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(54) **VARIABLE FLOW DIVIDER MECHANISM FOR A MULTI-STAGE COMBUSTOR**

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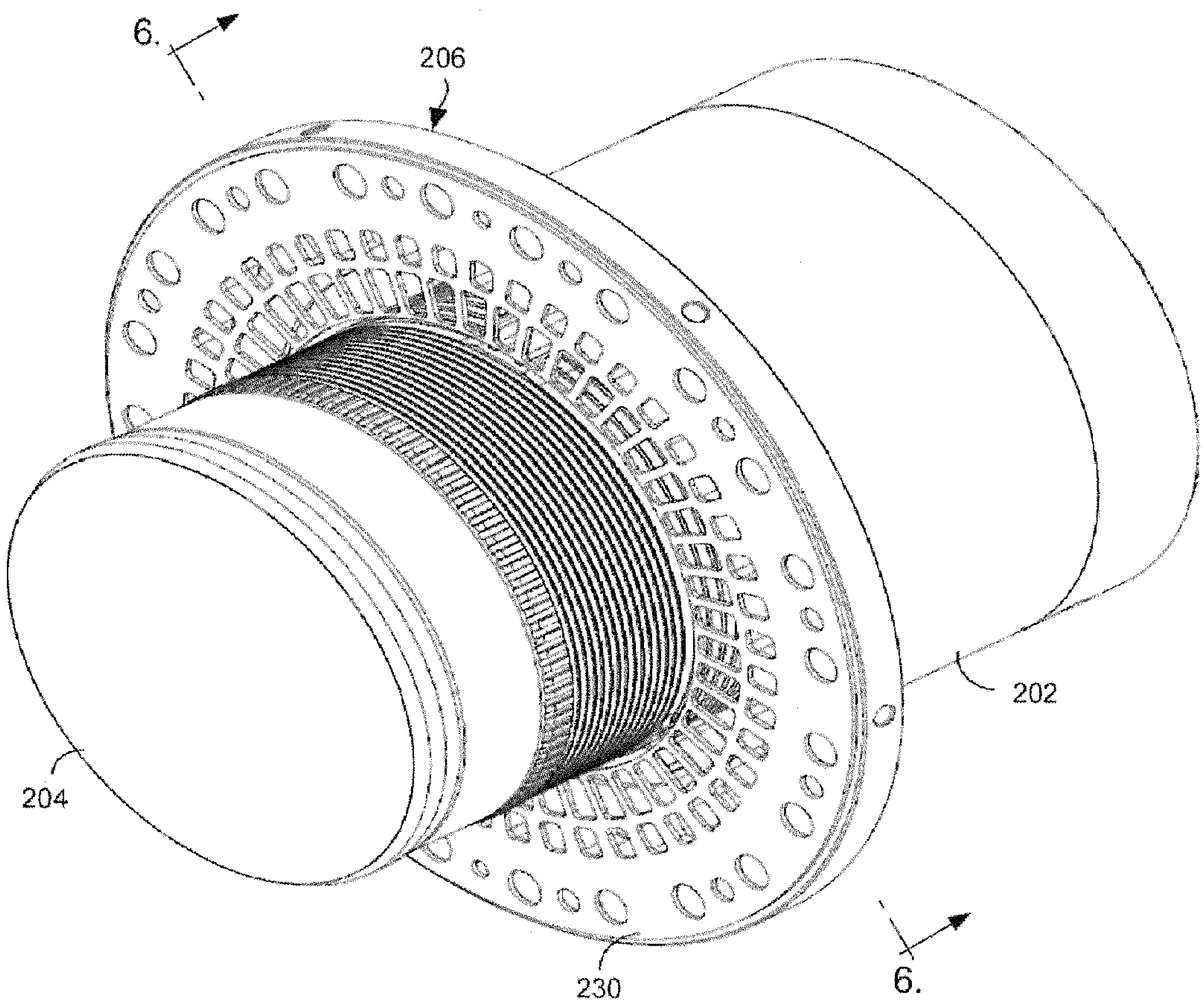
USPC **60/796**; 60/751

(57) **ABSTRACT**

The present invention discloses a novel apparatus and way for altering the airflow to a gas turbine combustion system. The apparatus comprises a flow divider mechanism which splits the airflow surrounding a combustion liner into two distinct portions, one directed towards a pilot and one directed towards a main stage combustion. The flow divider mechanism is interchangeable so as to provide a way of altering airflow splits between stages of the combustion system.



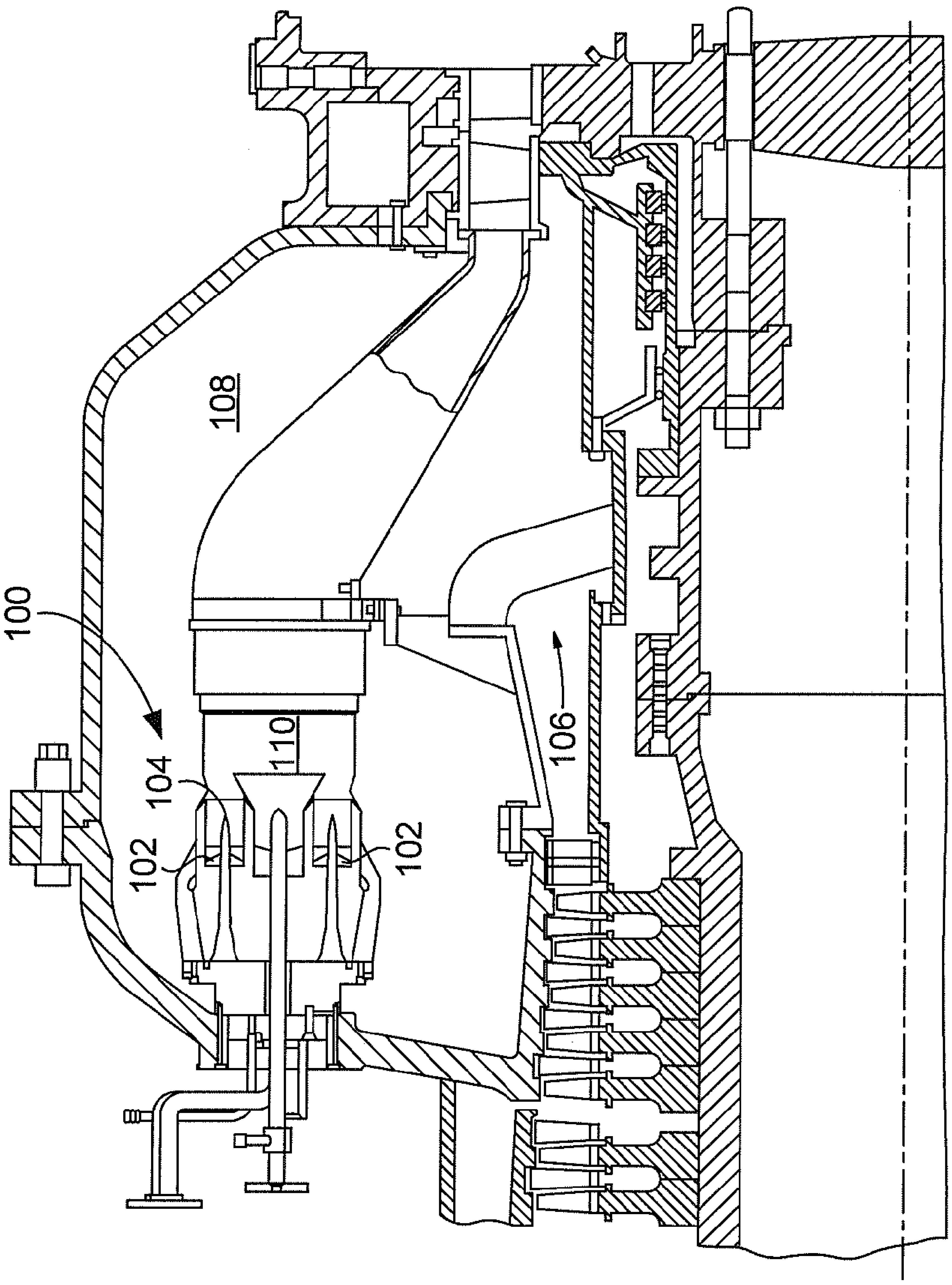


FIG. 1.
PRIOR ART

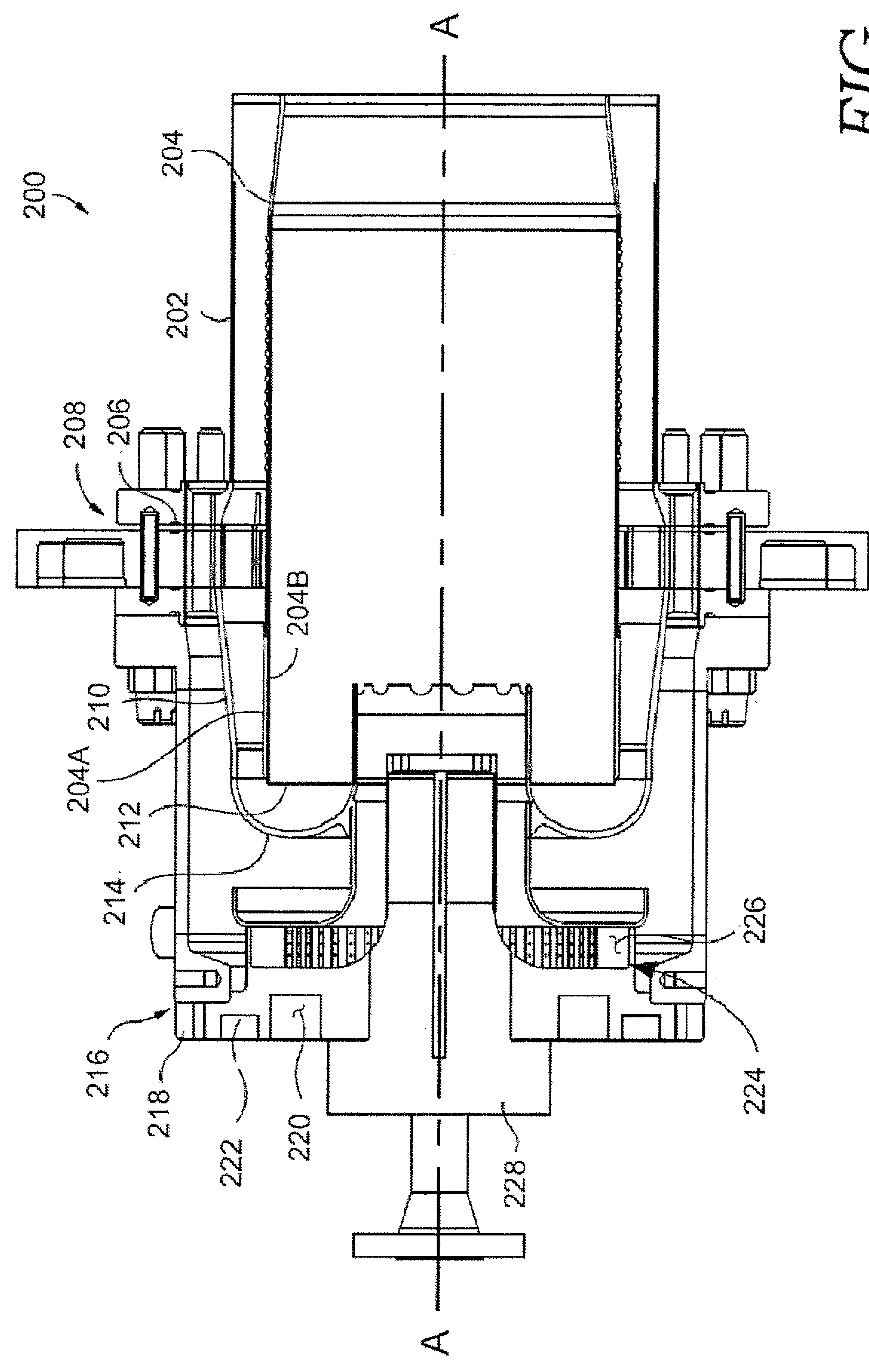

200
A
204
202
208
206
204B
210
204A
212
214
226
216
218
222
220
228
224
A

FIG. 2.

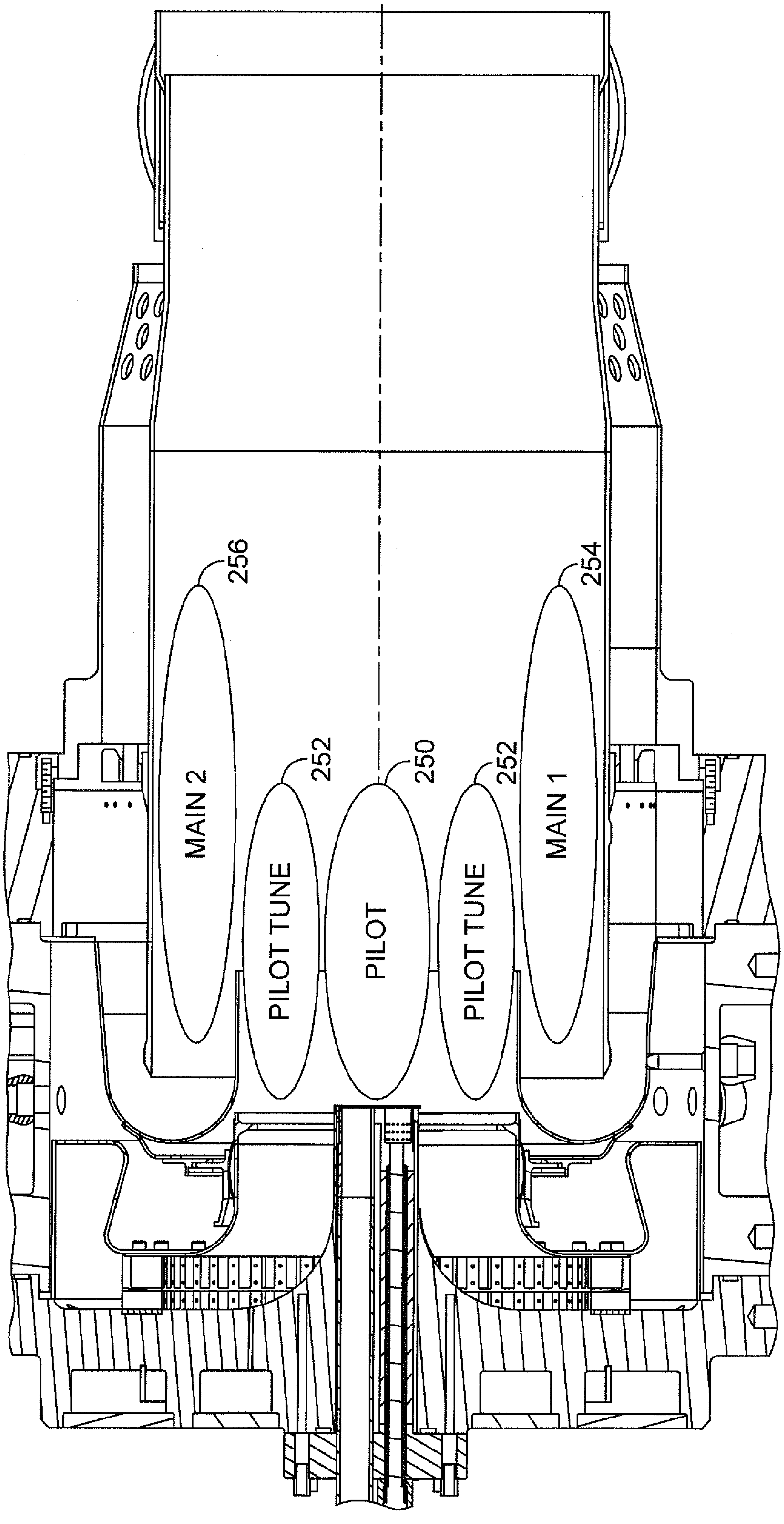


FIG. 3.

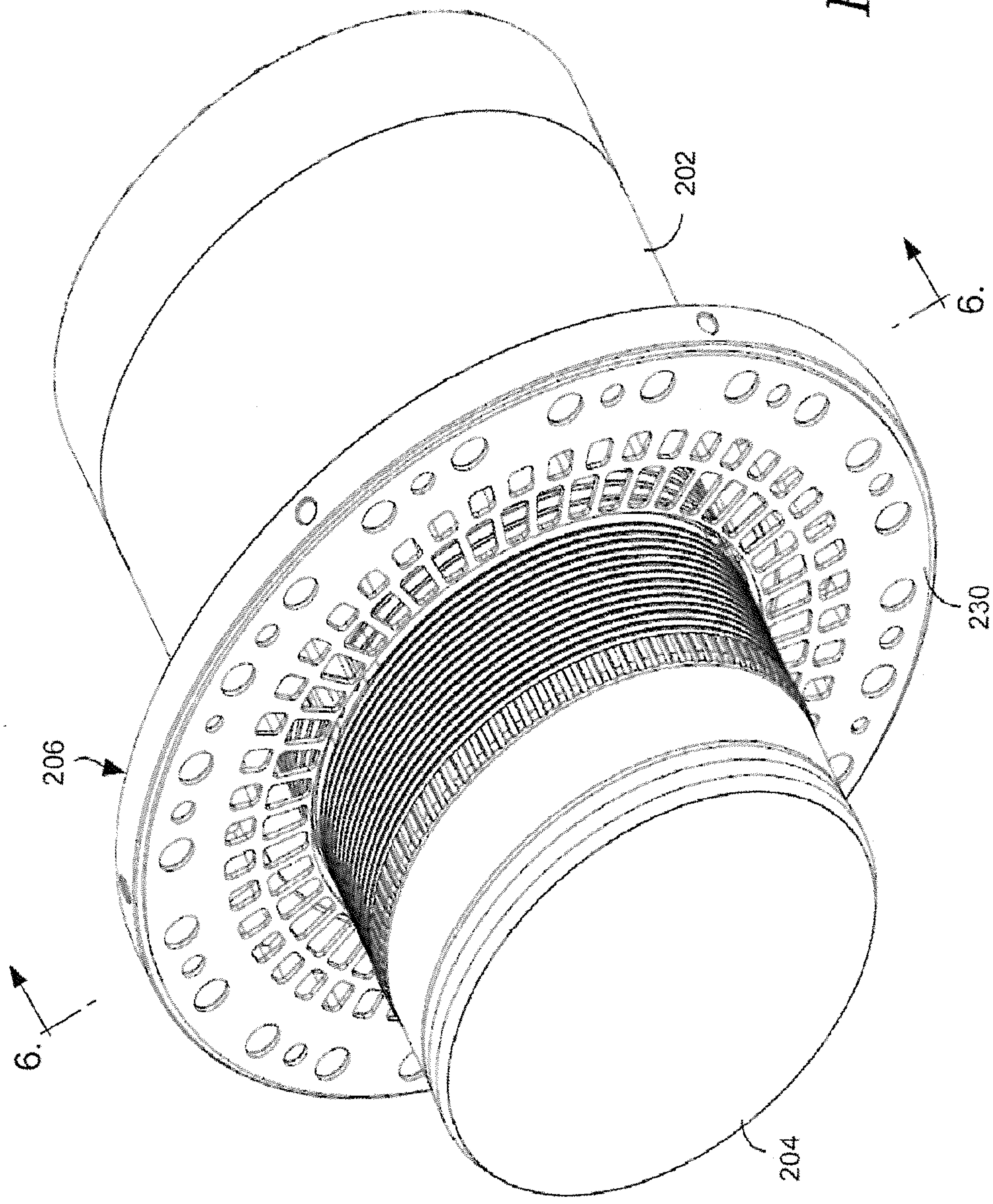


FIG. 4.

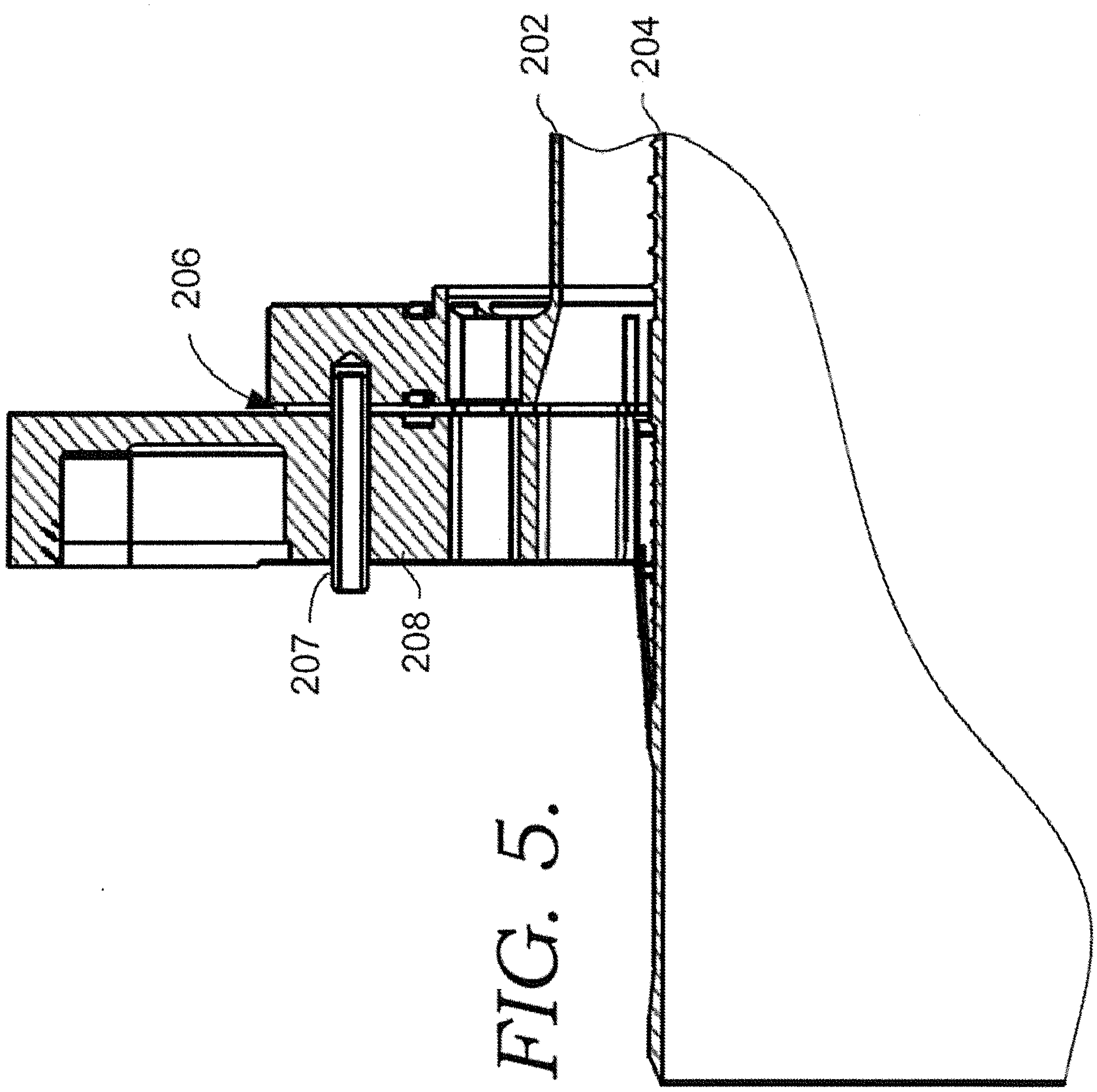


FIG. 5.

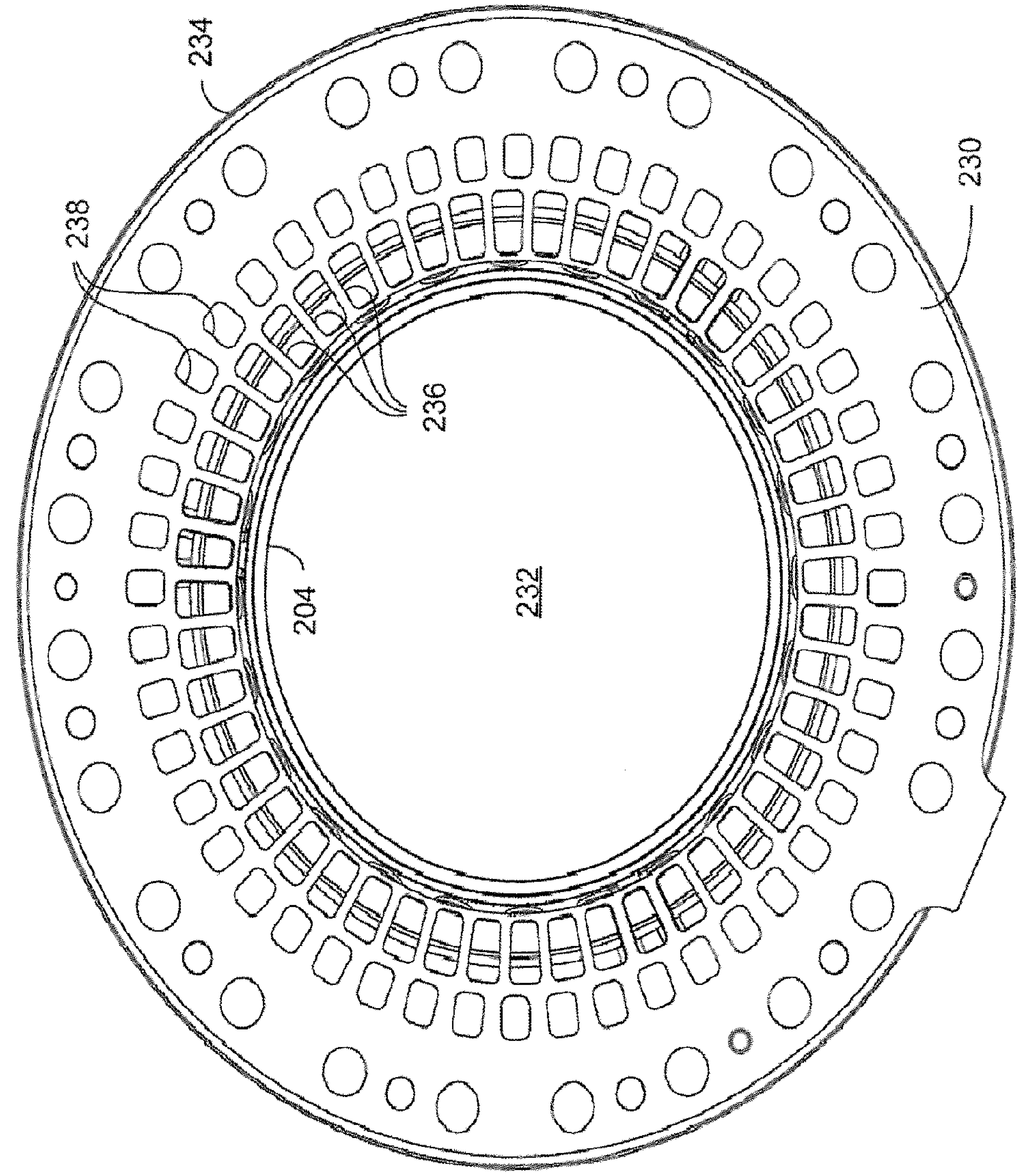


FIG. 6.

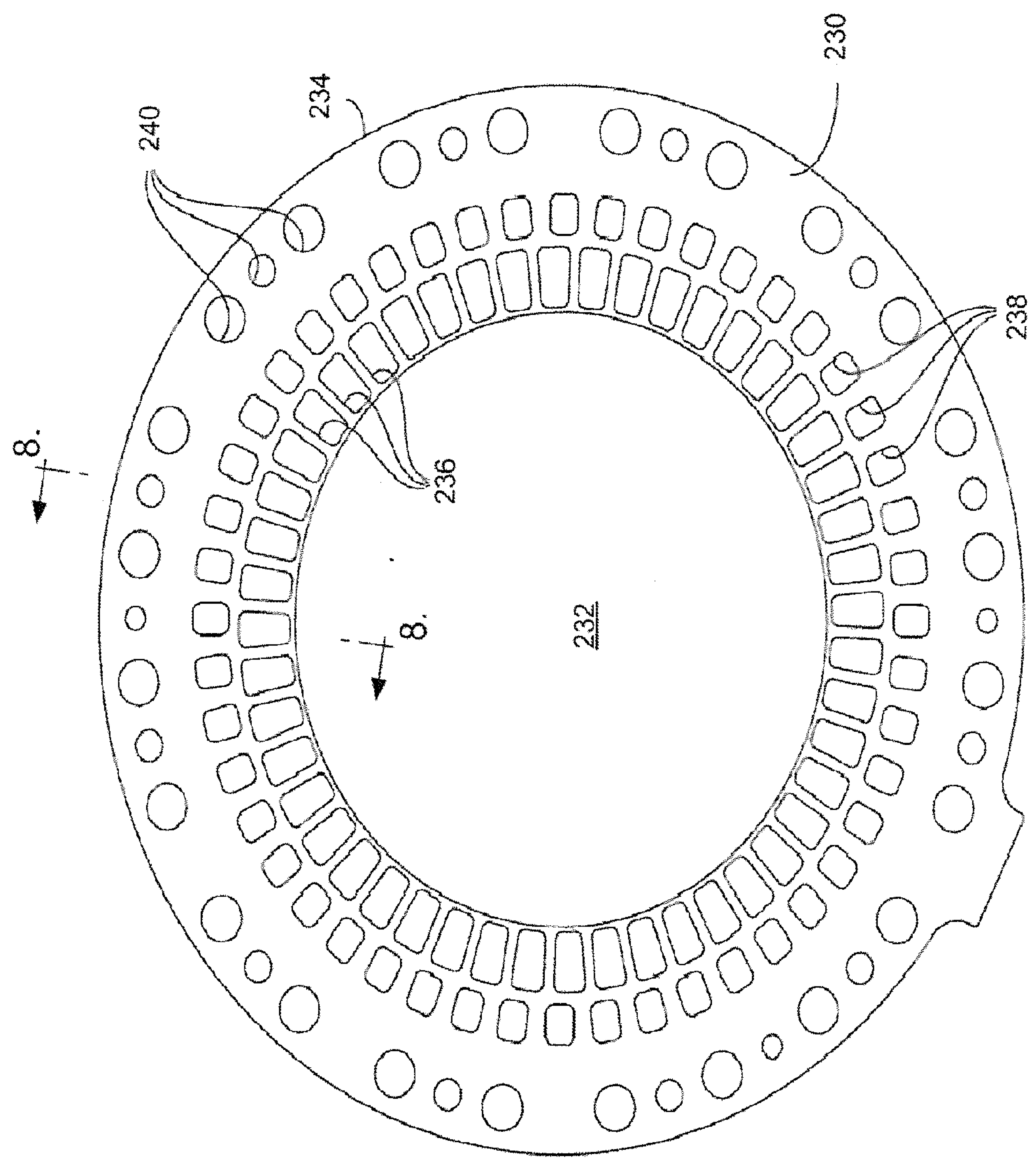
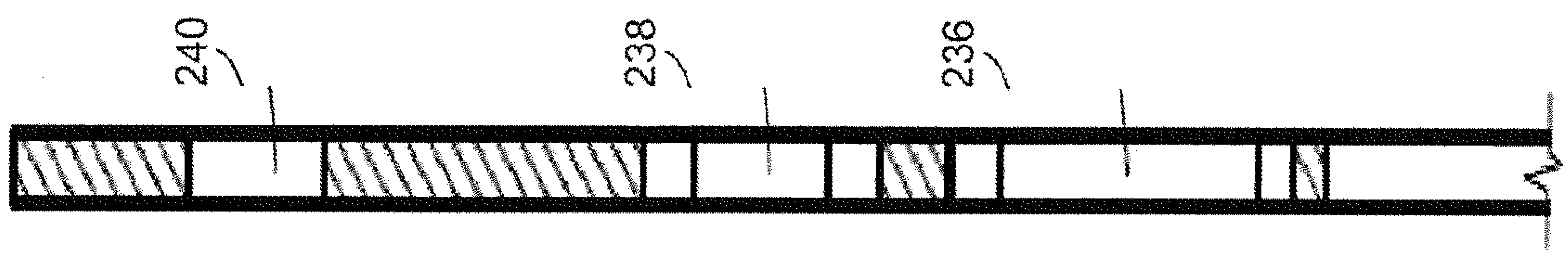


FIG. 7.

FIG. 8.



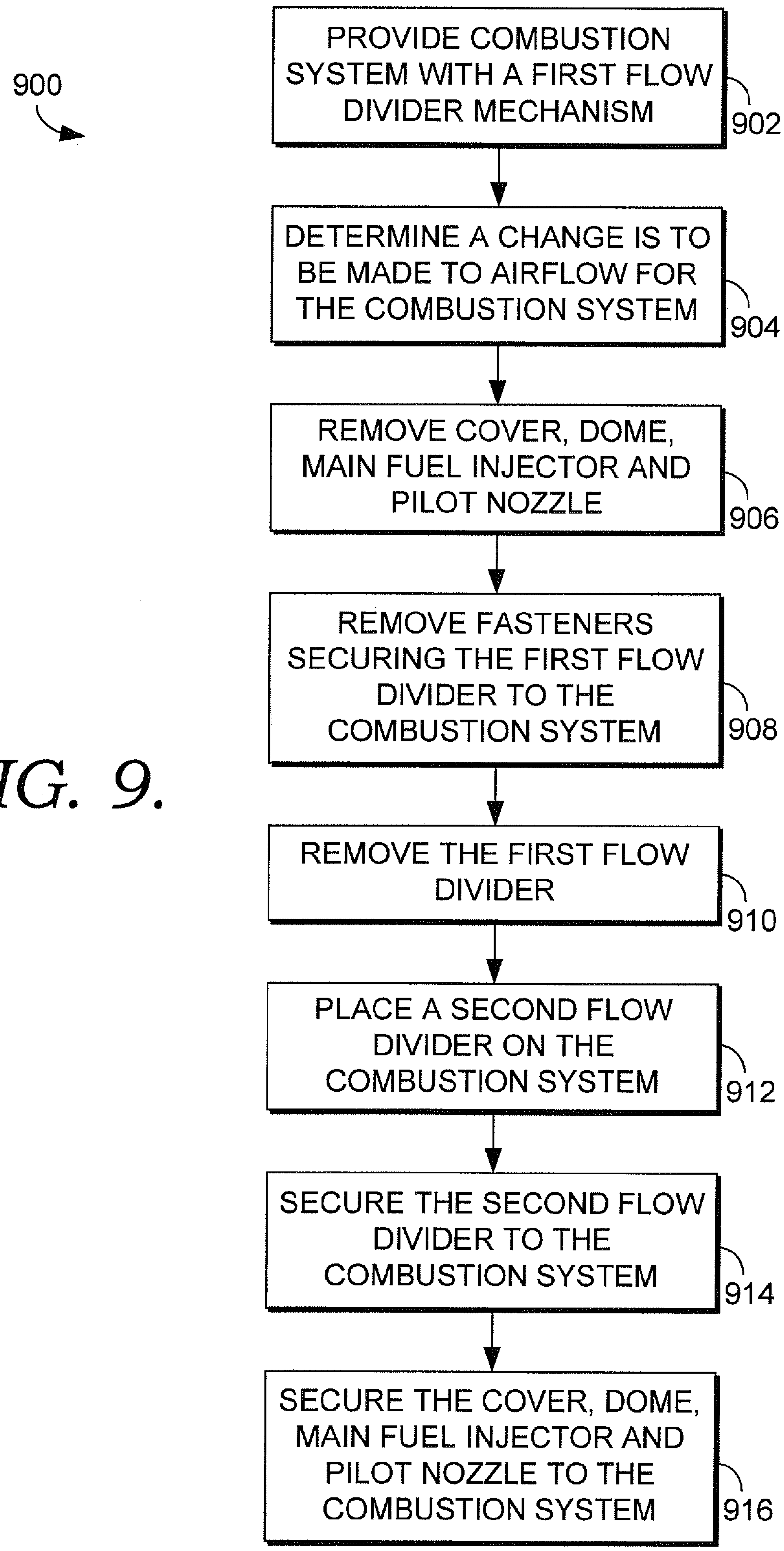

900
PROVIDE COMBUSTION SYSTEM WITH A FIRST FLOW DIVIDER MECHANISM
902
DETERMINE A CHANGE IS TO BE MADE TO AIRFLOW FOR THE COMBUSTION SYSTEM
904
REMOVE COVER, DOME, MAIN FUEL INJECTOR AND PILOT NOZZLE
906
REMOVE FASTENERS SECURING THE FIRST FLOW DIVIDER TO THE COMBUSTION SYSTEM
908
REMOVE THE FIRST FLOW DIVIDER
910
PLACE A SECOND FLOW DIVIDER ON THE COMBUSTION SYSTEM
912
SECURE THE SECOND FLOW DIVIDER TO THE COMBUSTION SYSTEM
914
SECURE THE COVER, DOME, MAIN FUEL INJECTOR AND PILOT NOZZLE TO THE COMBUSTION SYSTEM
916

FIG. 9.

VARIABLE FLOW DIVIDER MECHANISM FOR A MULTI-STAGE COMBUSTOR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Ser. No. 61/708,323 filed on Oct. 1, 2012.

TECHNICAL FIELD

[0002] The present invention relates generally to an apparatus and method for directing a predetermined airflow into a multi-stage gas turbine combustion system. More specifically, an interchangeable plate is positioned within the air flow path, external of the combustion process, to split the air flow between a main combustor stage and a pilot stage.

BACKGROUND OF THE INVENTION

[0003] In an effort to reduce the amount of pollution emissions from gas-powered turbines, governmental agencies have enacted numerous regulations requiring reductions in the amount of oxides of nitrogen (NOx) and carbon monoxide (CO). Lower combustion emissions can often be attributed to a more efficient combustion process, with specific regard to fuel injector location, airflow rates, and mixing effectiveness.

[0004] Early combustion systems utilized diffusion type nozzles, where fuel is mixed with air external to the fuel nozzle by diffusion, proximate the flame zone. Diffusion type nozzles produce high emissions due to the fact that the fuel and air burn essentially upon interaction, without mixing, and stoichiometrically at high temperature to maintain adequate combustor stability and low combustion dynamics.

[0005] An enhancement in combustion technology is the concept of premixing fuel and air prior to combustion to form a homogeneous mixture that burns at a lower temperature than a diffusion type flame and thereby produces lower NOx emissions. Premixing can occur either internal to the fuel nozzle or external thereto, as long as it is upstream of the combustion zone. An example of a premixing combustor of the prior art is shown in FIG. **1**. A combustor **100** has a plurality of fuel nozzles **102**, each injecting fuel into a premix cavity **104** where fuel mixes with compressed air **106** from plenum **108** before entering combustion chamber **110**. Premixing fuel and air together before combustion allows for the fuel and air to form a more homogeneous mixture, which, when ignited will burn more completely, resulting in lower emissions. However, in this configuration the fuel is injected in relatively the same plane of the combustor, and prevents any possibility of improvement through altering the mixing length.

[0006] An alternate means of premixing fuel and air and obtaining lower emissions can occur by utilizing multiple combustion stages. In order to provide a combustor with multiple stages of combustion, the fuel and air, which mix and burn to form the hot combustion gases, must also be staged. By controlling the amount of fuel and air passing into the combustion system, available power as well as emissions can be controlled. Fuel can be staged through a series of valves within the fuel system or dedicated fuel circuits to specific fuel injectors. Air, however, can be more difficult to stage given the large volume of air supplied by the engine compressor. In fact, because of the general design to gas turbine combustion systems, as shown by FIG. **1**, air flow to a combustor is typically controlled by the size of the openings in the combustion liner itself, and is therefore not readily adjustable.

SUMMARY

[0007] The present invention discloses an apparatus and method for controlling the amount of airflow directed into a multi-stage combustion system. More specifically, in an embodiment of the present invention, a flow divider mechanism is provided comprising an annular plate positioned about a combustion liner having a first plurality of openings for regulating airflow to a main stage of the combustion system while a second plurality of openings are located radially outward of the first plurality of openings and regulate airflow to a pilot stage of the combustion system. The flow divider mechanism is secured to the gas turbine combustion system in a way such that it is removable and can be replaced in the field thereby changing the airflow distribution to the combustion system.

[0008] In an alternate embodiment of the present invention, a multi-stage combustion system is provided in which airflow to multiple stages of the combustion system is regulated outside of a combustion liner. The combustion system comprises a flow sleeve surrounding a combustion liner and a flow divider mechanism for directing airflow into a pilot stage and a main combustion stage and a cylindrical flow separator extending from the flow divider mechanism towards an inlet of the combustion liner.

[0009] In yet another embodiment of the present invention, a method of altering an airflow distribution between multiple stages of a combustion system is disclosed. The method comprises providing a combustion system having a first flow divider mechanism capable of dividing airflow between two stages of a combustor, removing a portion of the combustion system in order to access the first flow divider mechanism, removing the first flow divider mechanism and replacing it with a second flow divider mechanism having different airflow characteristics than the first flow divider mechanism. The portion of the combustion system that was removed is then reinstalled and the engine is returned to operation.

[0010] Additional advantages and features of the present invention will be set forth in part in a description which follows, and in part will become apparent to those skilled in the art upon examination of the following, or may be learned from practice of the invention. The instant invention will now be described with particular reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0011] The present invention is described in detail below with reference to the attached drawing figures, wherein:

[0012] FIG. **1** is a cross section of a portion of a gas turbine engine and combustion system of the prior art.

[0013] FIG. **2** is a cross section of a gas turbine combustor in accordance with an embodiment of the present invention.

[0014] FIG. **3** is a cross section of a gas turbine combustor depicting the multiple stages of operation for the combustor of FIG. **2** in accordance with an embodiment of the present invention.

[0015] FIG. **4** is a perspective view of a portion of the gas turbine combustor of FIG. **2** in accordance with an embodiment of the present invention.

[0016] FIG. **5** is a detailed cross section of a portion of the gas turbine combustor of FIG. **2** in accordance with an embodiment of the present invention.

[0017] FIG. **6** is a cross section view of the gas turbine combustor of FIG. **4** in accordance with an embodiment of the present invention.

[0018] FIG. **7** is an end view of a flow divider mechanism in accordance with an embodiment of the present invention.

[0019] FIG. **8** is a partial cross section view of the variable flow meterplate of FIG. **7** in accordance with an embodiment of the present invention.

[0020] FIG. **9** is a flow chart depicting a process of by which airflow to the combustion system is changed in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

[0021] By way of reference, this application incorporates the subject matter of U.S. Pat. Nos. 6,935,116, 6,986,254, 7,137,256, 7,237,384, 7,308,793, 7,513,115, and 7,677,025.

[0022] The present invention discloses an apparatus for and way of regulating and adjusting the airflow distribution to multiple stages of a gas turbine combustion system. That is, embodiments of the invention disclosed provide means for distributing the airflow to stages of the combustor and altering the airflow to the combustion system when it is determined airflow levels to one or more stages of the combustion system should change.

[0023] The present invention will now be discussed with respect to FIGS. **2-8**. An embodiment of a gas turbine combustion system **200** on which the present invention operates is depicted in FIG. **2**. The combustion system **200** is an example of a multi-stage combustion system. The combustion system **200** extends about a longitudinal axis A-A and includes a flow sleeve **202** for directing a predetermined amount of compressor air along an outer surface of a combustion liner **204**. Compressor air then passes through a flow divider mechanism **206** before a portion of the air mixes with fuel from main fuel injectors **208**. The flow divider mechanism **206** is discussed in greater detail below. The divided portions of the flow exiting the airflow divider mechanism **206** remain divided due to a generally cylindrical flow separator **210** that extends from the flow divider mechanism **206** and forward towards an inlet end **212** of the combustion liner **204**.

[0024] The combustion system **200** also comprises a dome **214** that is positioned proximate the inlet end **212** of the combustion liner **204**. The dome **214** has a hemispherical cross-sectional shape such that when encountered by a portion of the airflow, it causes the airflow to reverse direction and enter the combustion liner **204**.

[0025] The combustion system **200** also comprises a radially staged premixer **216** with an end cover **218** having a first fuel plenum **220** extending about the longitudinal axis A-A of the combustion system **200** and a second fuel plenum **222** positioned radially outward of the first fuel plenum **220** and concentric with the first fuel plenum **220**. The radially staged premixer **216** also comprises a radial inflow swirler **224** having a plurality of vanes **226**.

[0026] Extending generally along the longitudinal axis A-A is a pilot fuel nozzle **228** for providing and maintaining a pilot flame for the combustion system. The pilot flame is used to ignite, support and maintain the main combustion flame generated by multiple stages from main fuel injectors **208**.

[0027] As one skilled in the art understands, a gas turbine engine typically incorporates a plurality of combustors. Generally, for the purpose of discussion, the gas turbine engine may include low emission combustors such as those disclosed herein and may be arranged in a can-annular configuration about the gas turbine engine. One type of gas turbine engine (e.g., heavy duty gas turbine engines) may be typically provided with, but not limited to, six to eighteen individual combustors, each of them fitted with the components outlined above. Accordingly, based on the type of gas turbine engine, there may be several different fuel circuits utilized for operating the gas turbine engine. The combustion system **200** disclosed in FIGS. **2** and **3** is a multi-stage premixing combustion system comprising four stages of fuel injection based on the loading of the engine. However, it is envisioned that the specific fuel circuitry and associated control mechanisms could be modified to include fewer or additional fuel circuits.

[0028] The pilot fuel nozzle **228** is connected to a fuel supply (not shown) and provides fuel to the combustion system **200** for supplying a pilot flame **250** where the pilot flame **250** is positioned generally along the longitudinal axis A-A. The radially staged premixer **216** including the fuel plenums **220** and **222**, radial inflow swirler **224** and its plurality of vanes **226** provide a fuel-air mixture through the vanes **226** for supplying additional fuel to the pilot flame **250** by way of a pilot tune stage, or P-tune, **252**.

[0029] As discussed above, combustion system **200** also includes main fuel injectors **208**. For the embodiment of the present invention shown in FIG. **2**, the main fuel injectors **208** are located radially outward of the combustion liner **204** and spread in an annular array about the combustion liner **204**. The main fuel injectors **208** are divided into two stages with a first stage extending approximately 120 degrees about the combustion liner **204** and a second stage extending the remaining annular portion, or approximately 240 degrees, about the combustion liner **204**. The first stage of the main fuel injectors **208** are used to generate a Main 1 flame **254** while the second stage of the main fuel injectors **208** generate a Main 2 flame **256**.

[0030] As discussed above, the present invention provides a flow divider mechanism **206** for regulating and splitting the amount of compressed air supplied to different parts of the combustion liner **204**. A flow divider mechanism **206**, in accordance with an embodiment of the present invention, is shown in detail in FIGS. **4** and **6-8**. The flow divider mechanism **206** comprises an annular plate **230** positioned about the combustion liner **204** and configured to divide a passing airflow between the pilot stage **250**/pilot tune stage **252** and the Main 1 and Main 2 combustion stages, **254** and **256**, respectively. For the embodiment of the present invention shown in FIGS. **4** and **6-8**, the annular plate **230** has a central opening **232**, an outer edge **234**, and a first plurality of openings **236** that are located about the central opening **232**. As it can be seen from FIG. **7**, the first plurality of openings **236** have a generally rectangular cross section and extend radially outward from adjacent the central opening **232**. Although the first plurality of openings can be of different shapes, a radially oriented generally rectangular cross sectional opening maximizes the available flow area for the material of the annular plate **230**. Furthermore, for the embodiment of the present invention shown in FIGS. **4** and **6-8**, the first plurality of openings **236**, through which compressed air for use in generating a main combustion flame (Main 1 and/or Main 2) passes, are preferably in alignment with a corresponding main stage mixing vane (not shown).

[0031] Referring back to FIG. **7**, the annular plate **230** further comprises a second plurality of openings **238** located radially outward of the first plurality of openings **236**. The second plurality of openings **238** regulate the amount of cooling air that is being passed into a passage supplying air to and in support of the pilot flame **250** and pilot tune stage **252**. The second plurality of openings **238** may have a generally rectangular or circular cross section oriented so as to extend radially outward. For the embodiment of the annular plate **230** depicted in FIG. **7**, the second plurality of openings **238** are offset circumferentially from the first plurality of openings **236**, but the first and second plurality of openings can also be in radial alignment. However, as discussed above with respect to first plurality of openings **236**, the second plurality of openings **238** can also vary in size and shape, depending on the airflow requirements and available area in the annular plate **230**.

[0032] The configuration of the annular plate **230** is generally a flat plate having a nominal thickness that should be accounted for in determining flow split. The present invention provides a means for thickness to be accounted for as a varying parameter in the design phase, and as such, is not limited to a specific thickness range.

[0033] The size and shape of the first plurality of openings **236** and the second plurality of openings **238** depends on a variety of conditions, such as size of the combustion system, desired fuel-air mixing levels, and required airflow to various stages of the combustion system, among others. Therefore, the shape of the openings **236** and **238** and their corresponding effective flow area will vary. In one embodiment, it is envisioned that approximately 60% of the compressed air passing through the flow divider mechanism **206** is directed through the first plurality of openings **236** with the remaining approximately 40% of compressed air directed through the second plurality of openings **238**. In alternate embodiments of the present invention, fewer or more openings can be located in the annular plate than those shown in the enclosed figures, such as arc-shaped openings to further increase the effective flow area.

[0034] As discussed above and referring back to FIG. **2**, the airflow exits the flow divider mechanism **206** in divided portions. The airflow portions remain separated due to the generally cylindrical flow separator **210** that extends from the flow divider mechanism **206** and forward towards an inlet end **212** of the combustion liner **204**.

[0035] Referring back to FIG. **7**, the annular plate **230** of the flow divider mechanism **206** further comprises a third plurality of openings **240** located adjacent the outer edge **234**. Instead of regulating airflow, the third plurality of openings **240** are used for properly orienting and securing the flow divider mechanism **206** on the combustion system **200**. The flow divider mechanism **206** is secured to the combustion system **200** by a plurality of removable fasteners (not shown).

[0036] As it can be seen from FIGS. **2** and **5**, the flow divider mechanism **206** is positioned axially between a flange of the flow sleeve **202** and the main injector **208** such that the annular plate **230** of the flow divider mechanism **206** is essentially sandwiched between adjacent components of the combustion system **200**. The fasteners **207** for securing the flow divider mechanism **206** pass through the third plurality of openings **240** and engage openings in the flow sleeve **202**.

[0037] As mentioned briefly above, the combustion system **200** includes a dome **214** having a hemispherical shape. The dome **214** provides a means for reversing a portion of the airflow passing through the flow divider mechanism **206**. More specifically, the first portion of air, which passes through the first plurality of openings **236** initially passes along an outer wall **204**A of the combustion liner **204** while external to the combustion liner and then, due to the dome **214**, reverses direction and passes along an inner wall **204**B of the combustion liner **204**. The portion of the compressed air passing through the second plurality of openings **238** initially passes radially outward of the first portion of the compressed air when external to the combustion liner **204**, but is then positioned radially inward of this first portion of the compressed air once inside the combustion liner **204**. While the dome **214** is used to provide a flow reversal mechanism to the portion of the compressed air passing through the first plurality of openings **236**, the portion of the air which passes through the second plurality of openings **238** reverses flow direction into the combustion liner **204** as a result of passing through the radial inflow swirler **224**.

[0038] In addition to the ability to regulate the amount of compressed air passing into each of the respective circuits of the combustion system, the present invention also provides a way of modifying or adjusting the airflow distribution between multiple stages of a combustion system. Referring to FIG. **9**, the process **900** for altering the airflow distribution to the combustion system **200** is provided. Initially, in a step **902**, the combustion system having a first flow divider mechanism is provided. This combustion system and first flow divider mechanism is similar to that previously described. Then, in a step **904**, a determination is made that a change to the airflow to the combustion system is required. This determination may be made due to a variety of factors such as emissions levels, combustion noise, and turndown, among others.

[0039] Once it has been determined that the airflow split between the pilot and main combustion stages must be changed, in order to access the flow divider mechanism, the cover, dome, main fuel injector and pilot fuel nozzle are removed in a step **906**. Once these components have been removed, the flow divider mechanism is accessible. Then, in a step **908**, the fasteners securing the flow divider mechanism to the combustion system are removed and in a step **910**, the first flow divider mechanism is removed.

[0040] In a step **912**, a second flow divider mechanism is placed on the combustion system. The second flow divider mechanism differs from the first flow divider mechanism in that at least one of the first plurality of openings and/or the second plurality of openings in the second flow divider mechanism differ in size so as to alter the overall effective flow area for the second flow divider mechanism when compared to the first plurality of openings and/or the second plurality of openings and effective flow area in the first flow divider mechanism. Therefore, multiple combinations of possible changes exist and can be made when switching from the first flow divider mechanism to the second flow divider mechanism.

[0041] In a step **914**, the second flow divider mechanism is clocked on the combustion system and secured to the combustion system using fasteners, as discussed above. Once the second flow divider mechanism has been secured to the combustion system, the cover, dome, main fuel injector and pilot nozzle are secured to the combustion system in a step **916**.

[0042] Upon reinstallation of all combustion hardware, fuel lines and any other hardware previously removed, the gas turbine engine can be restarted using the existing controls programming. That is, the changes to airflow to the combustion system are all hardware changes such that little to no software changes should have to be made with respect to the airflow changes. Slight changes in fuel scheduling may be required in order to ensure emissions compliance is maintained given the altered airflow configuration. If, upon further operation and analysis, it is determined that there must be another change to the airflow split of the combustion system, the process outlined above can be repeated and the second flow divider mechanism replaced with yet another flow divider mechanism.

[0043] While the invention has been described in what is known as presently the preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment but, on the contrary, is intended to cover various modifications and equivalent arrangements within the scope of the following claims. The present invention has been described in relation to particular embodiments, which are intended in all respects to be illustrative rather than restrictive.

[0044] From the foregoing, it will be seen that this invention is one well adapted to attain all the ends and objects set forth above, together with other advantages which are obvious and inherent to the system and method. It will be understood that certain features and sub-combinations are of utility and may be employed without reference to other features and sub-combinations. This is contemplated by and within the scope of the claims.

1. A flow divider mechanism comprising an annular plate positioned about a combustion liner for dividing airflow into a pilot stage and a main combustion stage of a gas turbine combustor, the annular plate having a central opening, an outer edge, a first plurality of openings located about the central opening, a second plurality of openings located radially outward of the first plurality of openings, and a third plurality of openings located adjacent the outer edge, wherein the first plurality of openings and second plurality of openings are sized to regulate and direct a predetermined amount of airflow through multiple stages of the gas turbine combustor.

2. The flow divider mechanism of claim **1**, wherein the second plurality of openings are offset circumferentially from the first plurality of openings.

3. The flow divider mechanism of claim **1**, wherein compressed air for use in generating a main stage combustion flame passes through the first plurality of openings in the annular plate.

4. The flow divider mechanism of claim **3**, wherein compressed air for use in generating and supporting a pilot flame passes through the second plurality of openings in the annular plate.

5. The flow divider mechanism of claim **1** further comprising a flow separator extending co-annular with the annular plate and perpendicular relative to the annular plate.

6. The flow divider mechanism of claim **1**, wherein the third plurality of openings are used for clocking and securing the flow divider mechanism to the gas turbine combustor.

7. The flow divider mechanism of claim **1**, wherein the first plurality of openings are in alignment with a corresponding main stage mixing vane.

8. A multi-stage combustion system for directing a predetermined amount of compressed air from outside of a combustion liner to multiple stages within the combustion liner, the combustion system comprising:

a flow sleeve surrounding the combustion liner;

a flow divider mechanism positioned axially between the flow sleeve and a main injector, the flow divider mechanism comprising an annular plate positioned about the combustion liner for dividing airflow passing between the flow sleeve and the combustion liner into a first portion and a second portion, the annular plate having a central opening, an outer edge, a first plurality of openings located about the central opening, a second plurality of openings located radially outward of the first plurality of openings, a third plurality of openings located adjacent an outer edge; and

a cylindrical flow separator extending from the annular plate and towards an inlet end of the combustion liner;

wherein compressed air passing between an outer wall of the combustion liner and the flow sleeve is split into two portions, with a first portion directed through the first plurality of openings and a second portion directed through the second plurality of openings, the first portion supplying compressed air to a main stage of combustion and the second portion supplying air to a pilot stage.

9. The combustion system of claim **8** further comprising a dome having a hemispherical portion which causes a reversal in flow direction of the first portion of compressed air.

10. The combustion system of claim **9**, wherein the first portion of compressed air passes along an outer wall of the combustion liner when external to the combustion liner and along an inner wall of the combustion liner after encountering the dome.

11. The combustion system of claim **10**, wherein the second portion of compressed air passes radially outward of the first portion of compressed air when external to the combustion liner and radially inward of the first portion of compressed air when internal of the combustion liner.

12. The combustion system of claim **8**, wherein the first plurality of openings are in airflow alignment with a corresponding main stage mixing vane.

13. The combustion system of claim **8**, wherein the flow divider mechanism is secured to the combustion system using the third plurality of openings.

14. The combustion system of claim **13**, wherein the flow divider mechanism is interchangeable upon disengagement of surrounding combustion hardware and fasteners securing the flow divider mechanism to the combustion system.

15. A method of altering an airflow distribution between multiple stages of a combustion system comprising:

providing a combustion system having a first flow divider mechanism in which compressed air for use in combustion is divided into a first portion and a second portion by an annular plate having a first plurality of openings and a second plurality of openings;

removing a cover, dome, main fuel injector, and pilot nozzle from the combustion system;

removing fasteners securing the first flow divider to the combustion system;

removing the first flow divider;

placing a second flow divider on the combustion system, the second flow divider having a first plurality of openings and a second plurality of openings, where at least one of the first plurality of openings or the second plurality of the second flow divider differs from the first plurality of openings or a second plurality of openings of the first flow divider;

securing the second flow divider to the combustion system; and

securing the cover, dome, main fuel injector and pilot nozzle to the combustion system such that the second flow divider is positioned axially between flanges of the main fuel injector and a flow sleeve.

16. The method of claim **15**, wherein the second plurality of openings in the second flow divider has an effective flow area greater than an effective flow area for the second plurality of openings in the first flow divider.

17. The method of claim **15**, wherein the second plurality of openings in the second flow divider has an effective flow area less than an effective flow area for the second plurality of openings in the first flow divider.

18. The method of claim **15**, wherein the first plurality of openings in the second flow divider has an effective flow area greater than an effective flow area for the first plurality of openings in the first flow divider.

19. The method of claim **15**, wherein the first plurality of openings in the second flow divider has an effective flow area less than an effective flow area for the first plurality of openings in the first flow divider.

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