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(54) **CYLINDRICAL AIR GUIDE IN A TURBINE ENGINE**

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***F02C 7/32*** (2006.01)

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CPC ................ ***F01D 25/18*** (2013.01); ***F02C 7/32*** (2013.01); *F05D 2260/609* (2013.01)

(58) **Field of Classification Search**
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USPC ........................................... 55/409, 413, 416
See application file for complete search history.

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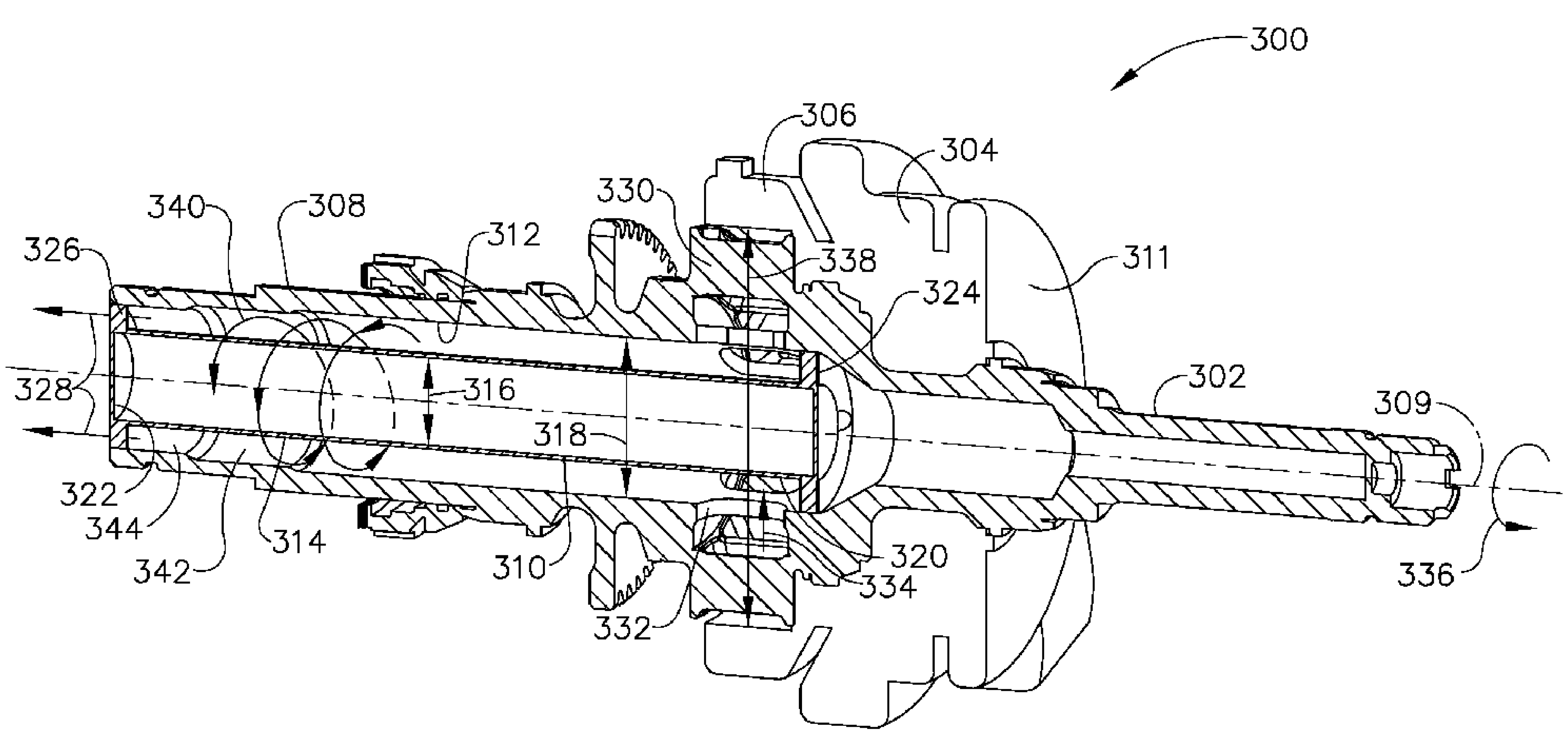
(57) **ABSTRACT**

An air/oil separator for a gas turbine engine includes a drive shaft having a central axis extending in an axial direction, a free vortex chamber mounted radially around the drive shaft, a separation chamber coupled with the free vortex chamber in the axial direction opposite to the drive shaft, and a rotatable outlet shaft radially rotatable and having an inlet end coupled with the separation chamber opposite to the free vortex chamber, an outlet end, and a hollow interior chamber therebetween. The hollow interior chamber has an inner circumference extending in the axial direction a cylindrical air guide extending coaxially therein. The cylindrical air guide has a nonporous cylindrical main body, an upstream end fixedly coupled with the inlet end of the rotatable outlet shaft, and a downstream end coaxially disposed within the outlet end of the rotatable outlet shaft.

**20 Claims, 4 Drawing Sheets**



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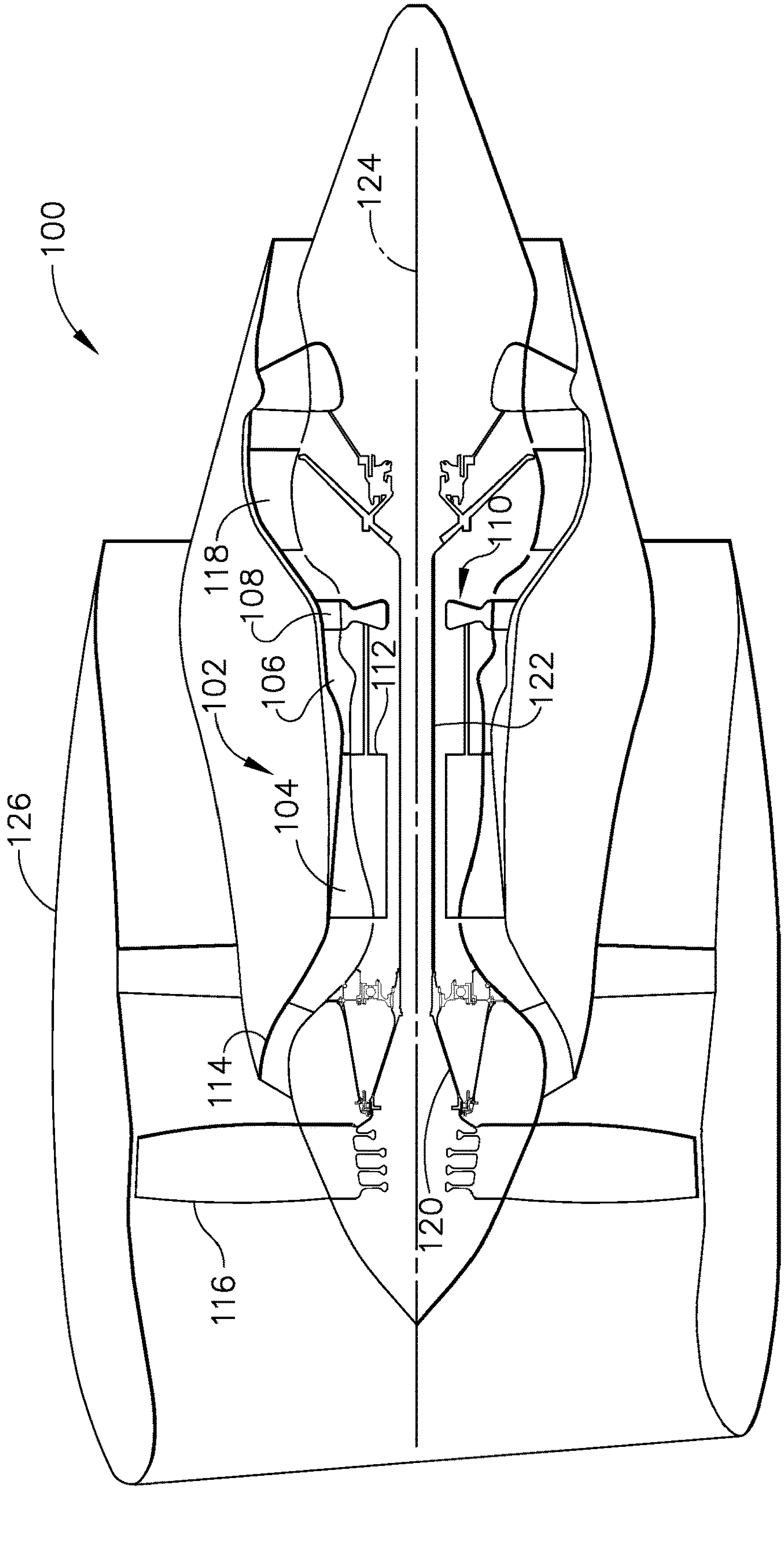


FIG. 1

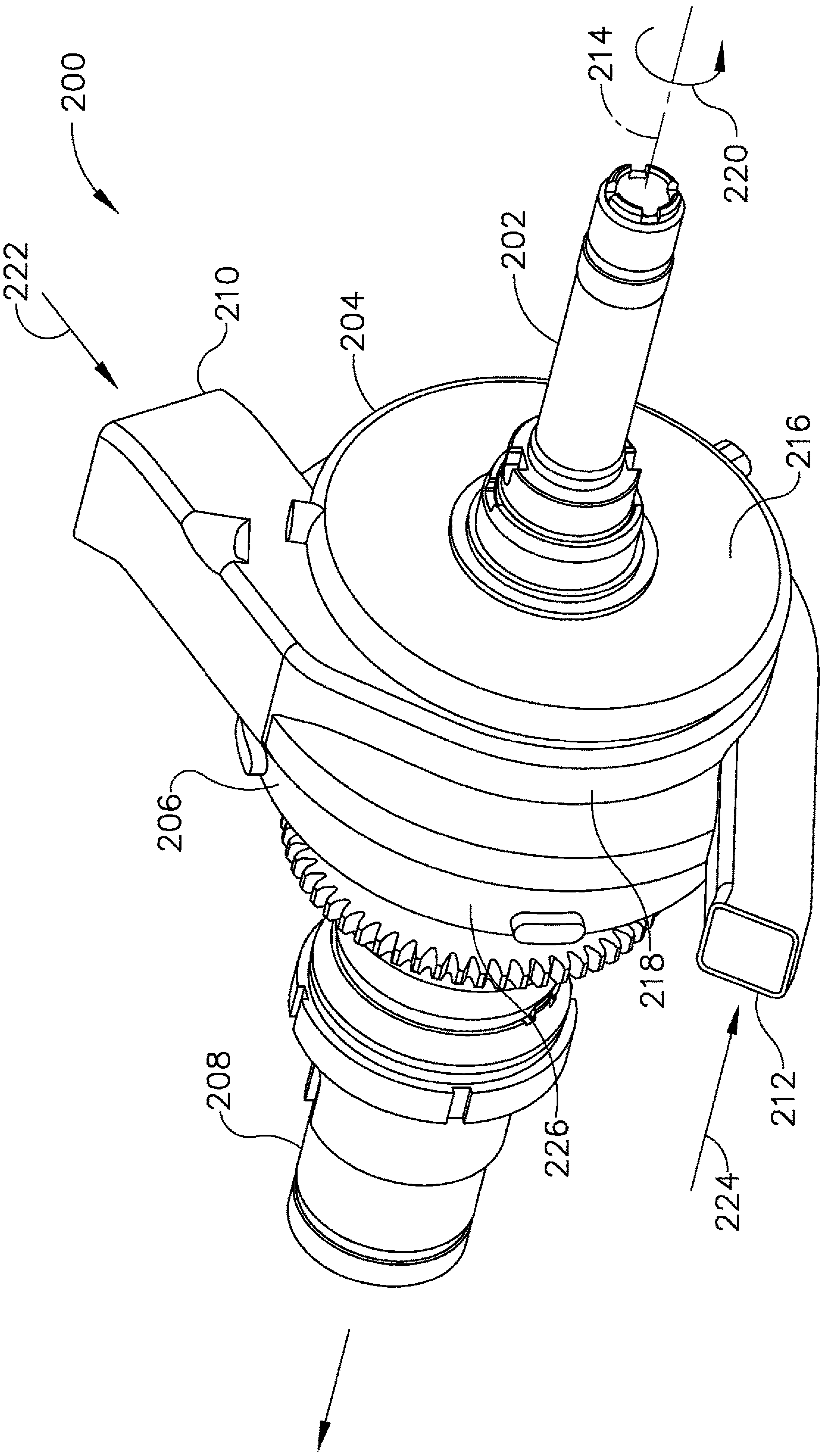


FIG. 2

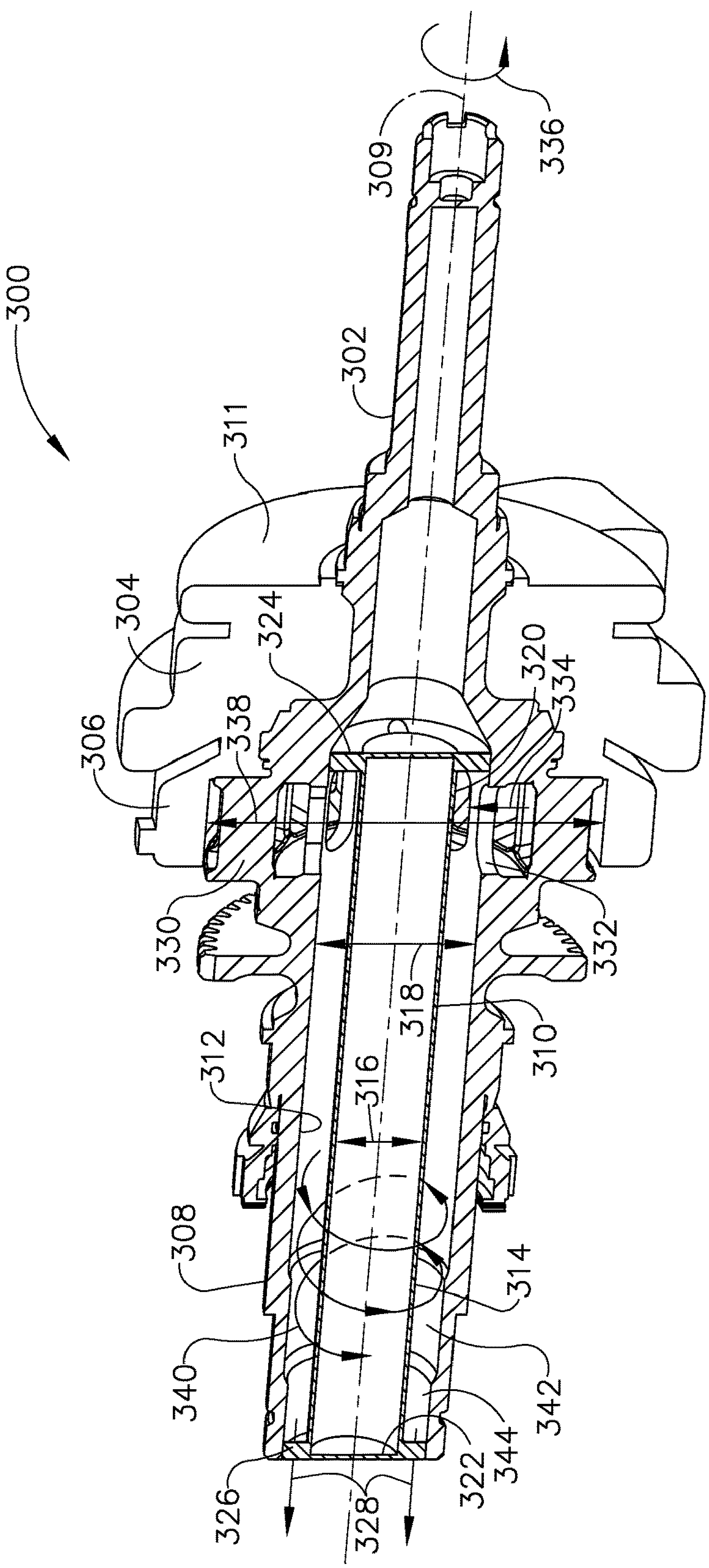
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FIG. 3

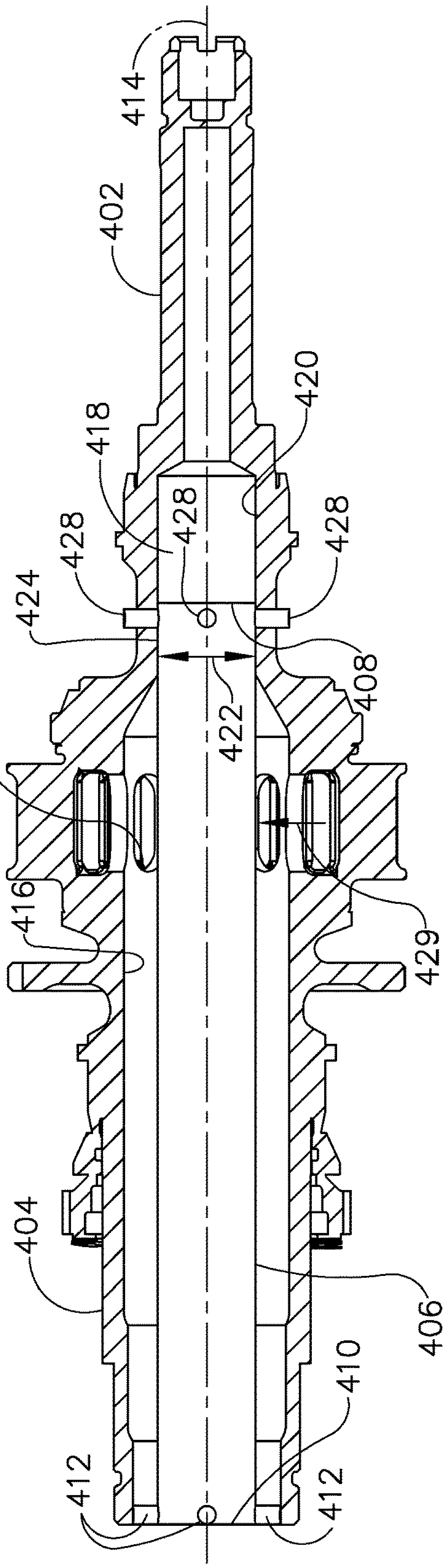
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FIG. 4

# CYLINDRICAL AIR GUIDE IN A TURBINE ENGINE

## BACKGROUND

The field of the disclosure relates generally to gas turbine engines and, more particularly, to an air guide to control air flow from an air/oil separator in a gas turbine engine.

Gas turbine engines typically include an air/oil separator (AOS), also known as deoilers, as part of a vented sump system to separate air that is intermixed with oil in the bearing compartments and gearboxes of the gas turbine engine. Separated air exits the AOS through a vent line in a high-speed free, that is, unforced-rotational, vortex in a hollow exit shaft. The exiting air travels at an axial speed downstream a length of the hollow shaft, while also swirling at a radial, or rotational, flow velocity around an inner circumference of the exit shaft. In the free vortex, the rotational flow velocity of the air is inversely proportional to the distance from the axial center of the hollow shaft, and thus the rotational velocity of the air traveling down the central axis of the hollow shaft is significantly higher in the rotational velocity of the air traveling near the inner circumference of the hollow shaft. This difference in rotational velocities in the free vortex creates air friction, which results in undesirable loss in pressure down the shaft.

At least some conventional AOS venting systems have been known to place baffles down the central axis of the hollow shaft in a radial cross configuration, thereby dividing the hollow shaft into four radial quadrants down its length. This approach, however, creates miniature vortexes in each of the quadrants, which are subject to undesirable pressure loss from vortex air friction. Additionally, the irregular radial shape is another source of air friction that contributes to pressure loss.

## BRIEF DESCRIPTION

In one embodiment, an air/oil separator for a gas turbine engine includes a drive shaft having a central axis extending in an axial direction, a free vortex chamber mounted radially around the drive shaft, a separation chamber coupled with the free vortex chamber in the axial direction opposite to the drive shaft, and a rotatable outlet shaft having an inlet end, an outlet end, and a hollow interior chamber therebetween. The hollow interior chamber has an inner circumference extending in the axial direction, the inlet end coupled with the separation chamber opposite to the free vortex chamber, and the rotatable outlet shaft radially rotatable around the axial direction. The air/oil separator further includes a cylindrical air guide having a nonporous cylindrical main body with an outer circumference extending coaxially within the inner circumference of the hollow interior chamber of the rotatable outlet shaft. The cylindrical air guide further includes an upstream end fixedly coupled with the inlet end of the rotatable outlet shaft, and a downstream end coaxially disposed within the outlet end of the rotatable outlet shaft.

In another embodiment, a method for discharging exhaust air from air/oil separator of a gas turbine engine, the air/oil separator having a separation chamber and a hollow rotatable outlet shaft, includes venting exhaust air from the separation chamber into a first end of the hollow rotatable outlet shaft through air discharge slots in a direction substantially perpendicular to a longitudinal central axis of the hollow rotatable outlet shaft. The air discharge slots provide air communication between the separation chamber and the rotatable outlet shaft. The method further includes rotating the rotatable outlet shaft around the longitudinal central axis, and guiding airflow of the exhaust air through the hollow rotatable outlet shaft, from a first end of the shaft to a second opposing end thereof, radially around a cylindrical air guide coaxially mounted within the rotating outlet shaft about the longitudinal central axis, while preventing airflow from reaching the central longitudinal axis.

In yet another embodiment, a gas turbine engine includes a core engine, a compressor, a high pressure turbine, a low pressure turbine, a combustor assembly, a fan, a rotor, and an air/oil separator. The air/oil separator includes a drive shaft having a central axis extending in an axial direction. The drive shaft is coupled with the gas turbine engine rotor. The air/oil separator further includes a free vortex chamber mounted radially around the drive shaft, a separation chamber coupled with the free vortex chamber in the axial direction opposite to the drive shaft, and a rotatable outlet shaft having an inlet end, an outlet end, and a hollow interior chamber therebetween. The hollow interior chamber has an inner circumference extending in the axial direction, the inlet end coupled with the separation chamber opposite to the free vortex chamber, and the rotatable outlet shaft radially rotatable around the axial direction. The air/oil separator further includes a cylindrical air guide having a nonporous cylindrical main body with an outer circumference extending coaxially within the inner circumference of the hollow interior chamber of the rotatable outlet shaft. The cylindrical air guide further includes an upstream end fixedly coupled with the inlet end of the rotatable outlet shaft, and a downstream end fixedly coupled with the outlet end of the rotatable outlet shaft.

## BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

FIGS. **1-4** show example embodiments of the method and system described herein.

FIG. **1** illustrates a sectional schematic view of a gas turbine engine.

FIG. **2** illustrates an oblique perspective view of an air/oil separator.

FIG. **3** illustrates a sectional perspective view of an air/oil separator for a gas turbine engine, in which an aspect of the methods and systems described herein may be employed in accordance with one embodiment of the present disclosure.

FIG. **4** illustrates a sectional schematic view of an exemplary embodiment of an air/oil separator for a gas turbine engine.

Although specific features of various embodiments may be shown in some drawings and not in others, this is for convenience only. Any feature of any drawing may be referenced and/or claimed in combination with any feature of any other drawing.

Unless otherwise indicated, the drawings provided herein are meant to illustrate features of embodiments of the disclosure. These features are believed to be applicable in a wide variety of systems comprising one or more embodiments of the disclosure. As such, the drawings are not meant to include all conventional features known by those of ordinary skill in the art to be required for the practice of the embodiments disclosed herein.

## DETAILED DESCRIPTION

In the following specification and the claims, reference will be made to a number of terms, which shall be defined to have the following meanings.

The singular forms "a", "an", and "the" include plural references unless the context clearly dictates otherwise.

"Optional" or "optionally" means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where the event occurs and instances where it does not.

Approximating language, as used herein throughout the specification and claims, may be applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as "about", "approximately", and "substantially", are not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value. Here and throughout the specification and claims, range limitations may be combined and/or interchanged, such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise.

The following detailed description illustrates embodiments of the disclosure by way of example and not by way of limitation. It is contemplated that the disclosure has general application to increasing recovered pressure from airflow into a bleed cavity of a gas turbine engine.

The following description refers to the accompanying drawings, in which, in the absence of a contrary representation, the same numbers in different drawings represent similar elements.

FIG. **1** is a schematic illustration of an exemplary gas turbine engine **100**. Gas turbine engine **100** includes a gas generator or core engine **102** that includes a high pressure compressor (HPC) **104**, a combustor assembly **106**, and a high pressure turbine (HPT) **108** in an axial serial flow relationship on a core engine rotor **110** rotating about a core engine shaft **112**. Gas turbine engine **100** also includes a low pressure compressor **114** and a fan **116**, and a low pressure turbine **118** arranged in an axial flow relationship on an engine rotor **120** by power engine shaft **122**.

During operation, air flows along a central axis **124**, and compressed air is supplied to high pressure compressor **104**. Highly compressed air is then delivered to combustor assembly **106**. Exhaust gas flow from combustor assembly **106** drives turbine **108**, and turbine **108** drives engine rotor **120**, in addition to low pressure compressor **114** and fan **116**. Gas turbine engine **100** also includes a containment case **126** for low pressure compressor **114** and fan **116**.

Furthermore, additional and/or different elements not shown may be contained in, or coupled to the elements shown in FIG. **1**, and/or certain illustrated elements may be absent. In some examples, the functions provided by the illustrated elements could be performed by less than the illustrated number of components or even by a single element.

FIG. **2** illustrates an embodiment of an air/oil separator (AOS) **200** for a gas turbine engine (e.g., gas turbine engine **100**, FIG. **1**). In an exemplary embodiment, AOS **200** is a rotating free vortex configuration, and includes a drive shaft **202**, a free vortex chamber **204**, a separation chamber **206**, and a rotatable outlet shaft **208**. Free vortex chamber **204** includes a vent inlet **210** and a scavenging inlet **212**.

Drive shaft **202** extends in an axial direction down central axis **214** and is coupled to a forward portion **216** of free vortex chamber **204**. Separation chamber **206** couples with free vortex chamber **204** along central axis **214** opposite drive shaft **202**. Rotatable outlet shaft **208** couples with separation chamber **206** along central axis **214** opposite free vortex chamber **204**. Vent inlet **210** and scavenging inlet **212** approach free vortex chamber **204** tangentially to an outer circumference **218** of free vortex chamber **204**, and in a direction of rotation **220** of rotatable outlet shaft **208**.

In operation, air-oil mixtures flow into vent inlet **210** from direction **222**, and into scavenging inlet **212** from direction **224**, and the two air-oil mixtures are combined at high rotational speeds within free vortex chamber **204** around drive shaft **202**. The rotating air-oil mixture proceeds from free vortex chamber **204** into separation chamber **206** and encounters rotating separator vanes (see element **330**, FIG. **3**), which steer encountered oil droplets from the combined mixture radially toward an outer wall **226** of separation chamber **206** by centrifugal action of rotating separator vanes. Once reaching outer wall **226**, the radially steered oil can be collected and fed back into the engine as desired. In an exemplary embodiment, AOS **200** can be integrated axially or radially with a gearbox drive shaft, a low pressure turbine shaft or other suitable rotating components shown in FIG. **1**.

FIG. **3** illustrates an exemplary embodiment of an AOS **300** for a gas turbine engine (e.g., gas turbine engine **100**, FIG. **1**). AOS **300** is similar to AOS **200** (FIG. **2**) in external construction and overall function. In an aspect of the embodiment, AOS **300** is also a rotating free vortex configuration, and similarly includes a drive shaft **302**, a free vortex chamber **304**, a separation chamber **306**, and a rotatable outlet shaft **308**.

Drive shaft **302** extends in an axial direction down central axis **309** and is coupled to a forward portion **311** of free vortex chamber **304**. Separation chamber **306** couples with free vortex chamber **304** along central axis **309** on a side of free vortex chamber (not numbered) opposite drive shaft **302**. Rotatable outlet shaft **308** couples with separation chamber **306** along central axis **309** on a side (not numbered) of separation chamber **306** opposite free vortex chamber **304**. Rotatable outlet shaft **308** includes a cylindrical air guide **310** disposed along central axis **309** within an inner circumference **312** of rotatable outlet shaft **308**. Cylindrical air guide **310** includes a nonporous outer wall **314** having an outer diameter **316**. Inner circumference **312** of rotatable outlet shaft **308** has a diameter **318** that is greater than diameter **316** of cylindrical air guide **310**.

Cylindrical air guide **310** further includes an upstream end **320** and a downstream end **322**. Nonporous outer wall **314** of cylindrical air guide **310** is cylindrically shaped, and runs substantially parallel to inner circumference **312** of rotatable outlet shaft **308** from upstream end **320** to downstream end **322**. In this exemplary embodiment, upstream end **320** of cylindrical air guide **310** is fixedly attached to inner circumference **312** of rotatable outlet shaft **308**, between free vortex chamber **304** and separation chamber **306**, by an upstream mount **324**. Upstream mount **324** is ring-shaped or disc-shaped, is nonporous and extends between cylindrical air guide **310** and rotatable outlet shaft **308**. Upstream mount **324** prevents airflow between cylindrical air guide **310** and rotatable outlet shaft **308** from moving upstream toward drive shaft **302**.

In the exemplary embodiment, downstream end **322** of cylindrical air guide **310** is not fixedly attached to inner circumference **312** of rotatable outlet shaft **308**, and is held coaxially with inner circumference **312** by the cantilevered attachment of upstream end **320** to inner circumference **312** by upstream mount **324**. In an alternative embodiment, downstream end **322** is fixedly attached to inner circumference **312** of rotatable shaft **308** by a mounting fastener **326**. In one embodiment, mounting fastener **326** is a single bolt passing through downstream end **322** and across the entirety of inner diameter **318**. In further alternative embodiments, mounting fastener **326** includes a plurality of connectors, or a single mounting spider configuration, fixedly attaching nonporous outer wall **314** to inner circumference **312**. Mounting fastener **326** is configured to allow airflow between cylindrical air guide **310** and rotatable outlet shaft **308** while exiting rotatable outlet shaft **308** in an exit direction **328**.

In operation, an air-oil mixture is injected into free vortex chamber **304** through a vent inlet (see element **210**, FIG. **2**) and a scavenging inlet (see element **212**, FIG. **2**), and the combined air-oil mixture is rotated together at high speeds (e.g. 12,000 rpm or greater) to create a free vortex phenomenon within free vortex chamber **304**. The free vortex in free vortex chamber **304** allows relatively large oil particles to be separated from the air/air-oil mixture and propelled radially outward toward an outer circumference (e.g., outer circumference **218**, FIG. **2**) of free vortex chamber **304** for collection and redistribution. The "large" oil particles are those having sufficient size such that they can be moved outwardly by the force of the free vortex alone within free vortex chamber **304**. The free vortexing air-oil mixture then flows into separation chamber **306** through a passage (not shown) between free vortex chamber **304** and separation chamber **306**, where a plurality of rotating separator vanes **330** remove smaller oil particles from the mixture, as described above with respect to FIG. **2**. The "small" oil particles are those having sufficient size such that they can condense on rotating separator vanes **330** and then be moved outwardly by centrifugal force of the spinning vanes. Substantially oil-free exhaust air is then forced from separation chamber **306** through air discharge slots **332** in rotatable outlet shaft **308** in a radial direction **334**. Air discharge slots **332** allow air communication between rotatable outlet shaft **308** and separation chamber **306**.

In further operation, rotatable outlet shaft **308** and rotating separator vanes **330** rotate in a rotational direction **336** at a significant percentage of the rotational speed of the core engine rotor about the core engine shaft (e.g., elements **110**, **112**, respectively, FIG. **1**). Air flowing into rotatable outlet shaft **308** from air discharge slots **332** rotates around central axis **309**, at a percentage of the rotational speed of rotatable outlet shaft **308**, due to air friction with rotating inner circumference **312** of rotatable outlet shaft **308**. Upstream mount **324** and mounting fastener **326** fixedly couple cylindrical air guide **310** to rotatable outlet shaft **308** such that cylindrical air guide **310** rotates at the same rotational speed as rotatable outlet shaft **308**.

In an exemplary embodiment, an inner diameter **338** of separation chamber **306** is greater than inner diameter **318** of rotatable outlet shaft **308**, and therefore rotational speed of air entering rotatable outlet shaft **308** is greater than the rotational speed of the air in separation chamber **306**. The rotation of the swirling air entering rotatable outlet shaft **308** is faster as the air gets closer to central axis **309**. This relative acceleration of air with respect to smaller radii is what is known as the free vortexing phenomenon that airflow exhibits within cylindrical bodies.

In practice, cylindrical airflow through AOS **300** experiences a "tornado" effect, where the rotational velocity of air near central axis **309** can be seen to be more than five times greater than the rotational velocity of air entering rotatable outlet shaft **308** in direction **334**. At the typical rotational speed of AOS **300** utilized in operation, for example, the rotational velocity of free vortexing air along central axis **309** within rotatable outlet shaft **308** can reach Mach **1** speeds, and thereby result significant in undesirable pressure losses.

Cylindrical air guide **310** is thus configured to create a smaller diameter (i.e., outer diameter **316**), coaxial shaft within a larger shaft (i.e. rotatable outlet shaft **308** having inner diameter **318**), thereby creating an annular flow path **340** through outlet shaft **308** around cylindrical air guide **310**. Cylindrical air guide **310** prevents airflow from reaching central axis **309**, and therefore also limits the difference in rotational velocities between airflow near inner circumference **312** and airflow near nonporous outer wall **314**. By limiting this difference, air friction from the free vortex phenomenon is significantly reduced, and therefore the loss in pressure from upstream end **320** to downstream end **322** is also significantly reduced. In practice, air friction created near nonporous outer wall **314** of cylindrical air guide **310** is considerably less than the air friction known to be created at central axis **309** by the free vortex phenomenon, without the air guide present.

In an aspect of the embodiment, outer diameter **316** and inner diameter **318** are sized such that the annular, radial cross sectional area (not shown) of available airflow between the diameters is substantially equivalent to the radial cross sectional area of an outlet shaft of a conventional AOS. Too much of a decrease in the cross-sectional area of available airflow within the outlet shaft can also lead to pressure loss from having the same volume of airflow pass through a smaller opening. By increasing the inner diameter (i.e., inner diameter **318**) of the outlet shaft (i.e., rotatable outlet shaft **308**) to compensate for the loss of radial sectional area now centrally occupied by cylindrical air guide **310**, a consistent radial cross-sectional area can be maintained. In an exemplary embodiment, inner diameter **318** of rotatable outlet shaft **308** can be gradually decreased in a first region **342** and a second region **344**, respectively, of inner circumference **312** near downstream end **322**, to further guide the airflow exiting in direction **328**.

In a further aspect of the embodiment, inner circumference **312** of rotatable outlet shaft **308** and nonporous outer wall **314** of cylindrical air guide **310** are smooth surfaces, to further minimize friction from airflow near both respective surfaces. Smooth, rounded surfaces to both respective circumferences **312**, **314** will also help to reduce pressure loss through AOS **300** by allowing the airflow to more easily transition the substantially ninety degree turn from direction **334** at upstream end **320**, to direction **328** at downstream end **322**. In an exemplary embodiment, downstream end **322** of cylindrical air guide **310** is aerodynamically shaped to further encourage a smooth exit to the airflow direction **328**.

In a still further aspect of the embodiment, cylindrical air guide **310** has a hollow interior to avoid an unnecessary increase in the weight of AOS **300**. For the same length, a cylindrical air guide according to the present embodiments weighs less than the conventional cross-shaped baffle, when the thickness of the cylinder wall is the same as the thickness of the spokes in the conventional cross-shaped baffle. Cylindrical air guide **310** therefore uses less material, and the cylindrical shape is easier to fabricate than the conventional cross-shape.

FIG. **4** illustrates an alternative exemplary embodiment of an AOS **400** for a gas turbine engine (e.g., gas turbine engine **100**, FIG. **1**). AOS **400** is similar to AOS **300** (FIG. **3**) in construction and overall function, and differs primarily from AOS **300** with respect to how upstream end **320** of cylindrical air guide **310** couples with drive shaft **302**. Similar to AOS **300**, in an aspect of this alternative embodiment, AOS **400** is also a rotating free vortex configuration.

AOS **400** includes a drive shaft **402**, a rotatable outlet shaft **404**, and a cylindrical air guide **406**. Cylindrical air guide **406** includes an upstream end **408** and a downstream end **410**. Downstream end **410** fixedly attaches to rotatable outlet shaft **404** by a plurality of mounting connectors **412**, similar to the attachment of downstream end **322** with rotatable outlet shaft **308** by mounting connector **326** in FIG. **3**. Driveshaft **402**, rotatable outlet shaft **404**, and cylindrical air guide **406** extend in an axial direction along central axis **414**, and cylindrical air guide **406** is coaxially mounted within an interior circumference **416** of rotatable outlet shaft **404**.

Driveshaft **402** includes a hollow inner portion **418**. Hollow inner portion **418** includes an interior circumference **420** sized to provide an interference fit with an outer diameter **422** of cylindrical air guide **406**. In an aspect of the embodiment, outer diameter **422** of upstream end **408** securely fits within a region **424** of hollow inner portion **418** such that airflow into rotatable outlet shaft **404**, from an air discharge slot in a direction **429**, is prevented from traveling upstream into hollow inner portion **418**. In an optional configuration, upstream end **408** of cylindrical air guide **406** is alternatively, or additionally, fixedly secured to driveshaft **402** by one or more mounting connectors **428**.

In an alternative embodiment, downstream end **410** does not fixedly attach to rotatable outlet shaft **404**, and is instead cantilevered by the fixed attachment of outer diameter **422** to interior circumference **420** of hollow inner portion **418**. In this configuration, downstream end is disposed within, and maintains a coaxial coupling with, interior circumference **420** without requiring a direct mounting connection to interior circumference **420**. In an optional configuration of the alternative embodiment, downstream end is aerodynamically inwardly toward central axis **414** and in the direction of airflow exiting rotatable outlet shaft **404**.

The foregoing detailed description illustrates embodiments of the disclosure by way of example and not by way of limitation. It is contemplated that the disclosure has general application to air/oil separators and sump venting for various purposes. It is further contemplated that the methods and systems described herein may be incorporated into existing aircraft engine designs and structures.

It will be appreciated that the above embodiments that have been described in particular detail are merely example or possible embodiments, and that there are many other combinations, additions, or alternatives that may be included. The apparatus illustrated is not limited to the specific embodiments described herein, but rather, components of each may be utilized independently and separately from other components described herein. Each system component can also be used in combination with other system components.

Approximating language, as used herein throughout the specification and claims, may be applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as “about” and “substantially”, are not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value. Here and throughout the specification and claims, range limitations may be combined and/or interchanged, such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise.

While the disclosure has been described in terms of various specific embodiments, it will be recognized that the disclosure can be practiced with modification within the spirit and scope of the claims.

This written description uses examples to describe the disclosure, including the best mode, and also to enable any person skilled in the art to practice the disclosure, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

**1**. An air/oil separator for a gas turbine engine, said air/oil separator comprising:

a drive shaft having a central axis extending in an axial direction;

a free vortex chamber mounted radially around said drive shaft;

a separation chamber coupled with said free vortex chamber in the axial direction on a side of said free vortex chamber opposite to said drive shaft;

a rotatable outlet shaft having an inlet end, an outlet end, and a hollow interior chamber therebetween, said hollow interior chamber having an inner circumference extending in the axial direction, said inlet end coupled with said separation chamber on a side of said separation chamber opposite to said free vortex chamber, and said rotatable outlet shaft radially rotatable about the central axis; and

a cylindrical air guide comprising;

a nonporous cylindrical main body having a smooth, uninterrupted outer surface and an outer circumference extending coaxially within the inner circumference of said hollow interior chamber of said rotatable outlet shaft, said inner circumference having a diameter greater than a diameter of the cylindrical air guide;

an upstream end fixedly coupled with said inlet end of said rotatable outlet shaft; and

a downstream end coaxially disposed within said outlet end of said rotatable outlet shaft.

**2**. The air/oil separator of claim **1**, wherein said rotatable outlet shaft further comprises a plurality of air discharge slots disposed radially about said hollow interior chamber at said inlet end.

**3**. The air/oil separator of claim **2**, wherein said plurality of air discharge slots are configured to allow air communication between said separation chamber and said hollow interior chamber of said rotatable outlet shaft.

**4**. The air/oil separator of claim **3**, further comprising an upstream mount, wherein said upstream end of said cylindrical air guide is fixedly coupled with said inlet end of said rotatable outlet shaft by said upstream mount, and wherein said upstream mount is mounted upstream of said plurality of air discharge slots.

**5**. The air/oil separator of claim **4**, wherein said upstream mount is configured to prevent air flowing upstream of said plurality of air discharge slots within said hollow interior chamber.

**6**. The air/oil separator of claim **4**, wherein said upstream mount is disc-shaped.

**7**. The air/oil separator of claim **4**, wherein said upstream mount is ring-shaped.

**8**. The air/oil separator of claim **7**, wherein said ring-shaped upstream mount has an inner circumference and an outer circumference, said inner circumference of said ring-shaped upstream mount configured to seal said ring-shaped upstream mount to said outer circumference of said upstream end of said cylindrical air guide, and said outer circumference of said ring-shaped upstream mount configured to seal said ring-shaped upstream mount to said inner circumference of said hollow interior chamber of said rotatable outlet shaft.

**9**. The air/oil separator of claim **3**, wherein said drive shaft further comprises a hollow interior shaft opening located upstream of said plurality of air discharge slots, said hollow interior shaft opening having an inner dimension configured to allow an interference fit with said upstream end of said cylindrical air guide.

**10**. The air/oil separator of claim **9**, wherein the interference fit of said upstream end of said cylindrical air guide with said hollow interior shaft opening of said drive shaft is configured to prevent air flowing upstream of said plurality of air discharge slots within said hollow interior chamber.

**11**. The air/oil separator of claim **10**, further comprising at least one mounting connector fixedly attaching said upstream end of said cylindrical air guide to said driveshaft upstream of said plurality of air discharge slots.

**12**. The air/oil separator of claim **1**, wherein said downstream end of said cylindrical air guide is fixedly coupled with said outlet end of said rotatable outlet shaft by at least one mounting connector.

**13**. The air/oil separator of claim **12**, wherein said at least one mounting connector is configured to permit airflow from exiting said hollow interior chamber of said rotatable outlet shaft at said outlet end.

**14**. The air/oil separator of claim **1**, wherein said downstream end of said cylindrical air guide is coaxially coupled with said outlet end of said rotatable outlet shaft by cantilevered support of said upstream end fixedly coupled with said inlet end of said rotatable outlet shaft.

**15**. The air/oil separator of claim **1**, wherein said nonporous cylindrical main body comprises a cylindrical outer wall, and wherein said nonporous cylindrical main body is hollow inside of said cylindrical outer wall.

**16**. The air/oil separator of claim **1**, wherein said hollow interior chamber of said rotatable shaft comprises a plurality of interior sections having a progressively smaller interior diameter approaching the outlet end of said rotatable outlet shaft.

**17**. A method for discharging exhaust air from air/oil separator of a gas turbine engine, the air/oil separator having a separation chamber and a hollow rotatable outlet shaft, said method comprising:

venting exhaust air from the separation chamber into a first end of the hollow rotatable outlet shaft through air discharge slots in a direction substantially perpendicular to a longitudinal central axis of the hollow rotatable outlet shaft, the air discharge slots providing air communication between the separation chamber and the rotatable outlet shaft;

rotating the rotatable outlet shaft around the longitudinal central axis; and

guiding airflow of the exhaust air through the hollow rotatable outlet shaft, from the first end to a second opposing end thereof, radially around a cylindrical air guide having a smooth, uninterruptable outer surface and coaxially mounted within the rotating outlet shaft about the longitudinal central axis, while preventing airflow from reaching the central longitudinal axis.

**18**. The method of claim **17**, further comprising discharging the airflow from the second opposing end of the rotating hollow rotatable outlet shaft through a radial cross-sectional area between the rotating outlet shaft and the cylindrical air guide.

**19**. A gas turbine engine including a core engine, a compressor, a high pressure turbine, a low pressure turbine, a combustor assembly, a fan, and a rotor, said gas turbine engine comprising:

an air/oil separator comprising:

a drive shaft having a central axis extending in an axial direction, said drive shaft coupled with said gas turbine engine rotor;

a free vortex chamber mounted radially around said drive shaft;

a separation chamber coupled with said free vortex chamber in said axial direction on a side of said free vortex chamber opposite to said drive shaft;

a rotatable outlet shaft having an inlet end, an outlet end, and a hollow interior chamber therebetween, said hollow interior chamber having an inner circumference extending in the axial direction, said inlet end coupled with said separation chamber on a side of said separation chamber opposite to said free vortex chamber, and said rotatable outlet shaft radially rotatable around the axial direction; and

a cylindrical air guide comprising;

a nonporous cylindrical main body having an outer circumference extending coaxially within said inner circumference of said hollow interior chamber of said rotatable outlet shaft, said nonporous cylindrical main body having a cylindrical outer wall with a smooth, uninterrupted outer surface, and wherein said nonporous cylindrical main body is hollow inside of said cylindrical outer wall;

an upstream end fixedly coupled with said inlet end of said rotatable outlet shaft; and

a downstream end coaxially disposed within said outlet end of said rotatable outlet shaft.

**20**. The gas turbine engine of claim **19**, further comprising a gearbox, wherein said drive shaft is radially coupled with said gearbox.

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