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(54) MIXER ASSEMBLY FOR COMBUSTOR OF A GAS TURBINE ENGINE HAVING A MAIN MIXER WITH IMPROVED FUEL PENETRATION

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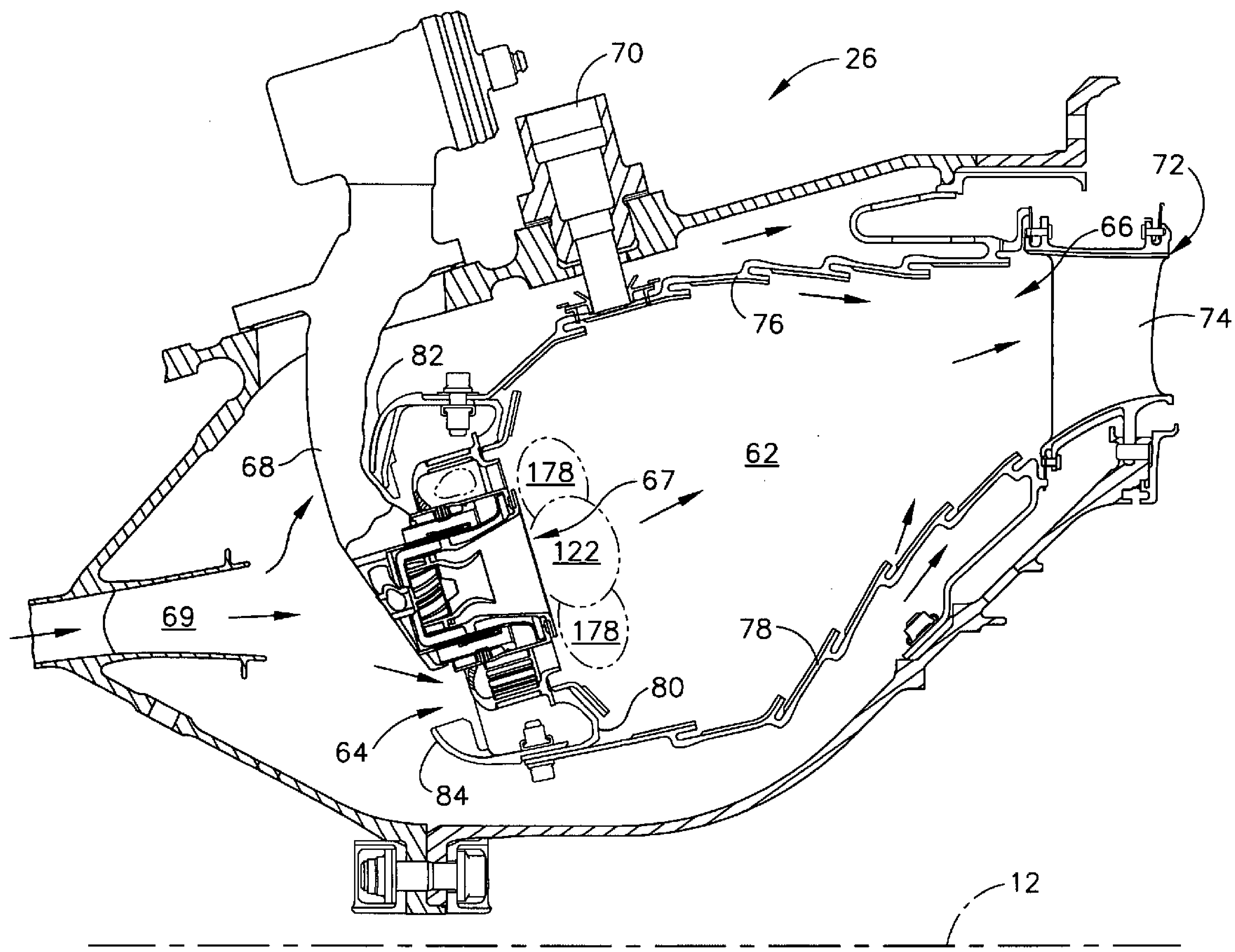
(57) **ABSTRACT**

A mixer assembly for use in a combustion chamber of a gas turbine engine includes a pilot mixer, a main mixer, and a fuel manifold positioned between the pilot mixer and main mixer. The pilot mixer includes an annular pilot housing having a hollow interior and a pilot fuel nozzle mounted in the housing and adapted for dispensing droplets of fuel to the hollow interior of the pilot housing. The main mixer includes: a main housing surrounding the pilot housing and defining an annular cavity having an upstream end and a downstream end including an upstream wall, an outer wall and an inner wall; a plurality of fuel injection ports for introducing fuel into the cavity, with the fuel injection ports being circumferentially spaced at a designated axial location of the inner wall of the annular cavity; and a swirler arrangement including at least one swirler in flow communication with the annular cavity, the swirler being incorporated into the outer wall of the annular cavity and extending from an upstream end to a downstream end, wherein each swirler of the arrangement has a plurality of vanes for swirling air traveling through such swirler to mix air and the droplets of fuel dispensed by the fuel injection ports. The main housing further includes a first plurality of passages oriented to provide air jets in a substantially axial direction into the annular cavity and a second plurality of passages oriented to provide air jets in a substantially radial direction into the annular cavity



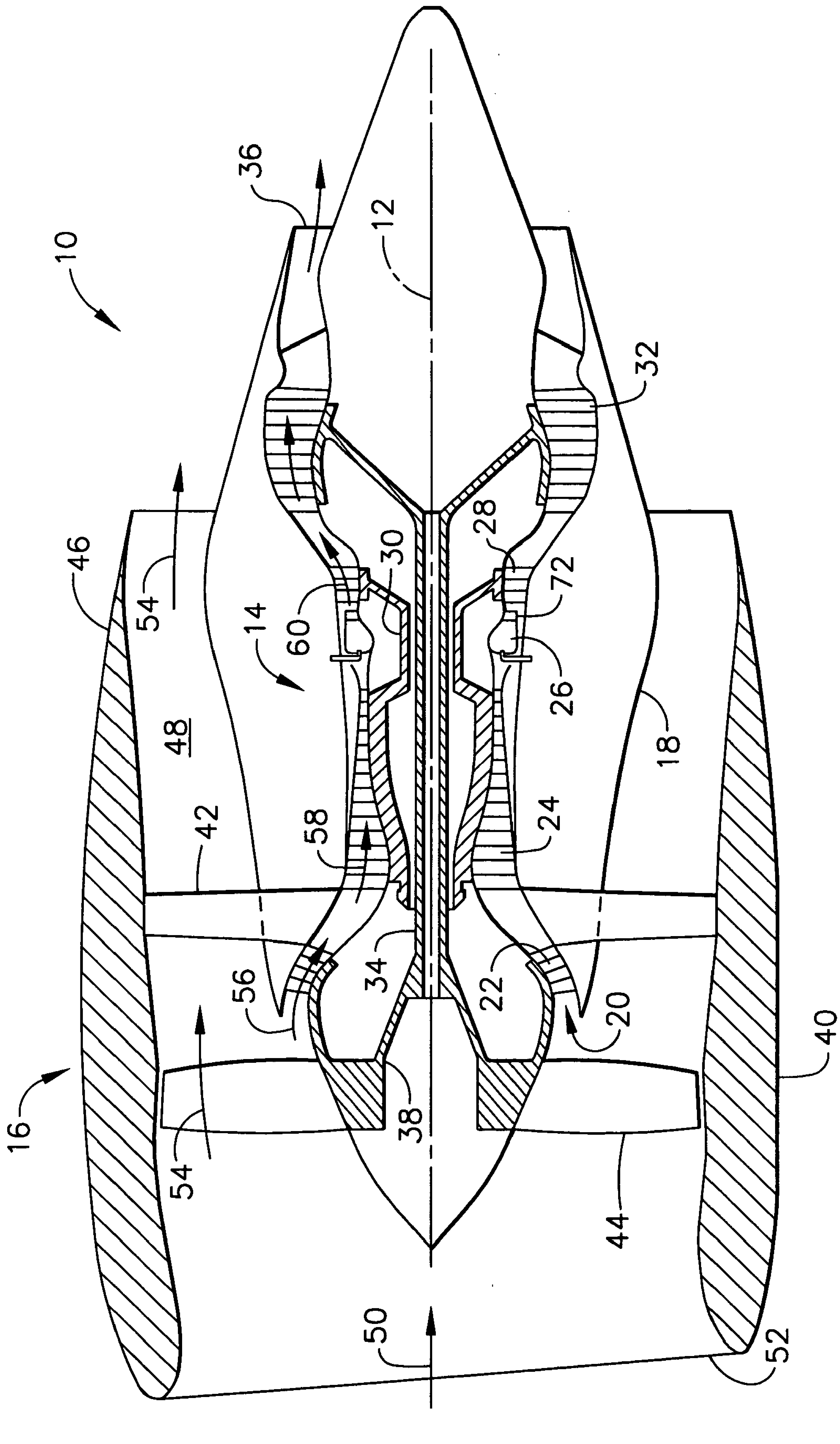

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FIG. 1

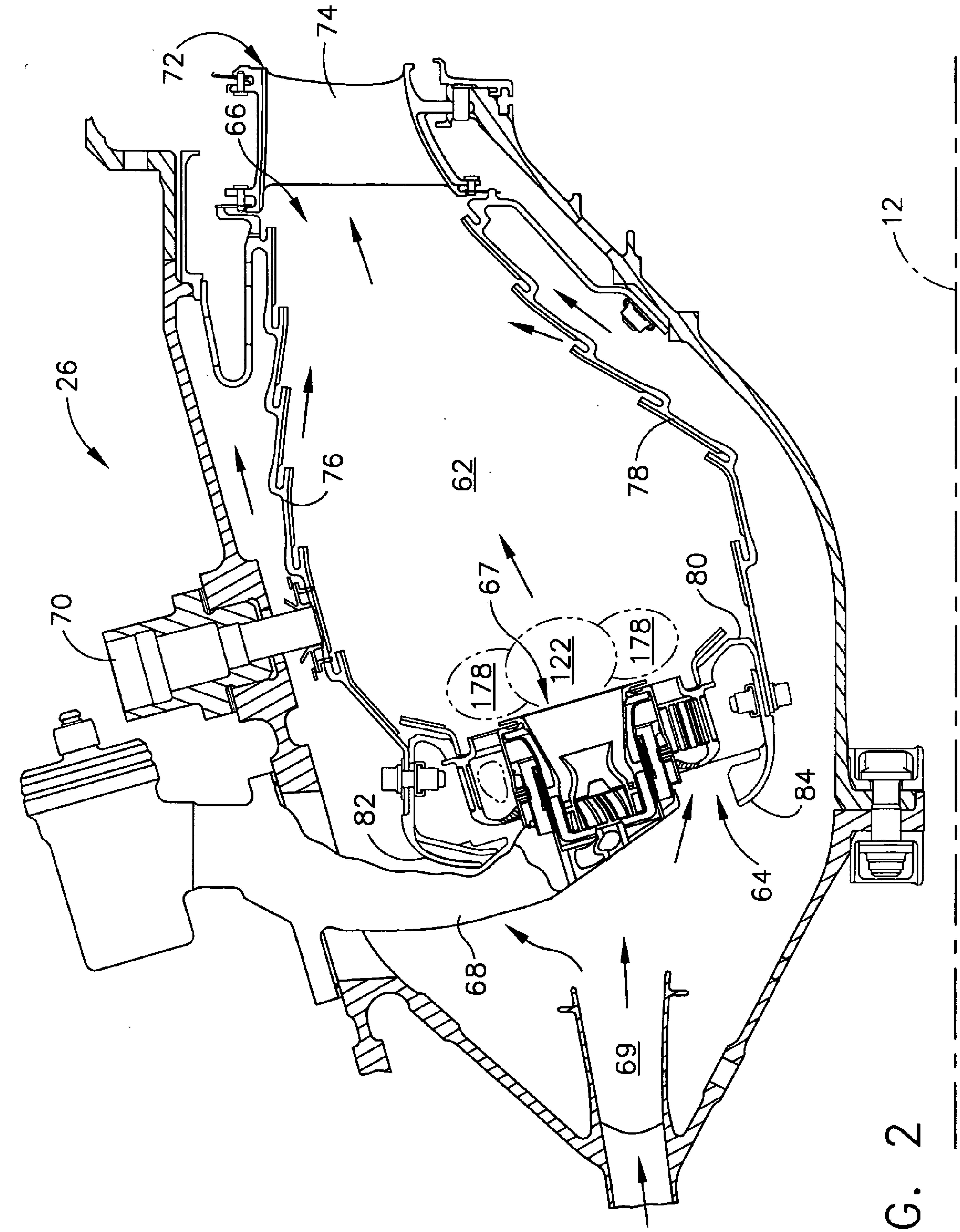

FIG. 2

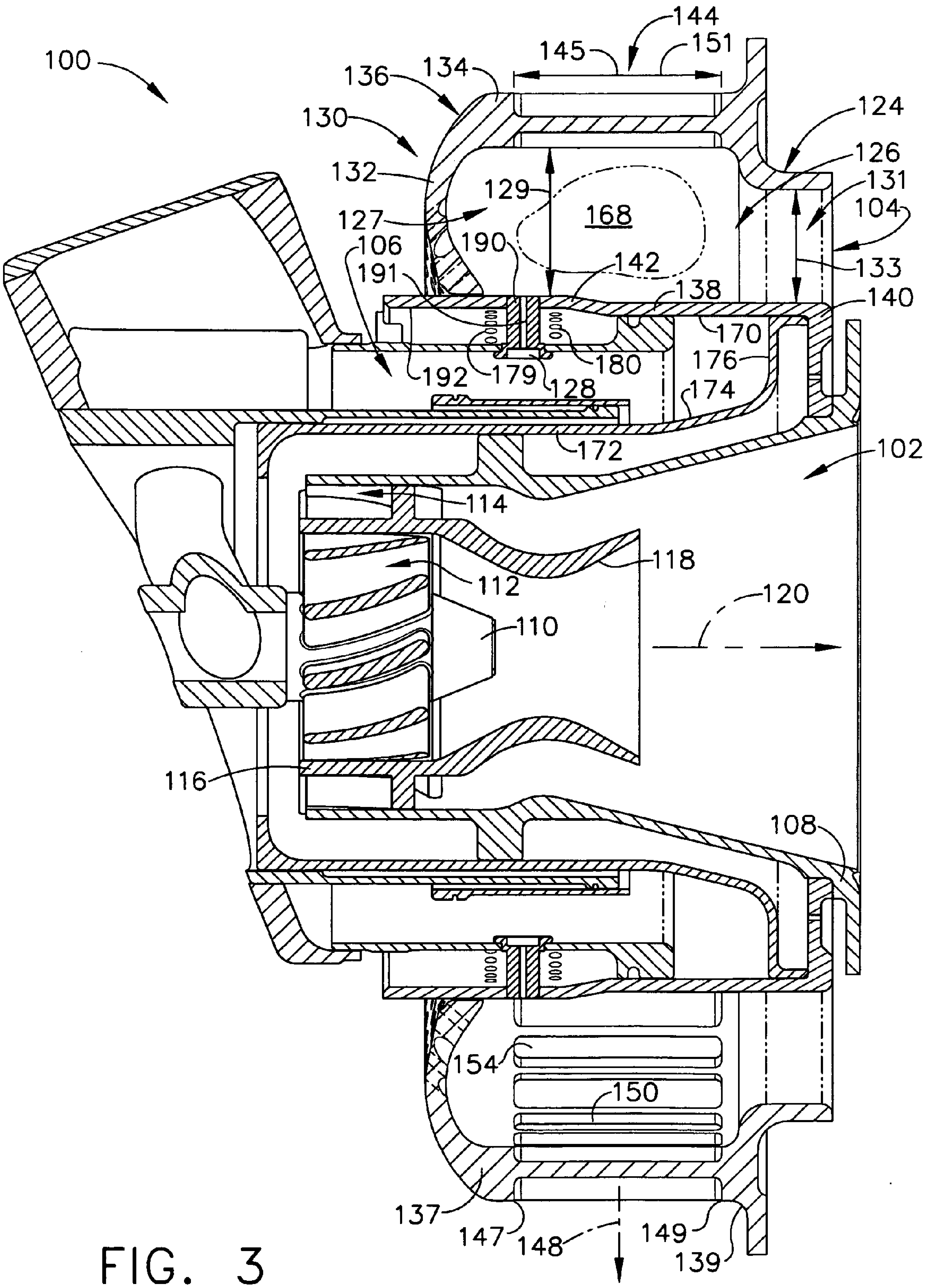
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FIG. 3

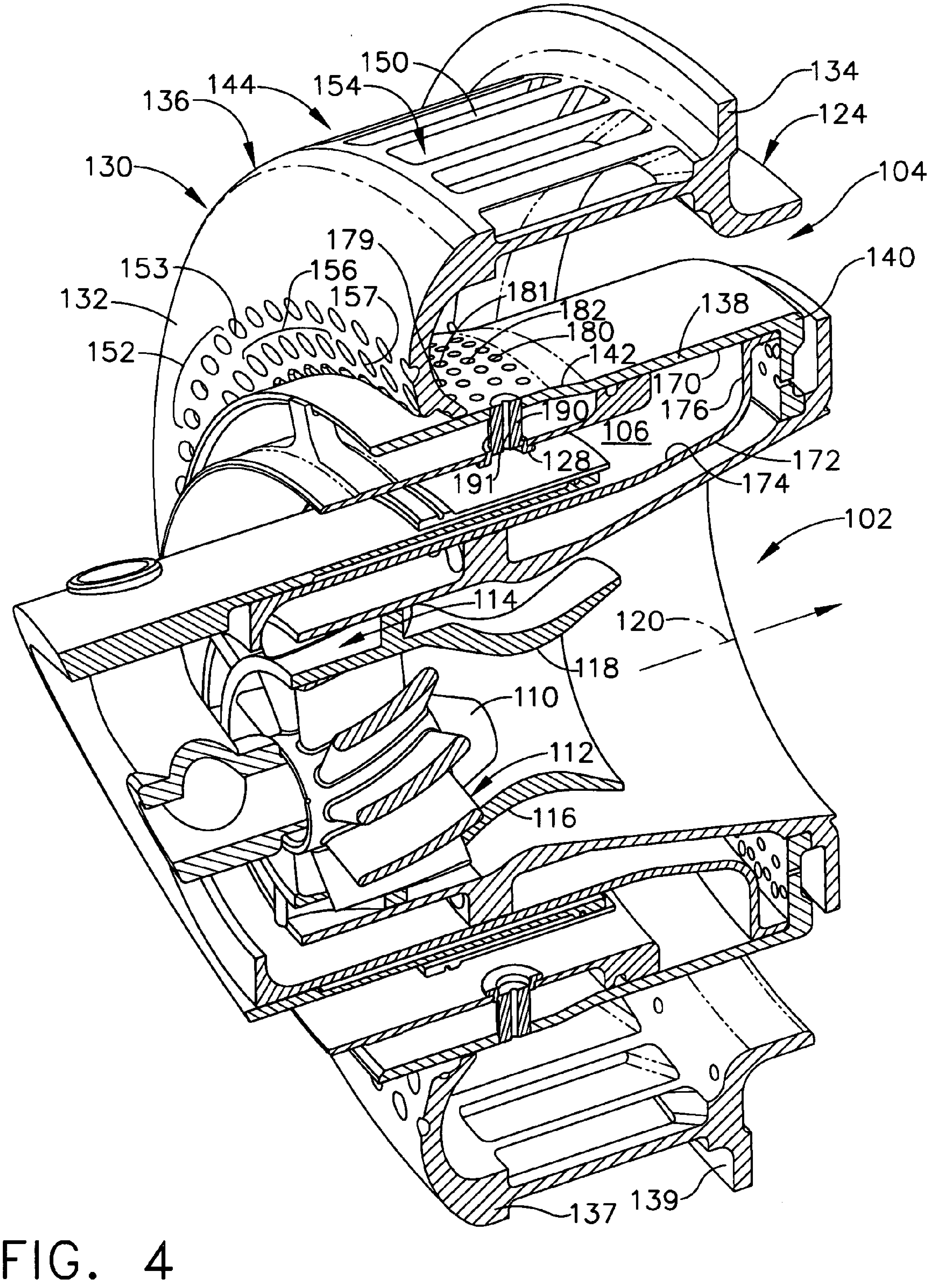
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FIG. 4

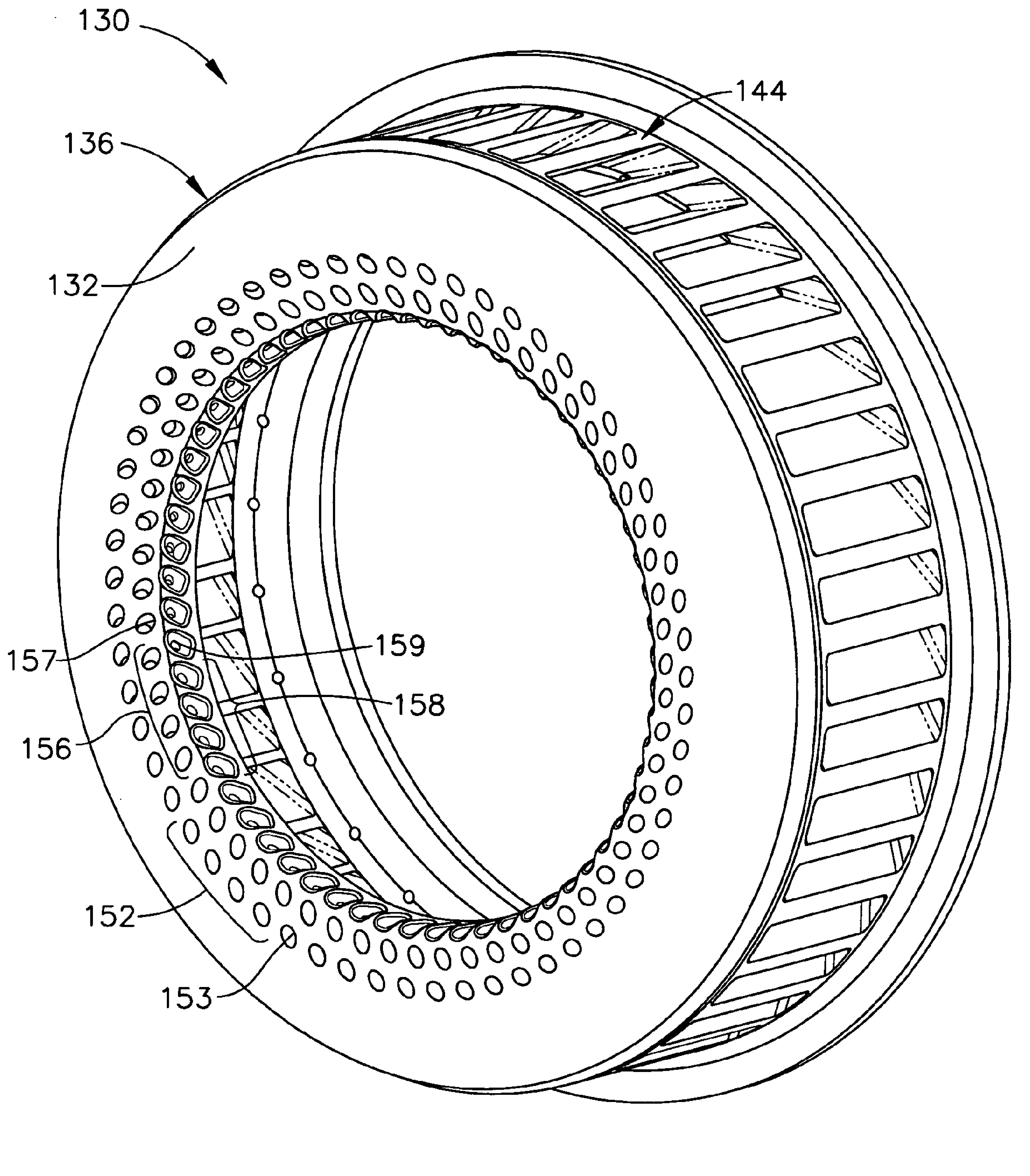

FIG. 5

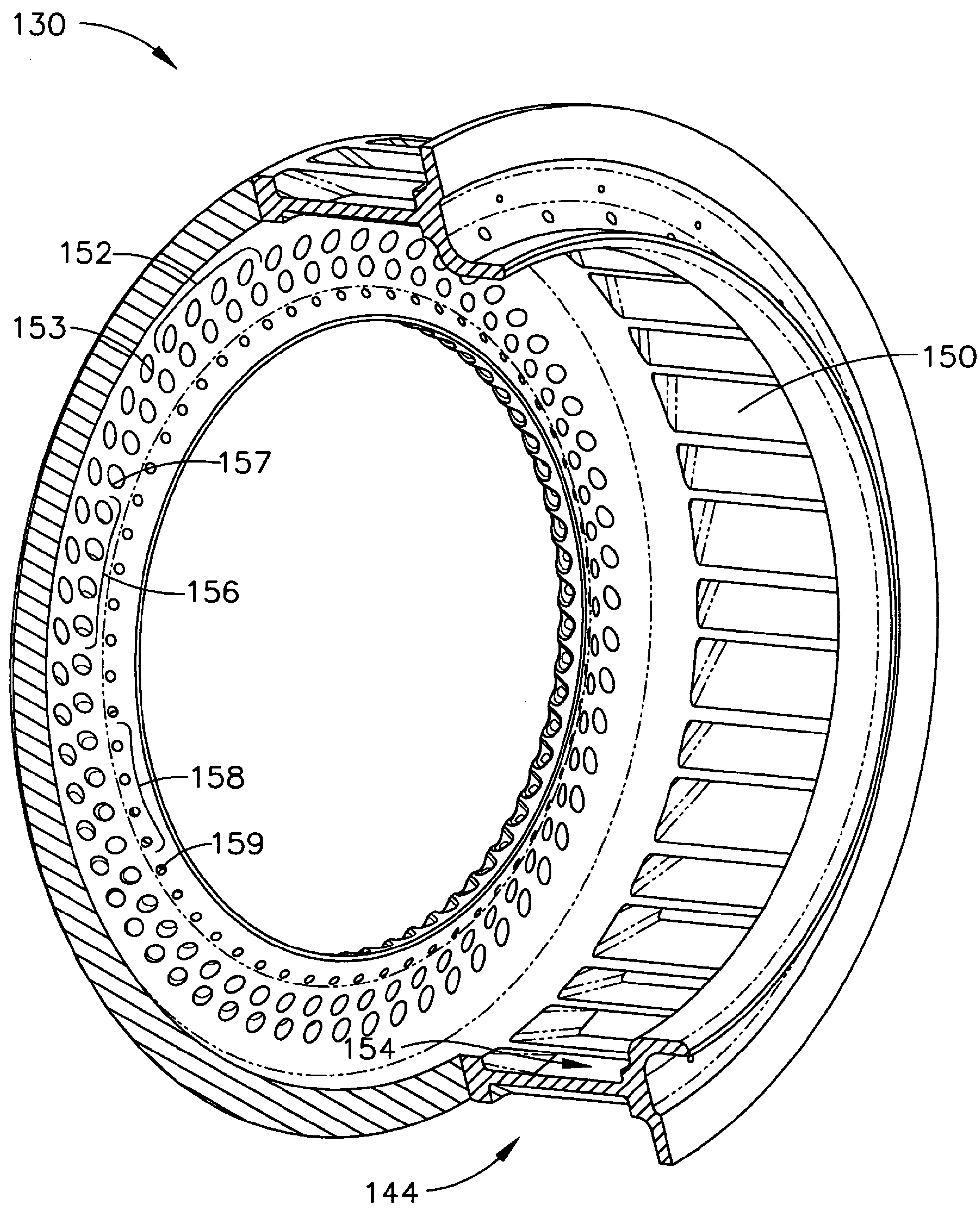

FIG. 6

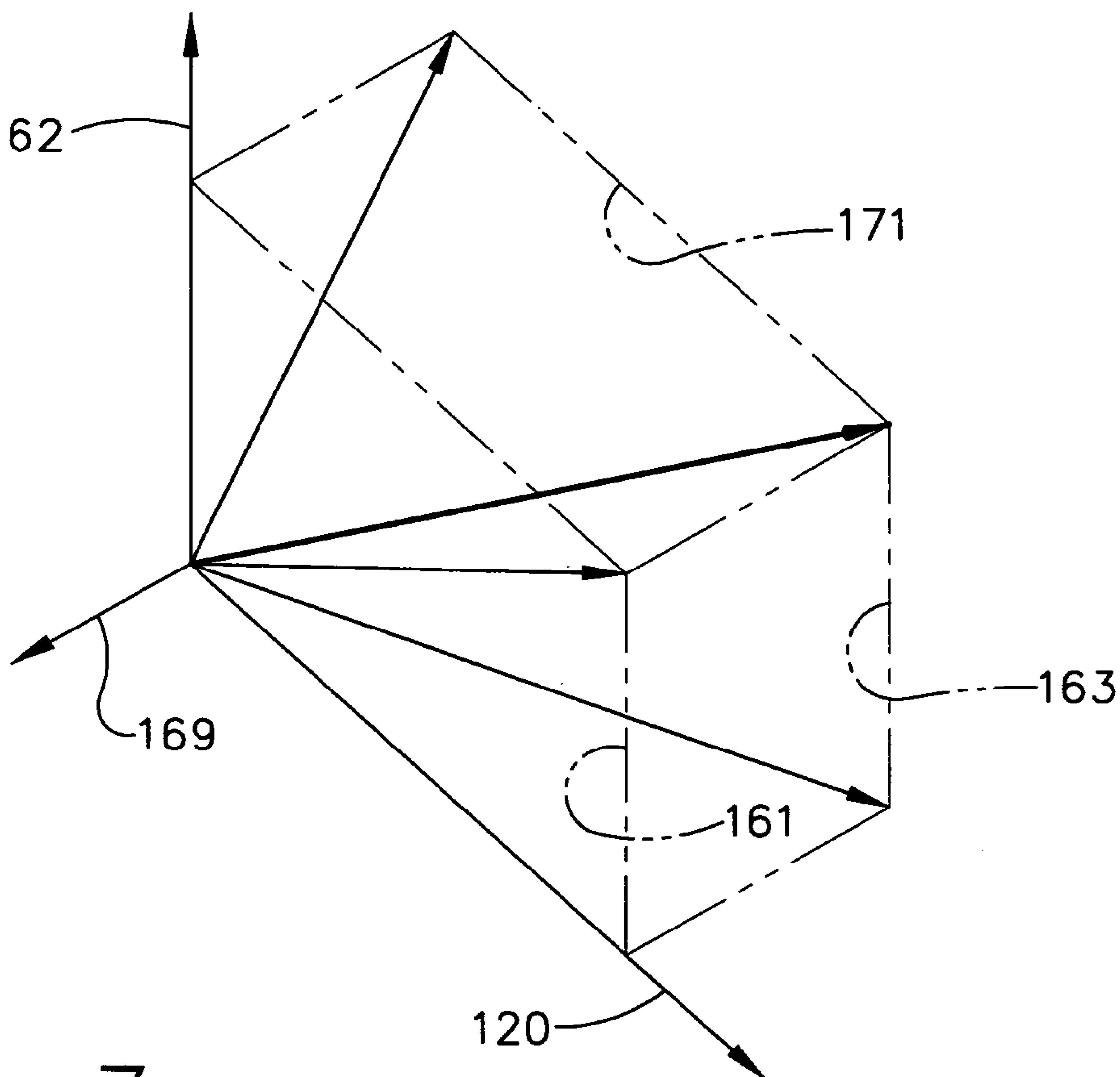

FIG. 7

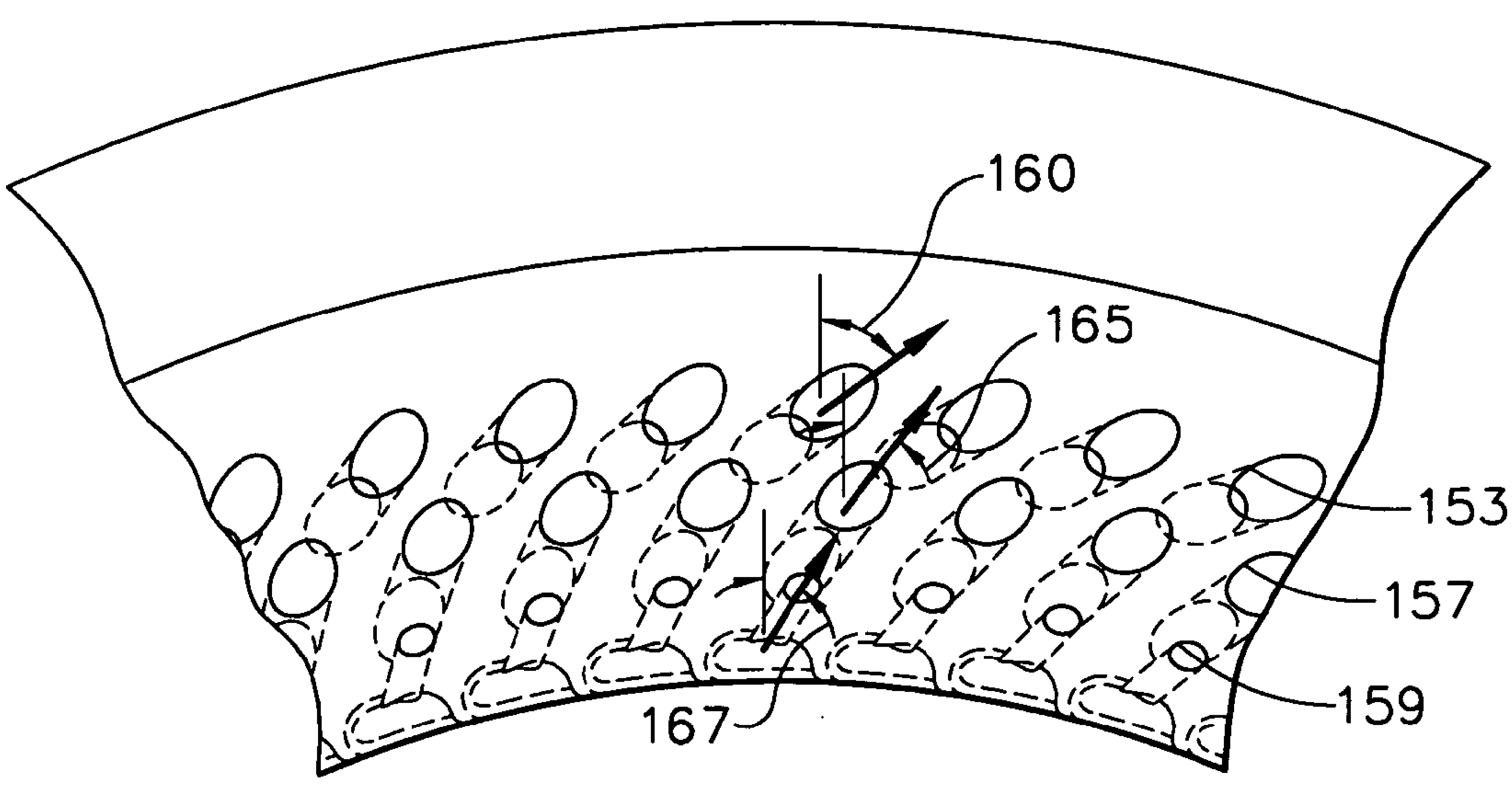

FIG. 8

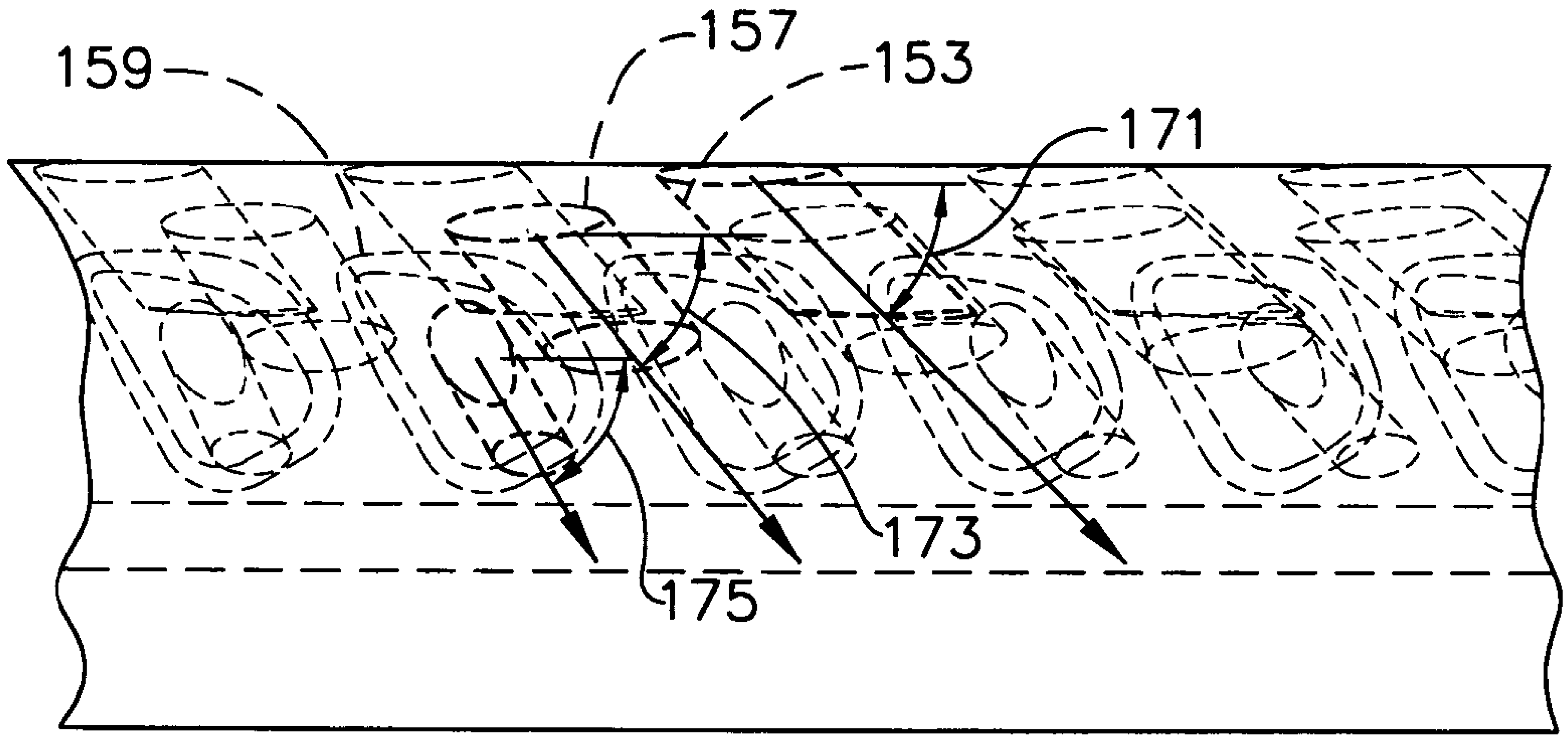

FIG. 9

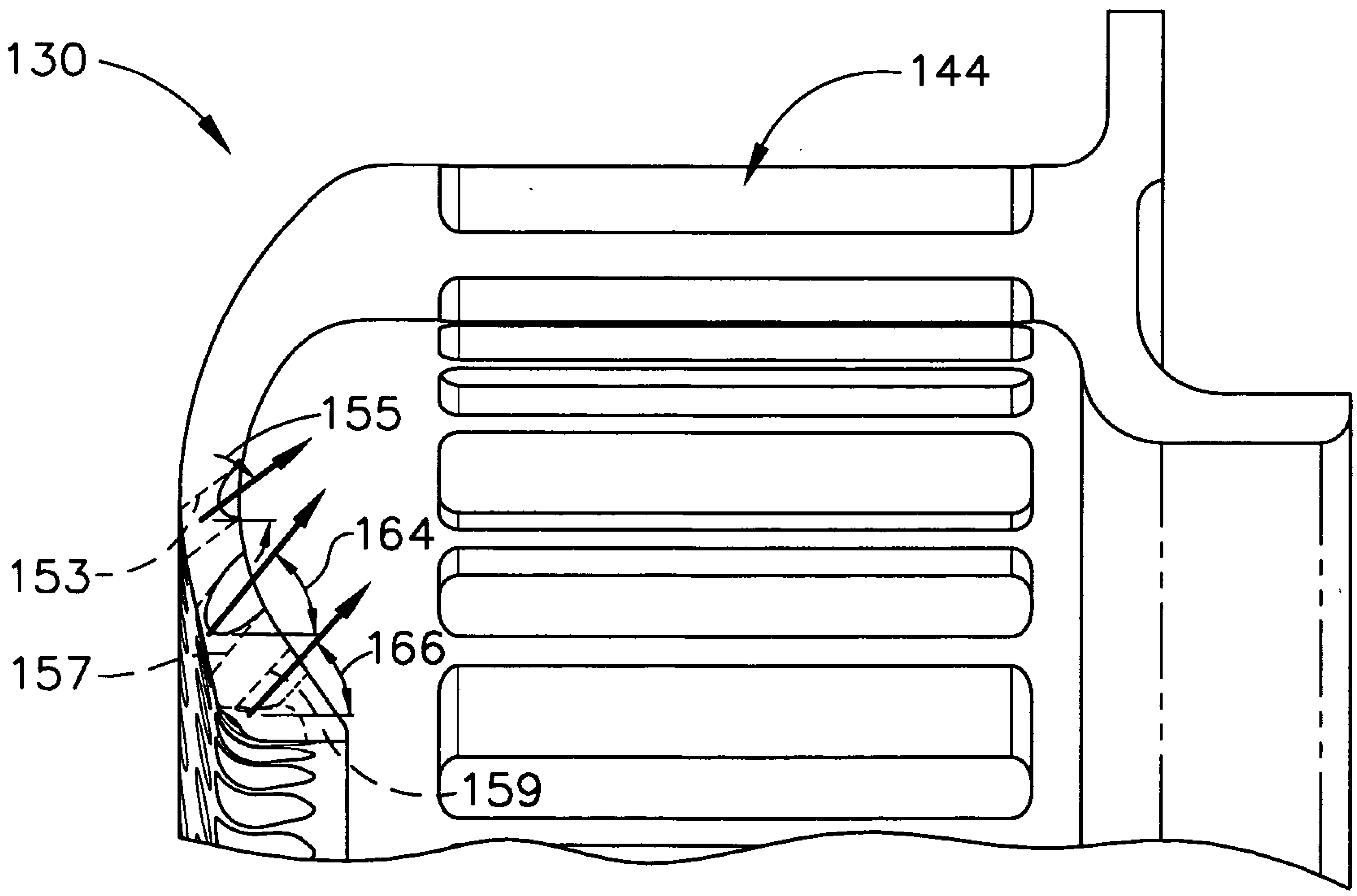

FIG. 10

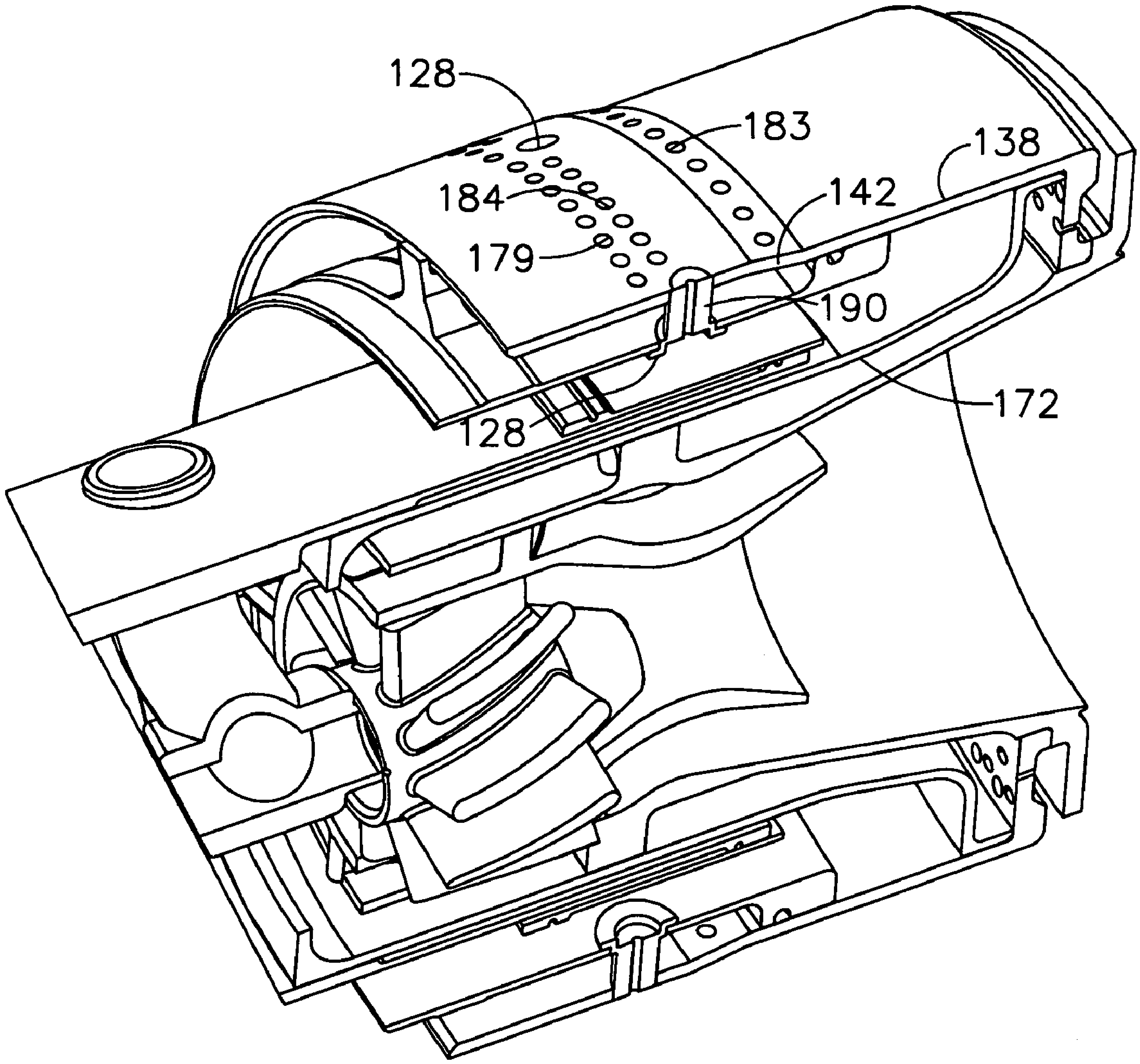

FIG. 11

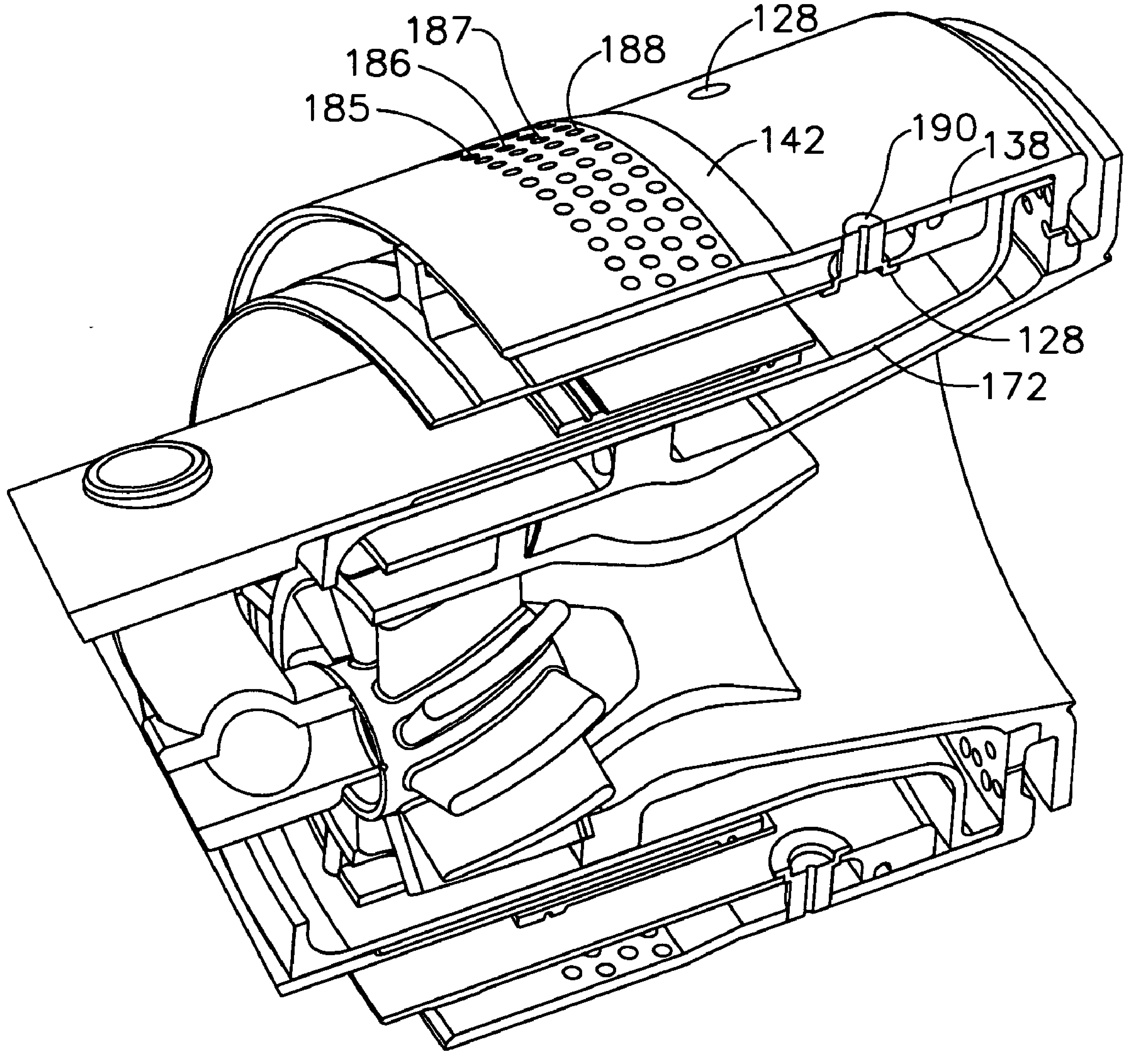

FIG. 12

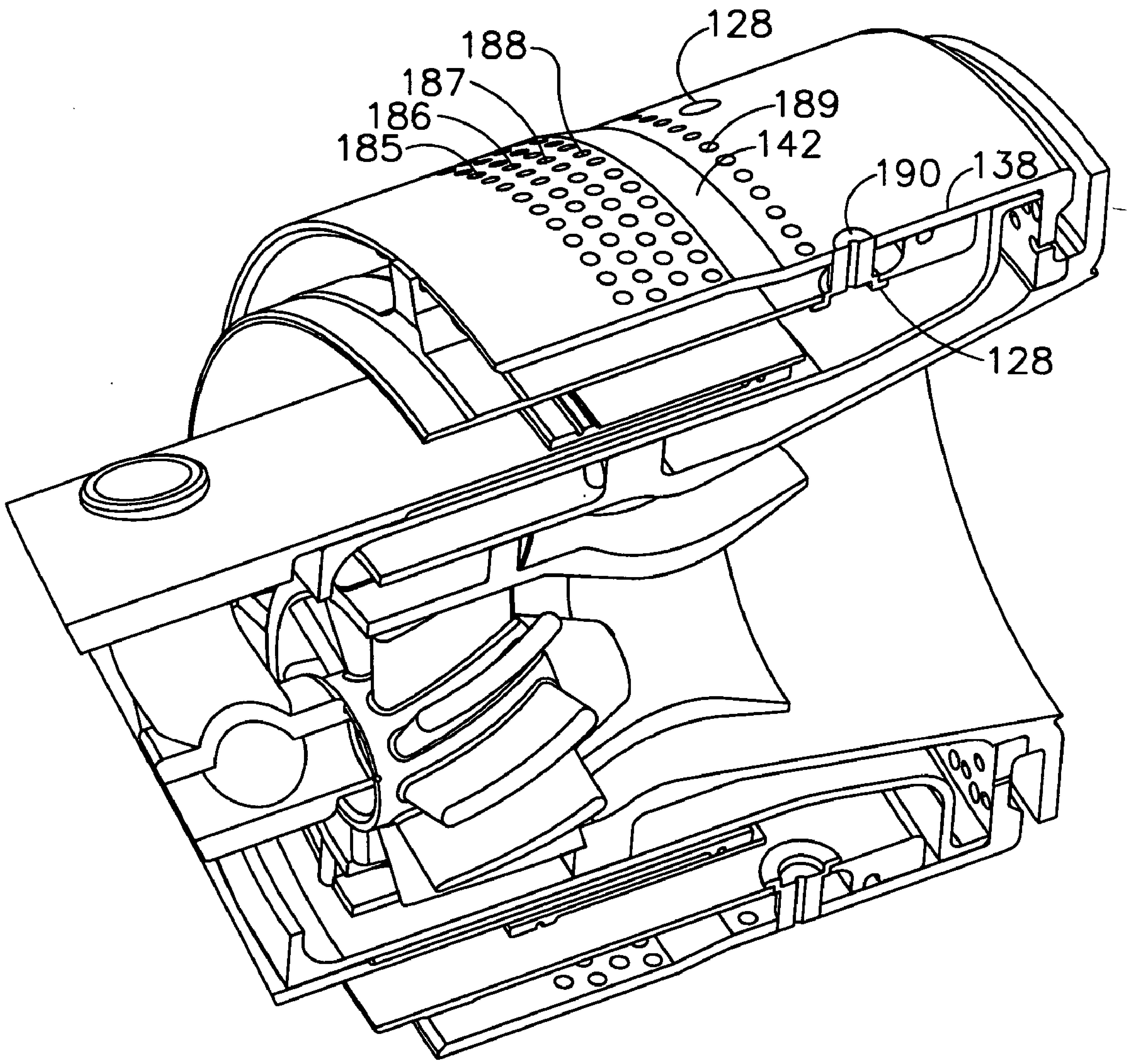

FIG. 13

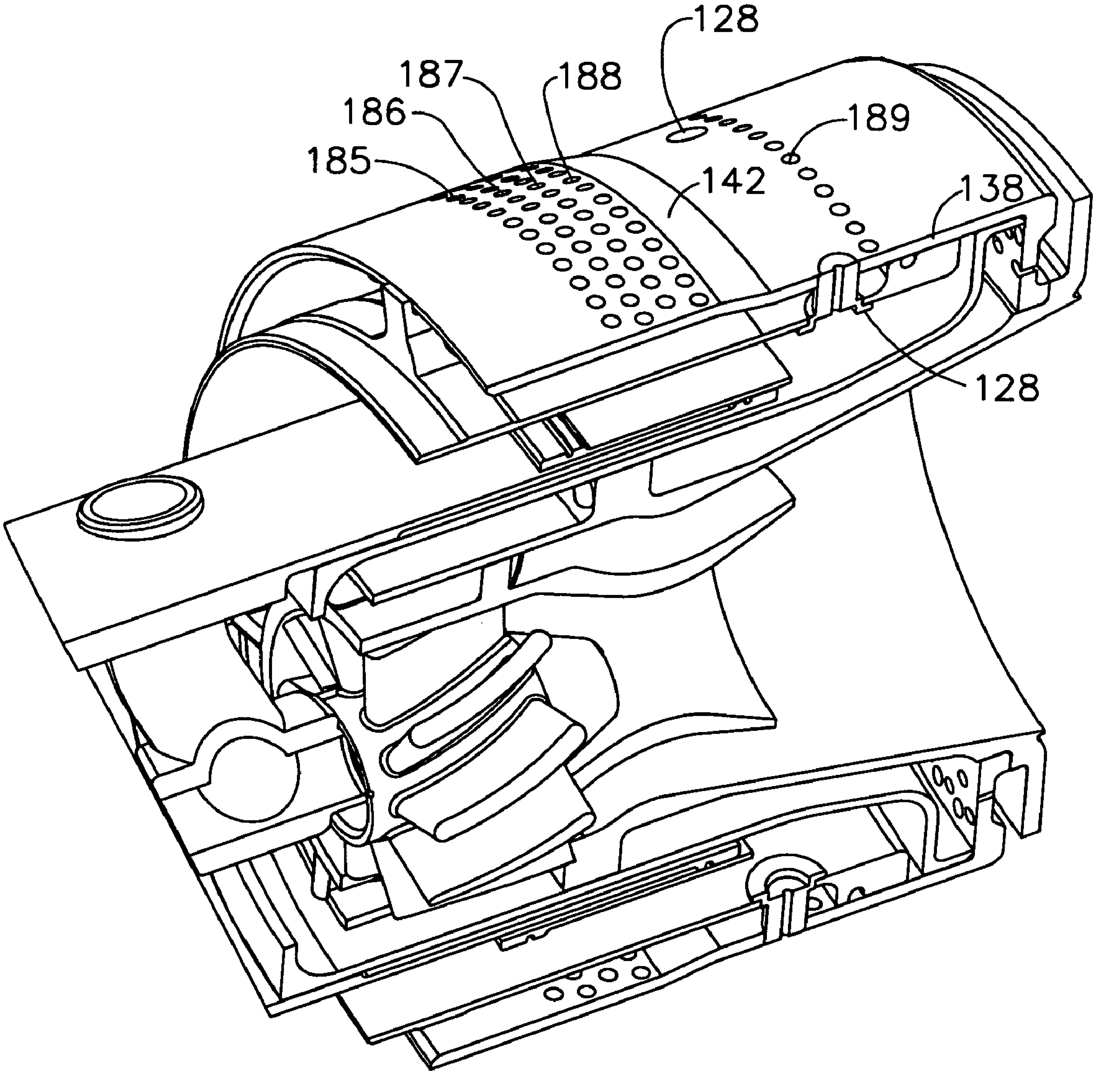

FIG. 14

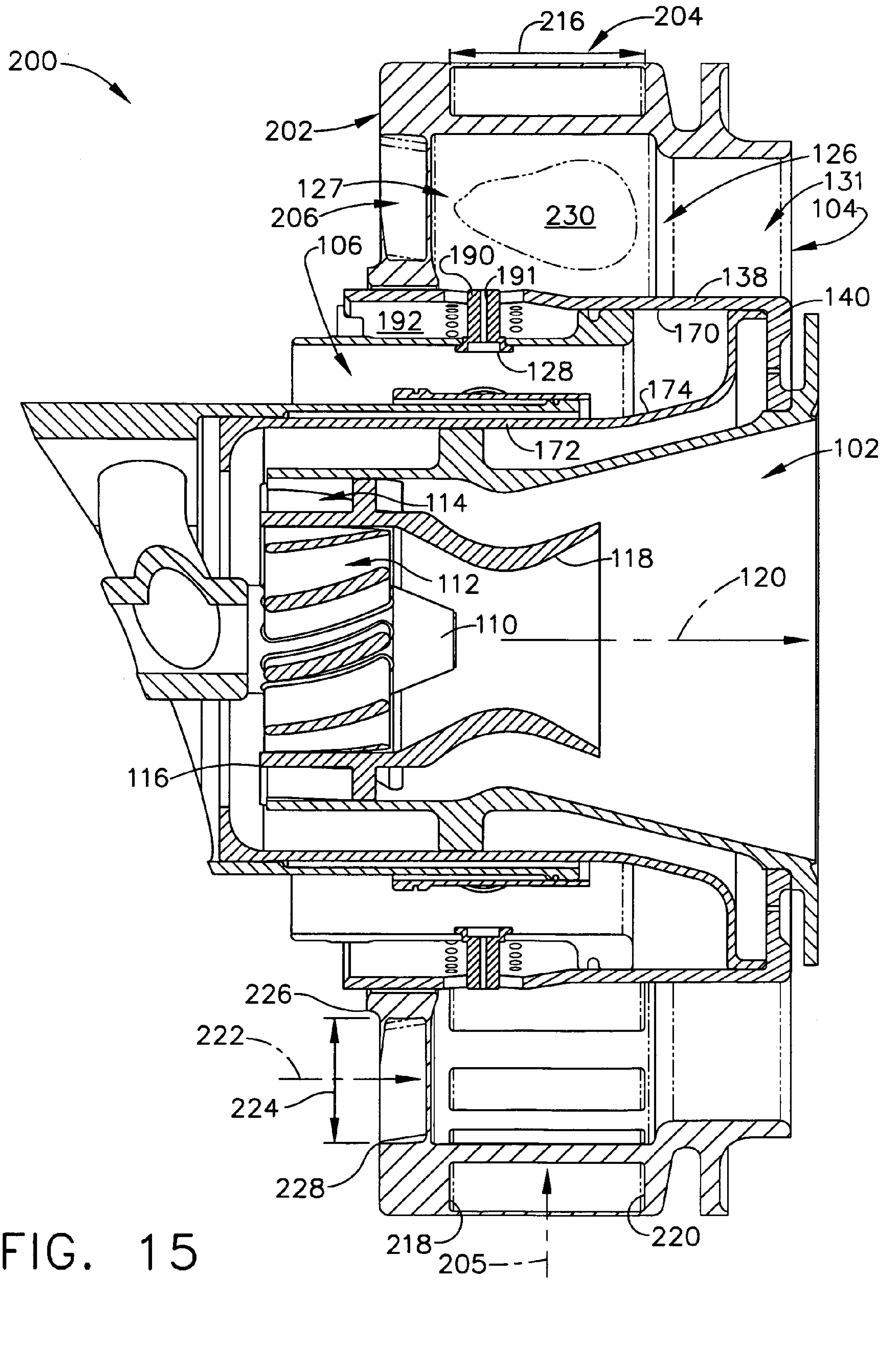

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FIG. 15

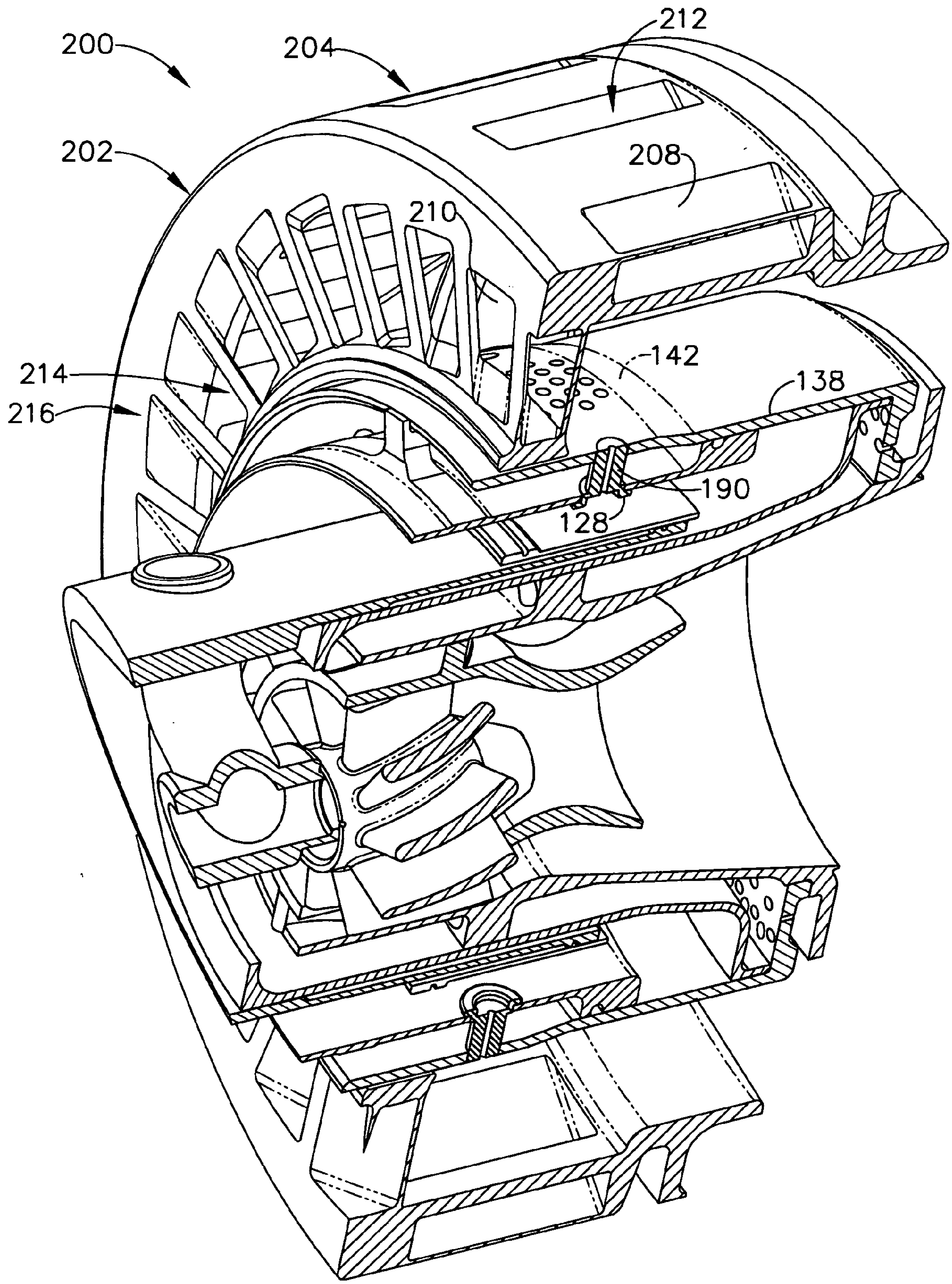

FIG. 16

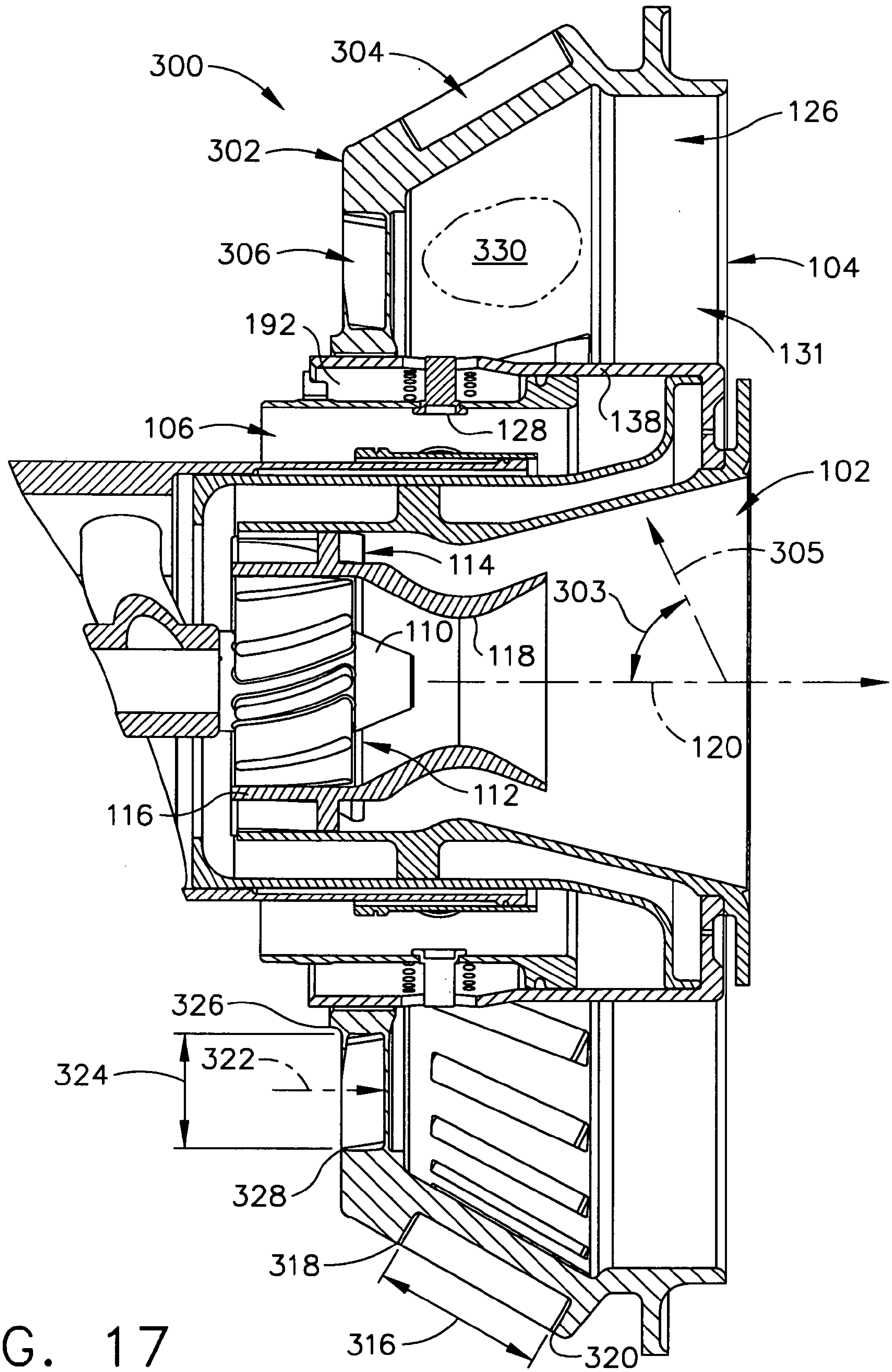
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FIG. 17

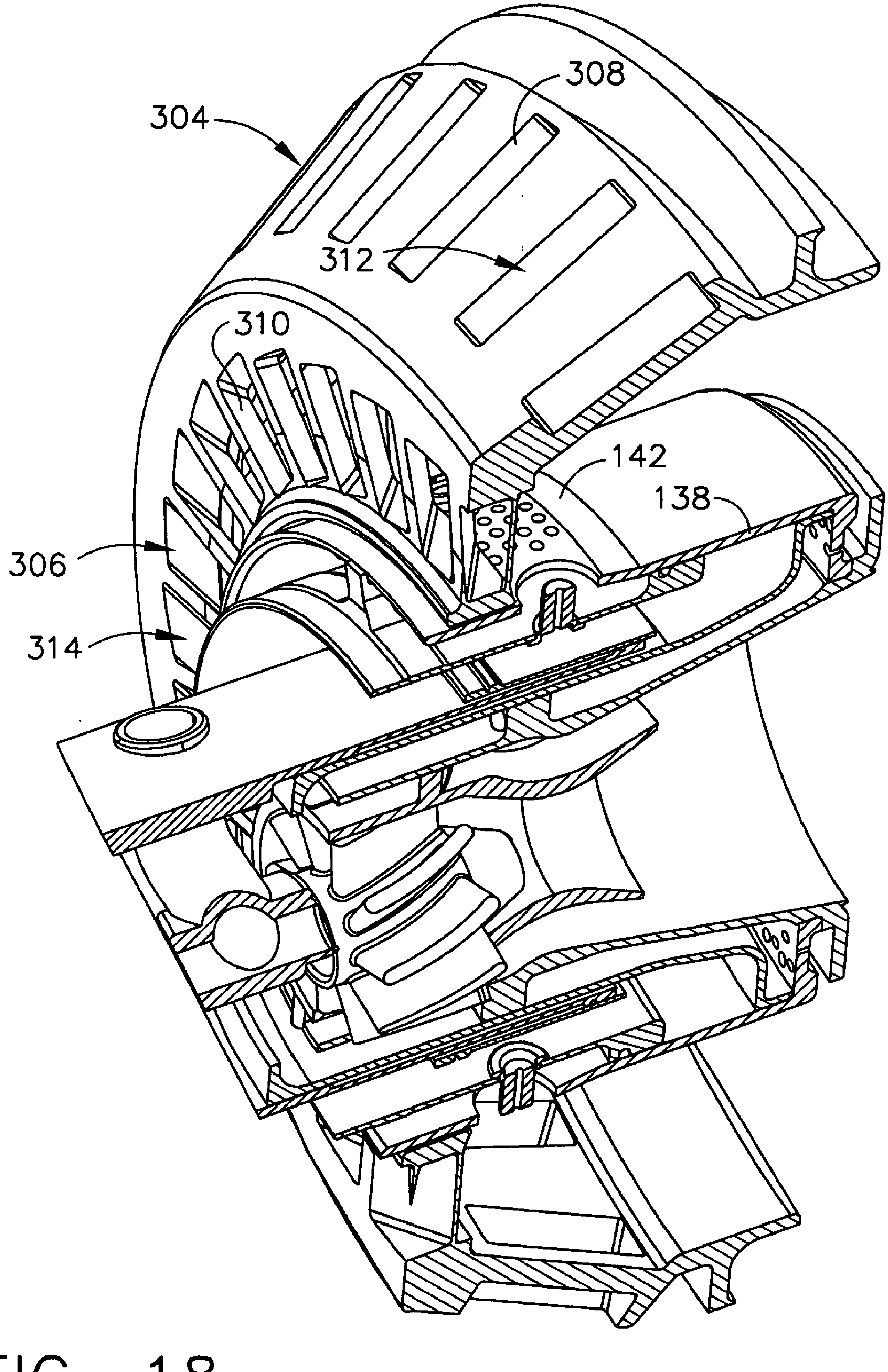

FIG. 18

MIXER ASSEMBLY FOR COMBUSTOR OF A GAS TURBINE ENGINE HAVING A MAIN MIXER WITH IMPROVED FUEL PENETRATION

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a staged combustion system in which the production of undesirable combustion product components is minimized over the engine operating regime and, more particularly, to a fuel injection arrangement for the main mixer of such system which enhances fuel penetration into an annular cavity for improved mixing of fuel and air therein.

[0002] Air pollution concerns worldwide have led to stricter emissions standards both domestically and internationally. Aircraft are governed by both Environmental Protection Agency (EPA) and International Civil Aviation Organization (ICAO) standards. These standards regulate the emission of oxides of nitrogen (NOx), unburned hydrocarbons (HC), and carbon monoxide (CO) from aircraft in the vicinity of airports, where they contribute to urban photochemical smog problems. Such standards are driving the design of gas turbine engine combustors, which also must be able to accommodate the desire for efficient, low cost operation and reduced fuel consumption. In addition, the engine output must be maintained or even increased.

[0003] It will be appreciated that engine emissions generally fall into two classes: those formed because of high flame temperatures (NOx) and those formed because of low flame temperatures which do not allow the fuel-air reaction to proceed to completion (HC and CO). Balancing the operation of a combustor to allow efficient thermal operation of the engine, while simultaneously minimizing the production of undesirable combustion products, is difficult to achieve. In that regard, operating at low combustion temperatures to lower the emissions of NOx can also result in incomplete or partially incomplete combustion, which can lead to the production of excessive amounts of HC and CO, as well as lower power output and lower thermal efficiency. High combustion temperature, on the other hand, improves thermal efficiency and lowers the amount of HC and CO, but oftentimes results in a higher output of NOx.

[0004] One way of minimizing the emission of undesirable gas turbine engine combustion products has been through staged combustion. In such an arrangement, the combustor is provided with a first stage burner for low speed and low power conditions so the character of the combustion products is more closely controlled. A combination of first and second stage burners is provided for higher power output conditions, which attempts to maintain the combustion products within the emissions limits.

[0005] Another way that has been proposed to minimize the production of such undesirable combustion product components is to provide for more effective intermixing of the injected fuel and the combustion air. In this way, burning occurs uniformly over the entire mixture and reduces the level of HC and CO that results from incomplete combustion. While numerous mixer designs have been proposed over the years to improve the mixing of the fuel and air, improvement in the levels of undesirable NOx formed under high power conditions (i.e., when the flame temperatures are high) is still desired.

[0006] One mixer design that has been utilized is known as a twin annular premixing swirler (TAPS), which is disclosed in the following U.S. Pat. Nos. 6,354,072; 6,363,726; 6,367,262; 6,381,964; 6,389,815; 6,418,726; 6,453,660; 6,484,489; and, 6,865,889. Published U.S. patent application 2002/0178732 also depicts certain embodiments of the TAPS mixer. It will be understood that the TAPS mixer assembly includes a pilot mixer which is supplied with fuel during the entire engine operating cycle and a main mixer which is supplied with fuel only during increased power conditions of the engine operating cycle. Because improvements in NOx emissions during high power conditions are of current primary concern, modification of the main mixer in the assembly is needed to maximize fuel-air mixing therein.

[0007] As shown in the '964 and '815 patents, fuel is injected from a fuel manifold into the main mixer by means of a plurality of fuel injection ports. Such ports are generally located downstream of a ramp portion defining an inner radial surface of an annular cavity. It has been found that fuel injected into such annular cavity has a tendency to break apart more quickly than desired and/or reside too closely to the inner radial surface thereof. In either event, the ability of the fuel and air in the annular cavity to form a more uniform mixture is impeded.

[0008] Accordingly, there is a desire for a gas turbine engine combustor in which the production of undesirable combustion product components is minimized over a wide range of engine operating conditions. More specifically, a mixer assembly for such gas turbine engine combustor is desired which provides increased mixing of fuel and air so as to create a more uniform mixture. It is desired that the fuel spray be injected further into the annular cavity of the main mixer and that a flow field be created therein which is conducive to retarding break-up of the fuel spray.

BRIEF SUMMARY OF THE INVENTION

[0009] In a first exemplary embodiment of the invention, a mixer assembly for use in a combustor of a gas turbine engine is disclosed as including a pilot mixer, a main mixer, and a fuel manifold positioned between the pilot mixer and main mixer. The pilot mixer includes an annular pilot housing having a hollow interior and a pilot fuel nozzle mounted in the housing and adapted for dispensing droplets of fuel to the hollow interior of the pilot housing. The main mixer includes: a main housing surrounding the pilot housing and defining an annular cavity having an upstream end and a downstream end, with the annular cavity including an upstream wall, an outer wall and an inner wall; a plurality of fuel injection ports for introducing fuel into the cavity, with the fuel injection ports being circumferentially spaced at a designated axial location of the inner wall of the annular cavity; and, a swirler arrangement including at least one swirler in flow communication with the annular cavity, the swirler being incorporated into the outer wall of the annular cavity and extending from an upstream end to a downstream end, wherein each swirler of the arrangement has a plurality of vanes for swirling air traveling through such swirler to mix air and the droplets of fuel dispensed by the fuel injection ports. The fuel injection ports for introducing fuel into the main mixer cavity are in flow communication with the fuel manifold.

[0010] In a second exemplary embodiment of the invention, a mixer assembly for use in a combustor of a gas turbine engine is disclosed at including a pilot mixer, a main mixer and a fuel manifold positioned between the pilot mixer and the main mixer. The pilot mixer includes an annular pilot housing having a hollow interior and a pilot fuel nozzle mounted in the housing and adapted for dispensing droplets of fuel to the hollow interior of the pilot housing. The main mixer includes: a main housing surrounding the pilot housing and defining an annular cavity; a plurality of fuel injection ports for introducing fuel into the annular cavity; and, a swirler arrangement including at least one swirler positioned upstream from the fuel injection ports, wherein each swirler of the arrangement has a plurality of vanes for swirling air traveling through such swirler to mix air and the droplets of fuel dispensed by the fuel injection ports. The main housing of the main mixer further includes: a ramp portion positioned at an upstream portion of the annular cavity; an upstream wall including a first plurality of openings in flow communication with an air supply, where the first openings are oriented to provide air jets in a substantially axial direction into the annular cavity; and, an axial wall downstream of the upstream wall including a second plurality of openings in flow communication with an air supply oriented to provide air jets in a substantially radial direction into the annular cavity. The fuel injection ports are positioned adjacent the ramp portion of the annular cavity and are in flow communication with the fuel manifold.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a diagrammatic view of a high bypass turbofan gas turbine engine;

[0012] FIG. **2** is a longitudinal, cross-sectional view of a gas turbine engine combustor having a staged arrangement;

[0013] FIG. **3** is an enlarged, cross-sectional view of the mixer assembly depicted in FIG. **2**;

[0014] FIG. **4** is a partial perspective view of the mixer assembly depicted in FIGS. **2** and **3**;

[0015] FIG. **5** is a front perspective view of the swirler arrangement removed from the mixer assembly depicted in FIGS. **2-4**;

[0016] FIG. **6** is an aft perspective view of the swirler arrangement depicted in FIG. **5**, where a portion thereof has been removed for clarity;

[0017] FIG. **7** is an exemplary coordinate system provided as a reference for the orientation of openings depicted in the swirler arrangement of FIGS. **5** and **6**;

[0018] FIG. **8** is a partial rear view of a portion of the swirler arrangement depicted in FIGS. **5** and **6**, where openings formed in an upstream wall are shown in greater detail;

[0019] FIG. **9** is a partial side view of a portion of the swirler arrangement depicted in FIGS. **5** and **6**, where openings formed in an inner wall are shown in detail;

[0020] FIG. **10** is a partial section view of the swirler arrangement depicted in FIGS. **5** and **6**, where the orientation of the openings depicted in FIG. **8** are shown therein;

[0021] FIG. **11** is a partial perspective view of the mixer assembly depicted in FIGS. **3** and **4**, where the swirler arrangement has been removed for clarity;

[0022] FIG. **12** is a partial perspective view of the mixer assembly similar to that depicted in FIG. **11**, where the fuel injection ports are located downstream of the ramp portion in the main mixer and openings are formed in the axial wall upstream of the ramp portion;

[0023] FIG. **13** is a partial perspective view of the mixer assembly similar to that depicted in FIG. **12**, where a row of purge holes is provided upstream of the fuel injection ports;

[0024] FIG. **14** is a partial perspective view of the mixer assembly similar to that depicted in FIG. **12**, where a row of purge holes is provided downstream of the fuel injection ports;

[0025] FIG. **15** is an enlarged, cross-sectional view of the mixer assembly including a second embodiment for the swirler arrangement depicted in FIGS. **3-6** and **8-10**, where a radial swirler and an axial swirler are provided;

[0026] FIG. **16** is an enlarged, partial perspective view of the mixer assembly depicted in FIG. **15**;

[0027] FIG. **17** is an enlarged, cross-sectional view of the mixer assembly including a third embodiment for the swirler arrangement depicted in FIGS. **3-6** and **8-10**, where a conical swirler and an axial swirler are provided; and,

[0028] FIG. **18** is an enlarged, partial perspective view of the mixer assembly depicted in FIG. **17**.

DETAILED DESCRIPTION OF THE INVENTION

[0029] Referring now to the drawings in detail, wherein identical numerals indicate the same elements throughout the figures, FIG. **1** depicts in diagrammatic form an exemplary gas turbine engine **10** (high bypass type) utilized with aircraft having a longitudinal or axial centerline axis **12** therethrough for reference purposes. Engine **10** preferably includes a core gas turbine engine generally identified by numeral **14** and a fan section **16** positioned upstream thereof. Core engine **14** typically includes a generally tubular outer casing **18** that defines an annular inlet **20**. Outer casing **18** further encloses and supports a booster compressor **22** for raising the pressure of the air that enters core engine **14** to a first pressure level. A high pressure, multi-stage, axial-flow compressor **24** receives pressurized air from booster **22** and further increases the pressure of the air. The pressurized air flows to a combustor **26**, where fuel is injected into the pressurized air stream to raise the temperature and energy level of the pressurized air. The high energy combustion products flow from combustor **26** to a first (high pressure) turbine **28** for driving high pressure compressor **24** through a first (high pressure) drive shaft **30**, and then to a second (low pressure) turbine **32** for driving booster compressor **22** and fan section **16** through a second (low pressure) drive shaft **34** that is coaxial with first drive shaft **30**. After driving each of turbines **28** and **32**, the combustion products leave core engine **14** through an exhaust nozzle **36** to provide propulsive jet thrust.

[0030] Fan section **16** includes a rotatable, axial-flow fan rotor **38** that is surrounded by an annular fan casing **40**. It will be appreciated that fan casing **40** is supported from core engine **14** by a plurality of substantially radially-extending, circumferentially-spaced outlet guide vanes **42**. In this way, fan casing **40** encloses fan rotor **38** and fan rotor blades **44**.

Downstream section **46** of fan casing **40** extends over an outer portion of core engine **14** to define a secondary, or bypass, airflow conduit **48** that provides additional propulsive jet thrust.

[0031] From a flow standpoint, it will be appreciated that an initial air flow, represented by arrow **50**, enters gas turbine engine **10** through an inlet **52** to fan casing **40**. Air flow **50** passes through fan blades **44** and splits into a first compressed air flow (represented by arrow **54**) that moves through conduit **48** and a second compressed air flow (represented by arrow **56**) which enters booster compressor **22**. The pressure of second compressed air flow **56** is increased and enters high pressure compressor **24**, as represented by arrow **58**. After mixing with fuel and being combusted in combustor **26**, combustion products **60** exit combustor **26** and flow through first turbine **28**. Combustion products **60** then flow through second turbine **32** and exit exhaust nozzle **36** to provide thrust for gas turbine engine **10**.

[0032] As best seen in FIG. **2**, combustor **26** includes an annular combustion chamber **62** that is coaxial with longitudinal axis **12**, as well as an inlet **64** and an outlet **66**. As noted above, combustor **26** receives an annular stream of pressurized air from a high pressure compressor discharge outlet **69**. A portion of this compressor discharge air flows into a mixing assembly **67**, where fuel is also injected from a fuel nozzle **68** to mix with the air and form a fuel-air mixture that is provided to combustion chamber **62** for combustion. Ignition of the fuel-air mixture is accomplished by a suitable igniter **70**, and the resulting combustion gases **60** flow in an axial direction toward and into an annular, first stage turbine nozzle **72**. Nozzle **72** is defined by an annular flow channel that includes a plurality of radially-extending, circularly-spaced nozzle vanes **74** that tun the gases so that they flow angularly and impinge upon the first stage turbine blades of first turbine **28**. As shown in FIG. **1**, first turbine **28** preferably rotates high pressure compressor **24** via first drive shaft **30**. Low pressure turbine **32** preferably drives booster compressor **24** and fan rotor **38** via second drive shaft **34**.

[0033] Combustion chamber **62** is housed within engine outer casing **18** and is defined by an annular combustor outer liner **76** and a radially-inwardly positioned annular combustor inner liner **78**. The arrows in FIG. **2** show the directions in which compressor discharge air flows within combustor **26**. As shown, part of the air flows over the outermost surface of outer liner **76**, part flows into combustion chamber **62**, and part flows over the innermost surface of inner liner **78**.

[0034] Contrary to previous designs, it is preferred that outer and inner liners **76** and **78**, respectively, not be provided with a plurality of dilution openings to allow additional air to enter combustion chamber **62** for completion of the combustion process before the combustion products enter turbine nozzle **72**. This is in accordance with a patent application entitled "Combustor Liner Having No Dilution Holes," filed concurrently herewith and hereby incorporated by reference, which is also owned by the assignee of the present invention. It will be understood, however, that outer liner **76** and inner liner **78** preferably include a plurality of smaller, circularly-spaced cooling air apertures (not shown) for allowing some of the air that flows along the outermost surfaces thereof to flow into the interior of combustion chamber **62**. Those inwardly-directed air flows pass along the inner surfaces of outer and inner liners **76** and **78** that face the interior of combustion chamber **62** so that a film of cooling air is provided therealong.

[0035] It will be understood that a plurality of axially-extending mixing assemblies **67** are disposed in a circular array at the upstream end of combustor **26** and extend into inlet **64** of annular combustion chamber **62**. It will be seen that an annular dome plate **80** extends inwardly and forwardly to define an upstream end of combustion chamber **62** and has a plurality of circumferentially spaced openings formed therein for receiving mixing assemblies **67**. For their part, upstream portions of each of inner and outer liners **76** and **78**, respectively, are spaced from each other in a radial direction and define an outer cowl **82** and an inner cowl **84**. The spacing between the forwardmost ends of outer and inner cowls **82** and **84** defines combustion chamber inlet **64** to provide an opening to allow compressor discharge air to enter combustion chamber **62**.

[0036] A mixing assembly **100** in accordance with one embodiment of the present invention is shown in FIG. **3**. Mixing assembly **100** preferably includes a pilot mixer **102**, a main mixer **104**, and a fuel manifold **106** positioned therebetween. More specifically, it will be seen that pilot mixer **102** preferably includes an annular pilot housing **108** having a hollow interior, as well as a pilot fuel nozzle **110** mounted in housing **108** and adapted for dispensing droplets of fuel to the hollow interior of pilot housing **108**. Further, pilot mixer **102** preferably includes a first swirler **112** located at a radially inner position adjacent pilot fuel nozzle **110**, a second swirler **114** located at a radially outer position from first swirler **112**, and a splitter **116** positioned therebetween. Splitter **116** extends downstream of pilot fuel nozzle **110** to form a venturi **118** at a downstream portion. It will be understood that first and second pilot swirlers **112** and **114** are generally oriented parallel to a centerline axis **120** through mixing assembly **100** and include a plurality of vanes for swirling air traveling therethrough. Fuel and air are provided to pilot mixer **102** at all times during the engine operating cycle so that a primary combustion zone **122** is produced within a central portion of combustion chamber **62** (see FIG. **2**).

[0037] Main mixer **104** further includes an annular main housing **124** radially surrounding pilot housing **108** and defining an annular cavity **126**, a plurality of fuel injection ports **128** which introduce fuel into annular cavity **126**, and a swirler arrangement identified generally by numeral **130**. More specifically, annular cavity **126** is preferably defined by an upstream wall **132** and an outer radial wall **134** of a swirler housing **136**, and by an inner radial wall **138** of a centerbody outer shell **140**. It will be seen that inner radial wall **138** preferably also includes a ramp portion **142** located at a forward position along annular cavity **126**. It will be appreciated that annular cavity **126** gently transitions from an upstream end **127** having a first radial height **129** to a downstream end **131** having a second radial height **133**. The difference between first radial height **129** and second radial height **133** of annular cavity **126** is due primarily to outer radial wall **134** of swirler housing **136** incorporating a swirler **144** therein at upstream end **127**. In addition, ramp portion **142** of inner radial wall **138** is preferably located within an axial length **145** of swirler **144**.

[0038] It will be seen in FIGS. **3-6** and **10** that swirler arrangement **130** preferably includes at least a first swirler **144** positioned upstream from fuel injection ports **128**. As shown, first swirler **144** is preferably oriented substantially radially to centerline axis **120** through mixer assembly **100** and has an axis **148** therethrough. It will be noted that first swirler **144** includes a plurality of vanes **150** extending between first and second portions **137** and **139** of outer radial wall **134**. It will be appreciated that vanes **150** are preferably oriented at an angle of approximately 30-70° with respect to axis **148**. Vanes **150** will preferably each have a height **151** which is measured across opposite ends (i.e., in the axial direction relative to centerline axis **120** of mixing assembly **100**) that is equivalent to axial length **145** of swirler **144**. Since vanes **150** are substantially uniformly spaced circumferentially, a plurality of substantially uniform passages **154** are defined between adjacent vanes **150**. It will be noted that vanes **150** preferably extend from upstream end **147** of swirler **144** to downstream end **149** thereof. Nevertheless, vanes **150** may extend only part of the way from upstream end **147** to downstream end **149** so that the tips thereof are stepped or lie on a different annulus. It will further be understood that swirler **144** may include vanes having different configurations so as to shape the passages in a desirable manner, as disclosed in a patent application entitled "Swirler Arrangement For Mixer Assembly Of A Gas Turbine Engine Combustor Having Shaped Passages," which is also filed concurrently herewith by the assignee of the present invention and is hereby incorporated herein.

[0039] Air is also provided at upstream end **127** of annular cavity **126** via a series of passages formed in upstream wall **132** of swirler housing **130**. More specifically, as best seen in FIGS. **4-6**, an outer row **152** of passages **153** and an inner row **156** of passages **157** are provided which direct jets of air in a substantially axial direction into annular cavity **126**. A third row **158** of passages **159** located within upstream wall **132** is further provided which direct jets of air in a substantially radial direction into annular cavity **126**. It will be appreciated from FIGS. **7-10** that passages **153** preferably are oriented to be at an angle **155** in a range of approximately 30-70° in relation to centerline axis **120** relative to a radial plane **161**. Passages **153** are also preferably oriented to be at an angle **160** in a range of approximately 30-70° with respect to a radial axis **162** relative to a tangential plane **163**. Similarly, passages **157** preferably are oriented to be at an angle **164** in a range of approximately 30-70° with respect to centerline axis **120** relative to radial plane **161** and at an angle **165** in a range of approximately 30-70° with respect to radial axis **162** relative to tangential plane **163**. It will be seen that passages **159** of third row **158** are preferably oriented to be at an angle **166** with respect to centerline axis **120** relative to radial plane **161**, as well as at an angle **167** with respect to a radial axis **162** relative to tangential plane **163**. Further, passages **153**, **157** and **159** may be oriented at angles **173**, **175** and **177**, respectively, to a tangential axis **169** relative to an axial plane **171**.

[0040] It will be understood that air flowing through swirler **144** will be swirled in a first direction and air flowing through passages **153**, **157** and **159** will preferably be swirled in a direction opposite the first direction. In this way, an intense mixing region **168** of air and fuel is created within annular cavity **126** having an enhanced total kinetic energy. By properly configuring swirler **144**, as well as passages **153**, **157** and **159**, intense mixing region **168** is substantially centered within annular cavity **126**, positioned axially adjacent fuel injection ports **128** and has a designated area. The configuration of vanes **150** in swirler **144** and orientation of passages **153**, **157** and **159** may be altered to vary the swirl direction of air flowing therethrough and not be limited to the exemplary swirl directions indicated hereinabove.

[0041] It will be understood that passages **154** between swirler vanes **150** preferably have a greater area than the cumulative area of passages **153**, **157** and **159**. Accordingly, a relatively greater amount of air flows through first swirler **144** than through passages **153**, **157** and **159** due to the greater passage area therefor. The relative area of swirler passages **154** and passages **153**, **157** and **159**, however, may be varied as desired to alter the distribution of air therethrough, so the sizes depicted are only illustrative. Regarding the amount of air flowing through passages **153**, **157** and **159**, it is preferred that this be approximately 15-30% of the total air flowing through main mixer **104**.

[0042] Fuel manifold **106**, as stated above, is located between pilot mixer **102** and main mixer **104** and is in flow communication with a fuel supply. In particular, outer radial wall **138** of centerbody outer shell **140** forms an outer surface **170** of fuel manifold **106**, and a shroud member **172** is configured to provide an inner surface **174** and an aft surface **176** thereof. Fuel injection ports **128** are in flow communication with fuel manifold **106** and spaced circumferentially around centerbody outer shell **140**. As seen in FIG. **3**, fuel injection ports **128** are preferably positioned axially adjacent ramp portion **142** of centerbody outer shell **140** so that fuel is provided in upstream end **127** of annular cavity **126**. In this way, fuel is preferably mixed with the air in intense mixing region **168** before entering downstream end **131** of annular cavity **126**. While fuel injection ports **128** are positioned upstream of ramp portion **142** in FIG. **3**, it will be noted that such ports **128** may be located immediately downstream thereof (see FIGS. **12-14**). In either case, it is preferred that the axial location of fuel injection ports **128** facilitate injection of fuel at least a specified distance into a middle radial portion of annular cavity **126** and away from the surface of inner radial wall **138**. Accordingly, such fuel injection ports **128** will generally be located within axial length **145** of radial swirler **144**.

[0043] It will be appreciated that injection of the fuel into the desired location of annular cavity **126** is a function of providing an air flow therein which accommodates such injected fuel (instead of forcing the fuel against inner radial wall **138**), as well as positioning fuel injection ports **128** so as to inject fuel in the manner best suited to the air flow. In addition, at least one row of circumferentially spaced purge holes is provided adjacent to and between each fuel injection port **128** to assist the injected fuel in its intended path. Such purge holes also assist in preventing injected fuel from collecting along inner radial wall **138**. More specifically, it will be seen in FIGS. **3** and **4** that a first row of purge holes **179** is located immediately upstream of and between fuel injection ports **128**, a second row of purge holes **180** is located immediately downstream of and between fuel injection ports **128**, and third and fourth rows of purge holes **181** and **182** are located between adjacent fuel injection ports **128**. An alternative configuration of purge holes may be utilized, as shown in FIG. **11**, where a downstream row of purge holes **183** is located within ramp portion **142** further downstream from fuel injection ports **128** and only a single row of intermediate purge holes **184** is located between adjacent fuel injection ports **128**.

[0044] Depending on the axial location of fuel injection ports **128**, the location of its purge holes may also be altered. For example, rows of purge holes **185**, **186**, **187** and **188** are located upstream of ramp portion **142** when fuel injection ports **128** are located downstream of such ramp portion **142** (see FIGS. **12-14**). Moreover, it will be noted that an additional row of purge holes **189** may be included upstream (FIG. **13**) or downstream (FIG. **14**) of fuel injection ports **128**.

[0045] In order to further facilitate injection of the fuel from fuel injection ports **128** into annular cavity **126**, it is also preferred that a post member **190** having an inner passage **191** be associated with each such fuel injection port **128**. It will be seen that post member **190** preferably extends from fuel injection port **128** through an air cavity **192** supplying compressed air to all applicable purge holes discussed hereinabove and through inner wall **138**. In this way, fuel not only is injected directly into annular cavity **126**, but the fuel is better able to travel into a middle annular portion of annular cavity **126** with the assistance of purge holes **179**, **180**, **181** and **182**.

[0046] When fuel is provided to main mixer **104**, an annular, secondary combustion zone **178** is provided in combustion chamber **62** that is radially outwardly spaced from and concentrically surrounds primary combustion zone **122**. Depending upon the size of gas turbine engine **10**, as many as twenty or so mixer assemblies **100** can be disposed in a circular array at inlet **64** of combustion chamber **62**.

[0047] FIGS. **15-16** depict an alternative swirler arrangement **200**, where swirler housing **202** includes a first swirler **204** oriented substantially radially to centerline axis **120** similar to swirler **144** described hereinabove with an axis **205** therethrough. In addition, swirler housing **202** includes a second swirler **206** which is oriented substantially axially to centerline axis **120** and is utilized to provide the counter swirling flow in annular cavity **126** instead of passages **153**, **157** and **159**. It will be appreciated that first and second swirlers **204** and **206** will each preferably have a plurality of vanes **208** and **210**, respectively, with passages **212** and **214** defined therebetween to provide the intended swirling air flows into annular cavity **126** to mix with the injected fuel.

[0048] It will be appreciated that vanes **208** of first swirler **204** are oriented at an angle of approximately 30-70° with respect to axis **205**. Vanes **208** each have a length **216** which is measured across opposite ends (i.e., in the axial direction perpendicular to axis **205**). Because vanes **208** are uniformly spaced circumferentially around swirler housing **202**, passages **212** defined between adjacent vanes are uniform. It will be noted that vanes **208** preferably extend from an upstream end **218** of first swirler **204** to a downstream end **220**. It will be understood, however, that first swirler **204** could include different vanes therein so as to form shaped passages therethrough.

[0049] Similarly, it will be appreciated that vanes **210** of second swirler **206** are oriented at an angle of approximately 30-70° with respect to an axis **222** parallel to centerline axis **120**. Vanes **210** each have a length **224** which is measured across opposite ends (i.e., in the radial direction perpendicular to axis **222**). Because vanes **210** are uniformly spaced circumferentially around swirler housing **202**, passages **214** defined between adjacent vanes are uniform. It will be noted that vanes **210** preferably extend from an inner radial end **226** of second swirler **206** to an outer radial end **228**. It will be understood that second swirler **206** could include different vanes therein so as to form shaped passages therethrough.

[0050] It will be understood that air flowing through first swirler **204** will be swirled in a first direction and air flowing through second swirler **206** will preferably be swirled in a direction opposite the first direction. In this way, an intense mixing region **230** of air and fuel is created within annular cavity **126** having an enhanced total kinetic energy. By properly configuring swirlers **204** and **206**, intense mixing region **230** is substantially centered within annular cavity **126**, positioned axially adjacent fuel injection ports **128** and has a designated area. The configuration of the vanes in swirlers **204** and **206** may be altered to vary the swirl direction of air flowing therethrough and not be limited to the exemplary swirl directions indicated hereinabove.

[0051] It will be seen that length **216** of first swirler vanes **208** is preferably greater than height **224** of second swirler vanes **210**. Accordingly, a relatively greater amount of air flows through first swirler **204** than second swirler **206** due to the greater passage area therefor. The relative lengths of swirlers **204** and **206** may be varied as desired to alter the distribution of air flowing therethrough, so the sizes depicted are only illustrative.

[0052] FIGS. **17** and **18** depict another alternative swirler arrangement **300** having a swirler housing **302** where swirler housing **302** includes a first swirler **304** oriented at an acute angle **303** to centerline axis **120** with an axis **305** therethrough. In addition, swirler housing **302** includes a second swirler **306** which is oriented substantially axially to centerline axis **120** and is utilized to provide the counter swirling flow in annular cavity **126**. It will be appreciated that first and second swirlers **304** and **306** will each preferably have a plurality of vanes **308** and **310**, respectively, with passages **312** and **314** defined therebetween to provide the intended swirling air flows into annular cavity **126** to mix with the injected fuel.

[0053] It will be appreciated that vanes **308** of first swirler **304** are oriented at an angle of approximately 30-70° with respect to axis **305**. Vanes **308** each have a length **316** which is measured across opposite ends (i.e., in the axial direction perpendicular to axis **305**). Because vanes **308** are uniformly spaced circumferentially around swirler housing **302**, passages **312** defined between adjacent vanes are uniform. It will be noted that vanes **308** preferably extend from an upstream end **318** of first swirler **304** to a downstream end **320**. It will be understood that first swirler **304** could include different vanes therein so as to form shaped passages therethrough.

[0054] Similarly, it will be appreciated that vanes **310** of second swirler **306** are oriented at an angle of approximately 30-70° with respect to an axis **322** parallel to centerline axis **120**. Vanes **310** each have a length **324** which is measured across opposite ends (i.e., in the radial direction perpendicular to axis **322**). Because vanes **310** are uniformly spaced circumferentially around swirler housing **302**, passages **314** defined between adjacent vanes are uniform. It will be noted that vanes **310** preferably extend from an inner radial end

326 of second swirler **306** to an outer radial end **328**. It will be understood that second swirler **306** could include different vanes therein so as to form shaped passages therethrough.

[**0055**] It will be understood that air flowing through first swirler **304** will be swirled in a first direction and air flowing through second swirler **306** will preferably be swirled in a direction opposite the first direction. In this way, an intense mixing region **330** of air and fuel is created within annular cavity **126** having an enhanced total kinetic energy. By properly configuring swirlers **304** and **306**, intense mixing region **330** is substantially centered within annular cavity **126**, positioned axially adjacent fuel injection ports **128** and has a designated area. The configuration of the vanes in swirlers **304** and **306** may be altered to vary the swirl direction of air flowing therethrough and not be limited to the exemplary swirl directions indicated hereinabove.

[**0056**] It will be seen that length **316** of first swirler vanes **308** is preferably greater than length **324** of second swirler vanes **310**. Accordingly, a relatively greater amount of air flows through first swirler **304** than second swirler **306** due to the greater passage area therefor. The relative lengths of swirlers **304** and **306** may be varied as desired to alter the distribution of air flowing therethrough, so the sizes depicted are only illustrative.

[**0057**] Although particular embodiments of the present invention have been illustrated and described, it will be apparent to those skilled in the art that various changes and modifications can be made without departing from the spirit of the present invention. Accordingly, it is intended to encompass within the appended claims all such changes and modification that fall within the scope of the present invention.

What is claimed is:

1. A mixer assembly for use in a combustion chamber of a gas turbine engine, comprising:

(a) a pilot mixer including an annular pilot housing having a hollow interior and a pilot fuel nozzle mounted in said housing and adapted for dispensing droplets of fuel to said hollow interior of said pilot housing;

(b) a main mixer including:

(1) a main housing surrounding said pilot housing and defining an annular cavity having an upstream end and a downstream end, said annular cavity including an upstream wall; an outer wall and an inner wall;

(2) a plurality of fuel injection ports for introducing fuel into said annular cavity, said fuel injection ports being circumferentially spaced at a designated axial location of said inner wall of said annular cavity; and,

(3) a swirler arrangement including at least one swirler in flow communication with said annular cavity, said swirler being incorporated into said outer wall of said annular cavity and extending from an upstream end to a downstream end, wherein each swirler of said arrangement has a plurality of vanes for swirling air traveling through such swirler to mix air and said droplets of fuel dispensed by said fuel injection ports; and,

(c) a fuel manifold positioned between said pilot mixer and said main mixer, wherein said plurality of fuel injection ports for introducing fuel into said main mixer cavity are in flow communication with said fuel manifold.

2. The mixer assembly of claim 1, said upstream wall of said annular cavity including a first plurality of circumferentially spaced passages in flow communication with compressed air.

3. The mixer assembly of claim 2, wherein said first passages are oriented to provide air jets in a substantially axial direction into said annular cavity.

4. The mixer assembly of claim 3, wherein said first passages are oriented to provide a designated swirl to said air jets in said annular cavity.

5. The mixer assembly of claim 4, wherein said designated swirl of said air jets is at an angle in a range of about 25° to about 60° with respect to a centerline axis through said mixer assembly.

6. The mixer assembly of claim 4, wherein said air jets are swirled in a direction opposite air swirled by said swirler.

7. The mixer assembly of claim 2, said upstream wall of said annular cavity further including a second plurality of passages in flow communication with compressed air.

8. The mixer assembly of claim 7, wherein said second passages are oriented to provide air jets in a substantially radial direction into said annular cavity.

9. The mixer assembly of claim 8, wherein said second passages are oriented to provide a designated swirl to said air jets in said annular cavity.

10. The mixer assembly of claim 9, wherein said designated swirl of said air jets is at an angle in a range of about 25° to about 60° with respect to an axis substantially perpendicular to a centerline axis through said mixer assembly.

11. The mixer assembly of claim 9, wherein said air jets are swirled in a direction opposite air swirled by said swirler.

12. The mixer assembly of claim 1, wherein said fuel injection ports are located immediately downstream of a ramp portion in said inner wall of said annular cavity.

13. The mixer assembly of claim 1, wherein said fuel injection ports are located immediately upstream of a ramp portion in said inner wall of said annular cavity.

14. The mixer assembly of claim 1, wherein said fuel injection ports are spaced circumferentially around said annular cavity.

15. The mixer assembly of claim 14, further comprising a plurality of purge holes between each said fuel injection port in flow communication with compressed air.

16. The mixer assembly of claim 1, said fuel injection ports further comprising a post member having an inner passage in flow communication therewith.

17. The mixer assembly of claim 16, wherein said post member of said fuel injection ports extends at least even with an outer surface of said inner wall of said annular cavity.

18. The mixer assembly of claim 1, said swirler arrangement further comprising at least one swirler oriented substantially radially to a centerline axis through said mixer assembly having a designated axial length.

19. The mixer assembly of claim 18, wherein said injection ports are located within said axial length of said swirler.

20. The mixer assembly of claim 1, said swirler arrangement further comprising at least one swirler oriented at an acute angle to a centerline axis through said mixer assembly.

21. The mixer assembly of claim 1, said swirler arrangement further comprising at least one swirler oriented substantially parallel to a centerline axis through said mixer assembly.

22. The mixer assembly of claim 1, wherein fuel droplets from said fuel injection ports are able to penetrate to a designated position within said annular cavity.

23. The mixer assembly of claim 7, wherein air injected through said first and second plurality of passages is in a range of about 15% to about 30% of total air flowing through said main mixer.

24. A mixer assembly for use in a combustion chamber of a gas turbine engine, comprising:

(a) a pilot mixer including an annular pilot housing having a hollow interior and a pilot fuel nozzle mounted in said housing and adapted for dispensing droplets of fuel to said hollow interior of said pilot housing;

(b) a main mixer including:

(1) a main housing surrounding said pilot housing and defining an annular cavity, said main housing further comprising:

(a) a ramp portion positioned at an upstream portion of said annular cavity;

(b) an upstream wall including a first plurality of passages and a second plurality of passages in flow communication with an air supply, wherein said first passages are oriented to provide air jets in a substantially axial direction into said annular cavity and said second passages are oriented to provide air jets in a substantially radial direction into said annular cavity;

(2) a plurality of fuel injection ports for introducing fuel into said annular cavity, wherein said fuel injection ports are positioned adjacent said ramp portion of said annular cavity; and,

(3) a swirler arrangement including at least one swirler positioned upstream from said fuel injection ports, wherein each swirler of said arrangement has a plurality of vanes for swirling air traveling through such swirler to mix air and said droplets of fuel dispensed by said fuel injection ports; and,

(c) a fuel manifold positioned between said pilot mixer and said main mixer, wherein said plurality of fuel injection ports for introducing fuel into said main mixer cavity are in flow communication with said fuel manifold.

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