **9**, the symmetry is created by wrapping bottom portion **235**C of housing **106**C and top portion **237**C of housing **106**C radially inward at the tip inlet port **136**C and the tip outlet port **138**C.

FIG. **10** is a cross-section, cut across either one of the lines **10-10** of FIG. **9**. Because the top portion **237**C and the bottom portion **235**C of the tip inlet port **136**C and the tip outlet port **138**C are substantially similar, the cross-sections across either of lines **10-10** of FIG. **9** will also be substantially similar. FIG. **10** shows the housing **106**C, the outer gerotor **108**C, the inner gerotor **110**C, and the shaft **192**C. FIG. **10** also shows how respective portions of the engine system **100**C may be viewed as an intake section **172**C, a compression section **174**C, an exhaust section **176**C, and a sealing section **178**C.

FIG. **11** is a side cross-sectional view of an engine system **100**D, according to another embodiment of the invention. The engine system **100**D of FIG. **11** may include features similar to the engine system **100**B of FIG. **5**, including a housing **106**D, an outer gerotor **108**D, an outer gerotor chamber **144**D, an inner gerotor **110**D, a shaft **192**D, a synchronizing mechanism **118**D, a tip inlet port **136**D, a face inlet port **132**D, a tip outlet port **138**D and bearings **202**D, **204**D, **206**D, and **208**D. And, similar to engine system **100**B, engine system **100**D in various embodiments may include more, fewer, or different component parts, including but not limited the components from various configurations described herein with reference to other embodiments. The engine system **100**D of FIG. **11** may be designed as a compressor, expander, or both, depending on the embodiment or intended application. For purposes of illustration, the engine system **100**D of FIG. **11** will be described as a compressor. The embodiment of the engine system **100**D of FIG. **11** differs from the embodiment of the engine system **100**B, described herein, in the arrangement of various components, for example, bearing **204**D.

As briefly referenced with reference to FIGS. **4**A, **4**B, and **4**C, above, components of a system may expand (e.g., for thermal reasons) from a thermal datum. In such expansion, it desirable to avoid perturbances of seals between the housing **106**D and the outer gerotor **108**D or seals between other components. Accordingly, the engine system **100**D of FIG. **11** moves a thermal datum **190**D of the engine system **100**D into substantially the same plane as a seal between the housing **106**D and the outer gerotor **108**D. In other embodiments, the thermal datum **190**D may be substantially in the same plane as seals between other components (e.g., seal between the housing **106**D and the inner gerotor **110**D). With such configurations, thermal expansion occurs away from the thermal datum **190**D and seals, thereby minimizing perturbances of seals between the housing **106**D and the outer gerotor **108**D or seals between other components. In such configurations, the thermal datum may also be viewed as substantially within the same plane of the tip inlet port **136**D and the tip outlet port **138**D.

In particular embodiments, the thermal datum **190**D may be moved substantially into the same plane as a seal between the housing **106**D and the outer gerotor **108**D by moving bearing **204**D down into the engine system **100**D in a configuration that resists axial movement. More particularly, the bearing **204**D is positioned radially outward from a portion **210**D of the housing **106**D that extends down into the engine system **100**D. Other arrangements, including other bearing configurations may additionally be utilized, to move the thermal datum into substantially the same plane as a seal between the housing **106**D and the outer gerotor **108**D or a seal between other components.

FIG. **12** is a side cross-sectional view of an upper portion of an engine system **100**E, according to another embodiment of the invention. The upper portion of the engine system **100**E of FIG. **11** may include features similar to the engine system **100**D of FIG. **11**, including a housing **106**E, an outer gerotor **108**E, an inner gerotor **110**E, a shaft **192**E, a tip inlet port **136**E, a face inlet port **132**E, a tip outlet port **138**E, and a bearing **202**E. And, similar to engine system **100**D, engine system **100**E in various embodiments may include more, fewer, or different component parts, including but not limited the components from various configurations described herein with reference to other embodiments. The engine system **100**E of FIG. **12** may be designed as a compressor, expander, or both, depending on the embodiment or intended application. The embodiment of the engine system **100**E of FIG. **12** differs from the embodiment of the engine system **100**D, described herein, in that engine system **100**E employs a journal bearing **212**E.

Journal bearings are generally desirable because in particular configurations they are more economical than ball bearings and can take higher loads than ball bearings. However, conventional journal bearings generally have too large of a gap to allow for precision alignment of the sealing surfaces, and thus are not suitable for gerotor devices. Accordingly, the arrangement of the journal bearing **212**E in the engine system **100**E of FIG. **12** may be utilized to allow tight gaps. Further details of the journal bearing **212**E are described below with reference to FIG. **13**.

FIG. **13** is a cross-section of FIG. **12** taken across lines **13**-**13** of FIG. **12**. The journal bearing **212**E is created by an interaction between the stationary housing **106**E and the rotating outer gerotor **108**E. In such an interaction, a variety of fluids (e.g., an oil film) suitable for the journal bearing **212**E may be positioned in a gap **214**E between the housing **106**E and the outer gerotor **108**E. And, the outer gerotor **108**E may include a plurality of portions **218**E circumferentially disposed around the outer gerotor **108**E. A slot **216**E may also be disposed between each portion **218**E. At low rotational speeds of the outer gerotor **108**E, the gap **214**E may be small with little, if any, centering forces (pressures created by the fluid in the gap **214**E). As the outer gerotor **108**E begins to speed up, the weight of the portions **118**E stretch an inner circumference **280**E of the outer gerotor **108**E, thereby opening up the gap **214**E. Simultaneously, hydrodynamic centering forces are developed. At high speeds, the centering forces are significant and thus may provide the necessary centering precision for the outer gerotor **108**E. The gap **214**E in the journal bearing **212**E can expand readily because the slots **216**E (which may have a helical pattern when viewed from the exterior of the journal bearing **212**E) in the outer periphery make the journal bearing **212**E flexible.

FIG. **14** is a side cross-sectional view of an engine system **100**F, according to another embodiment of the invention. The engine system **100**F of FIG. **14** may include features similar to the engine system **100**B of FIG. **5**, including a housing **106**F, an outer gerotor **108**F, an inner gerotor **110**F, an outer gerotor chamber **144**F, a shaft **192**F, a synchronizing mechanism **118**F, a tip inlet port **136**F, an face inlet port **132**F, a tip outlet port **138**F and bearings **202**F, **204**F, **206**F, and **208**F. And, similar to engine system **100**B, engine system **100**F in various embodiments may include more, fewer, or different component parts, including but not limited the components from various configurations described herein with reference to other embodiments. The engine system **100**F of FIG. **14** may be designed as a compressor, expander, or both, depending on the embodiment or intended application.

The embodiment of the engine system **100**F of FIG. **14** differs from the embodiment of the engine system **100**B, described herein, in that the shaft **192**F of engine system **100**F is stationary or rigid with respect to the housing **106**F. Accordingly, engine system **100**F is powered through a pulley system **220**F that powers the outer gerotor **108**F. Although a pulley system **220**F is shown, the engine system **100**F could also be powered by a chain drive, a gear drive, or other suitable powering systems in other embodiments. To accommodate the pulley system **220**F or other suitable powering system, the engine system **100**F of FIG. **14** includes a power port **224**F.

FIG. **15**A is a cross section taken along lines **15**A-**15**A of FIG. **14**. FIG. **15**A shows the housing **106**F, the shaft **192**F, the outer gerotor **108**F, and the face inlet port **134**F though the housing **106**F.

FIG. **15**B is a cross section taken along lines **15**B-**15**B of FIG. **14**. FIG. **15**B shows the housing **106**F, the shaft **192**F, the outer gerotor **108**F and a plurality of gerotor chamber face inlet ports **195**F disposed in the outer gerotor **108**F. The gerotor chamber face inlet ports **195**B are shown with a tear drop shape. However, in other embodiments, the gerotor chamber face inlet ports **195**F may have other shapes. In a manner similar to that described above with reference to FIG. **6**B, the shape and arrangement of the gerotor chamber face inlet ports **195**F of FIG. **15**B may be selected so that the gerotor chamber face inlet ports **195**F are open during an intake portion of the cycle and blocked during an exhaust portion of the cycle. Such a configuration reduces dead volume because the inlet ports **195**F are only open, allowing passage of fluids, when the inlet ports are adjacent the face inlet port **134**F. The shape, structure, and location of the gerotor chamber face inlet ports **195**F can be changed based upon the inner gerotor **110**F and the outer gerotor **108**F utilized.

FIG. **15**C is a cross section taken along lines **15**C-**15**C of FIG. **14**. FIG. **15**C shows the housing **106**F, the shaft **192**F, the inner gerotor **110**F, and the outer gerotor **108**F. FIG. **15**C also shows portions of the engine system **100**F that may roughly correspond to an intake section **172**F, a compression section **174**F, an exhaust section **176**F, and a sealing section **178**F.

FIG. **15**D is a cross section taken along lines **15**D-**15**D of FIG. **14**. FIG. **15**D shows the housing **106**F, the shaft **192**F, the inner gerotor **110**F, and the outer gerotor **108**F. In FIG. **15**D, the outer gerotor **108**F is not interrupted by ports. Accordingly, the outer gerotor **108**F can resist centrifugal forces without support rings or strengthening bands, for example, as described with reference to FIG. **2**.

FIGS. **15**E and **15**F are cross sections respectively taken along lines **15**E-**15**E and lines **15**F-**15**F of FIG. **14**. FIGS. **15**E and **15**F show the housing **106**F, the shaft **192**F, and the outer gerotor **108**F. FIG. **15**F also shows the inner gerotor **110**F and further details of the synchronizing mechanism **118**F. The synchronizing mechanism **118**F of FIG. **15**F is a trochoidal gear arrangement between the inner gerotor **110**F and the outer gerotor **108**F. The synchronizing mechanism **118**F in other embodiments may include involute gears, peg-and-cam systems, or other suitable synchronizing systems.

FIG. **15**G is a cross section taken along lines **15**G-**15**G of FIG. **14**. FIG. **15**G shows the housing **106**F, shaft **192**F, the outer gerotor, pulley system **220**F, and power port **224**F.

FIG. **16** is a side cross-sectional view of an engine system **100**G, according to another embodiment of the invention. The engine system **100**G of FIG. **16** may include features similar to the engine system **100**F of FIG. **15**, including a housing **106**G, an outer gerotor **108**G, an outer gerotor chamber **144**G, an inner gerotor **110**G, a stationary shaft **192**G, a tip inlet port **136**G, a face inlet port **132**G, a tip outlet port **138**G, a pulley system **220**G, a power port **224**F, and bearings **202**F, **204**F, **206**F, and **208**F. And, similar to engine system **100**F, the engine system **100**G in various embodiments may include more, fewer, or different component parts, including but not limited the components from various configurations described herein with reference to other embodiments. The engine system **100**G of FIG. **16** may be designed as a compressor, expander, or both, depending on the embodiment or intended application. For purposes of illustration, the engine system **100**G is shown as a compressor.

The embodiment of the engine system **100**G of FIG. **16** differs from the embodiment of the engine system **100**F, described herein, in that the outer gerotor **108**G directly drives the inner gerotor **110**G using a strip of low-friction material **187**G. Further details of this direct drive are provided below with reference to FIG. **17**.

FIG. **17** is a cross section taken along lines **17**-**17** of FIG. **16**. FIG. **17** shows the housing **106**G, the shaft **192**G, the outer gerotor **108**G, the inner gerotor **110**G, and the low-friction material **187**G. As the inner gerotor **110**G and the outer gerotor **108**G rotate relative to one another, at least portions of an outer surface **262**G of the inner gerotor **110**G contacts at least portions of an inner surface **260**G of the outer gerotor **108**G, which synchronizes the rotation of the inner gerotor **110**G and the outer gerotor **108**G. Thus, as shown in FIG. **17**, the outer surface **262**G of the inner gerotor **110**G and the inner surface **260**G of the outer gerotor **108**G may provide the synchronization function that is provided by separate synchronization mechanisms **118** discussed herein with regard to other embodiments.

In order to reduce friction and wear between the inner gerotor **110**G and the outer gerotor **108**G, at least a portion of the outer surface **262**G of the inner gerotor **110**G and/or the inner surface **260**G of the outer gerotor **108**G is formed from one or more relatively low-friction materials **187**G. Such low-friction materials **187**G may include, for example, a polymer (phenolics, nylon, polytetrafluoroethylene, acetyl, polyimide, polysulfone, polyphenylene sulfide, ultrahigh-molecular-weight polyethylene), graphite, or oil-impregnated sintered bronze. In some embodiments, such as embodiments in which water is provided as a lubricant between outer surface **187**G of inner gerotor **110**G and inner surface **260**G of outer gerotor **108**G, low-friction materials **187**G may comprise Vescanite.

Regions for the low-friction materials **187**G may include portions (or all) of inner gerotor **110**G and/or outer gerotor **108**G, or low-friction implants coupled to, or integral with, the inner gerotor **110**G and/or the outer gerotor **108**G. Depending on the particular embodiment, such regions of the low-friction materials **187**G may extend around the inner perimeter of the outer gerotor **108**G and/or the outer perimeter of the inner gerotor **110**G, or may be located only at particular locations around the inner perimeter of the outer gerotor **108**G and/or the outer perimeter of inner gerotor **110**G, such as proximate the tips of inner gerotor **110**G and/or outer gerotor **108**G. As shown in FIG. **17**, the low-friction material **187**G may be placed on tips of the inner surface **260**G of the outer gerotor **108**G.

In particular embodiments, the low-friction materials **187**G on the inner gerotor **110**G and/or the outer gerotor **108**G may sufficiently reduce friction and wear such that the gerotor apparatus may be run dry, or without lubrication. However, in some embodiments, a lubricant may be provided to further reduce friction and wear between the inner gerotor **110**G and the outer gerotor **108**G. The lubricant may include any one or more suitable substances suitable to provide lubrication between multiple surfaces, such as oils, graphite, grease, water, or any other suitable lubricants.

FIG. **18** is a side cross-sectional view of an engine system **100**H, according to another embodiment of the invention. The engine system **100**H of FIG. **18** may include features similar to the engine system **100**G of FIG. **16**, including a housing **106**H, an outer gerotor **108**H, an inner gerotor **110**H, an outer gerotor chamber **144**H; a stationary shaft **192**H, a tip inlet port **136**H, a tip outlet port **138**H, a direct drive with a low-friction material **187**H, a pulley system **220**H, a power port **224**H, and bearings **202**H, **204**H, **206**H, and **208**H. And, similar to engine system **100**G, engine system **100**H in various embodiments may include more, fewer, or different component parts, including but not limited the components from various configurations described herein with reference to other embodiments. Further, the engine system **100**H of FIG. **18** may be designed as a compressor, expander, or both, depending on the embodiment or intended application. For purposes of illustration, the engine system **100**H is shown as a compressor. The embodiment of the engine system **100**H of FIG. **18** differs from the embodiment of the engine system **100**G, described herein, in that in that the engine system **100**F includes a bottom face inlet port **234**H.

In utilizing the bottom face inlet port **234**H at the opposite end from the tip inlet port **136**H, the engine system **100**H is allowed to be filed from both ends during intake, thereby allowing faster rotational speeds, among other reasons, due to the speed at which fluid travels. This configuration may be contrasted with other configurations in which fluid must travel the length of the engine system to reach, for example, a bottom **280**H of engine system **100**H.

FIG. **19** is a cross section taken along lines **19**-**19** of FIG. **18**. FIG. **19** shows the housing **106**H, the shaft **192**B, the inner gerotor **110**H, the outer gerotor **108**B, and the bottom face inlet port **234**H though the housing **106**B. Although not shown, the engine system **100**H may additionally utilize a configuration similar to the teardrop configurations of FIG. **6**B for selective passage of fluid in the intake portion of the cycle. In such embodiments, the teardrop intake would be positioned adjacent the bottom face inlet port **234**H.

FIG. **20** is a side cross-sectional view of an engine system **100**I, according to another embodiment of the invention. The engine system **100**I of FIG. **20** may include features similar to the engine system **100**G of FIG. **15**, including a housing **106**I, an outer gerotor **108**I, an inner gerotor **110**I, outer gerotor chamber **144**I, a stationary shaft **192**I, a direct drive with a low-friction material **187**I, a tip outlet port **138**I, a pulley system **220**I, a power port **224**I, and bearings **202**I, **204**I, **206**I, and **208**I. And, similar to the engine system **100**G, the engine system **100**I in various embodiments may include more, fewer, or different component parts. The embodiment of the engine system **100**I of FIG. **20** differs from the embodiment of the engine system **100**G, described herein, in that the embodiment of the engine system **100**I includes a bottom face inlet port **234**I and a bottom tip inlet port **236**I. Because the fluid exits from the tip outlet port **138**I, the fluid must linear traverse the engine system **100**I up through chamber **144**I.

FIGS. **21**A and **21**B are cross sections respectively taken along line **21**A-**21**A and line **21**B-**21**B of FIG. **20**. FIGS. **21**A and **21**B show the housing **106**I, the shaft **192**I, the inner gerotor **110**I, and the outer gerotor **108**.

FIG. **22** is a side cross-sectional view of an engine system **100**J, according to another embodiment of the invention. The engine system **100**J of FIG. **22** may include features similar to the engine system **100**I of FIG. **20**, including a housing **106**J, an outer gerotor chamber **144**J, an outer gerotor **108**J, an inner gerotor **110**J, a stationary shaft **192**J, a synchronizing mechanism **118**J, a tip outlet port **138**J, a pulley system **220**J, a power port **224**J, bottom face inlet port **234**J, a bottom tip inlet port **236**J, and bearings **202**J, **204**J, **206**J, and **208**J. And, similar to engine system **100**I, engine system **100**J in various embodiments may include more, fewer, or different component parts. Engine system **100**I additionally includes an electrical motor **250**J, which receives electrical power through electrical lines **252**J. The electrical motor **250**J in particular may power the inner rotor **110**J. The electric motor may be of a variety of suitable types, such as an induction motor, permanent magnet motor, or switched reluctance motor. In this embodiment, the pulley system **220**J may be used to power auxiliary equipment, such as pumps or other devices.

Although specific designs, shapes, and configurations of the inner gerotors and the outer gerotors have be described above with various embodiments, it should be expressly understood that a variety of other designs, shapes, and configurations for the inner gerotors and the outer gerotors may be utilized without departing from the scope of the invention as defined by the claims below.

Furthermore, although the present invention has been described with several embodiments, a myriad of changes, variations, alterations, transformations, and modifications may be suggested to one skilled in the art, and it is intended that the present invention encompass such changes, variations, alterations, transformation, and modifications as they fall within the scope of the appended claims.

What is claimed is:

1. A system, comprising:
a housing; and
an outer gerotor at least partially disposed in the housing and at least partially defining an outer gerotor chamber,
wherein:
the housing includes a single movable slider configured to circumferentially move with respect to a circumferential wall of the housing to adjust a ratio of compression or expansion in the outer gerotor chamber,
the single movable slider has a maximum length of circumferential movement, and
the system is configured such that the circumferential movement of the slider over the maximum length does not modify a radial distance between the single movable slider and the circumferential wall of the housing.

2. The system of claim **1**, further comprising:
a temperature regulator at least partially disposed in the housing, the temperature regulator configured to regulate a temperature of the housing, the temperature regulator including at least one channel configured to receive a fluid.

3. The system of claim **2**, further comprising:
an inner gerotor at least partially disposed within the outer gerotor chamber; and
a seal between the housing and one of the outer gerotor or the inner gerotor, wherein the temperature regulator is configured to thermally expand the housing away from the seal.

4. The system of claim **1**, further comprising:
an inner gerotor at least partially disposed within the outer gerotor chamber,
wherein:
the housing further includes a tip outlet port,
the tip outlet port is configured to allow fluid to exit the outer gerotor chamber,
the tip outlet port includes a top portion and a bottom portion,
a first seal is located between the top portion and one of the inner gerotor or the outer gerotor,
a second seal is located between the bottom portion and the one of the inner gerotor or the outer gerotor, and
the top portion and the bottom portion are substantially symmetrical.

5. The system of claim **4**, wherein the substantially symmetrical top and bottom portions are operable to balance pressures created by a fluid leak associated with at least one of the first seal or the second seal.

6. The system of claim **1**, further comprising:
an inner gerotor at least partially disposed within the outer gerotor chamber; and
a seal between the housing and one of the inner gerotor or the outer gerotor, wherein a thermal datum for the system is substantially in a same plane as the seal.

7. The system of claim **6**, further comprising:
at least one bearing substantially in the same plane as the thermal datum.

8. The system of claim **1**, further comprising:
an inner gerotor at least partially disposed within the outer gerotor chamber,
wherein:
the system is configured such that an interaction between a portion of one of the inner gerotor or the outer gerotor and a portion of the housing creates a journal bearing, and
the journal bearing includes a gap between the housing and the one of the inner gerotor or the outer gerotor.

9. The system of claim **8**, wherein:
the one of the inner gerotor or the outer gerotor includes peripheral portions separated by at least one slot, and
a weight of the peripheral portions centrifugally forces an inner perimeter of the one of the inner gerotor or the outer gerotor to open up when the one of the inner gerotor or the outer gerotor rotates.

10. The system of claim **1**, further comprising:
an inner gerotor at least partially disposed within the outer gerotor chamber,
wherein the system is configured to introduce power to an engine system through the inner gerotor.

11. The system of claim **10**, wherein:
the system is configured to introduce the power through a rotatable shaft, and
the inner gerotor is rigidly coupled to the rotatable shaft.

12. The system of claim **1**, wherein the system is configured to introduce power to an engine system through the outer gerotor.

13. The system of claim **1**, further comprising:
an inner gerotor at least partially disposed within the outer gerotor chamber; and
a motor imbedded in the inner gerotor.

14. The system of claim **1**, further comprising:

an inner gerotor at least partially disposed within the outer gerotor chamber;

wherein at least a portion of one of the outer gerotor or the inner gerotor comprises a low-friction material.

15. The system of claim **1**, further comprising:

an adjustable sealing structure operable to adjustably create a seal between the housing and the outer gerotor.

16. The system of claim **15**, wherein:

the outer gerotor includes at least one strengthening band,

the adjustable sealing structure is configured to receive the strengthening band, and

the seal is located between the housing and the strengthening band.

17. The system of claim **16**, wherein:

the adjustable sealing structure includes at least one groove having a gap configured to receive the strengthening band,

the at least one groove includes a first seat disposed on one side of the gap and a second seat disposed on a second side of the gap,

at least one of the first seat or the second seat is actuatable towards another of the first seat or the second seat to reduce the gap, and

the system is configured such that the actuation of at least one of the first seat or the second seat forces the first seat and the second seats against the strengthening band.

18. The system of claim **17**, wherein at least one of the first seat or the second seat includes tubing that is configured to receive fluid to actuate towards the other of the first seat or the second seat.

19. The system of claim **1**, wherein:

the outer gerotor includes at least one gerotor chamber face inlet port that is configured to rotate with the outer gerotor, and

the at least one gerotor chamber face inlet port is configured to be opened during an intake of fluids into the outer gerotor chamber and to be closed during an exhaust of fluids out of the outer gerotor chamber.

20. The system of claim **19**, further comprising:

an inner gerotor at least partially disposed within the outer gerotor chamber,

wherein:

the at least one gerotor chamber face inlet port is in fluid communication with a face inlet port of the housing and the outer gerotor chamber during the intake of fluids into the outer gerotor chamber, and

the at least one gerotor chamber face inlet port is blocked on one side by the housing and on another side by the inner gerotor during the exhaust of fluids out of the outer gerotor chamber.

21. The system of claim **1**, further comprising:

an inner gerotor at least partially disposed within the outer gerotor chamber.

22. The system of claim **1**, wherein the single movable slider is configured to provide a different ratio of compression or a different ratio of expansion at each location along the maximum length of circumferential movement.

23. The system of claim **1**, wherein the system is configured such that movement of the single movable slider alone adjusts the ratio of compression in the outer gerotor chamber.

24. The system of claim **1**, wherein the system is configured such that the movement of the movable slider does not introduce dead space into the system.

25. A system, comprising:

a housing; and

an outer gerotor at least partially disposed in the housing and at least partially defining an outer gerotor chamber,

wherein:

the housing includes a single movable slider configured to adjust a ratio of compression or expansion in the outer gerotor chamber by modifying a compression or expansion area in the outer gerotor chamber,

the single movable slider has a maximum length of circumferential movement with respect to a circumferential wall of the housing, and

the system is configured such that the circumferential movement of the slider over the maximum length does not modify a radial distance between the single movable slider and the circumferential wall of the housing.

26. The system of claim **25**, further comprising:

an inner gerotor at least partially disposed within the outer gerotor chamber.

27. A system, comprising:

a housing; and

an outer gerotor at least partially disposed in the housing and at least partially defining an outer gerotor chamber,

wherein:

the housing includes a movable slider configured to adjust a ratio of compression or expansion in the outer gerotor chamber by modifying a compression or expansion area in the outer gerotor chamber,

the single movable slider has a maximum length of circumferential movement with respect to a circumferential wall of the housing, and

the single movable slider is configured to provide a different ratio of compression or a different ratio of expansion at each location along the maximum length of circumferential movement.

28. The system of claim **27**, further comprising:

an inner gerotor at least partially disposed within the outer gerotor chamber.

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