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

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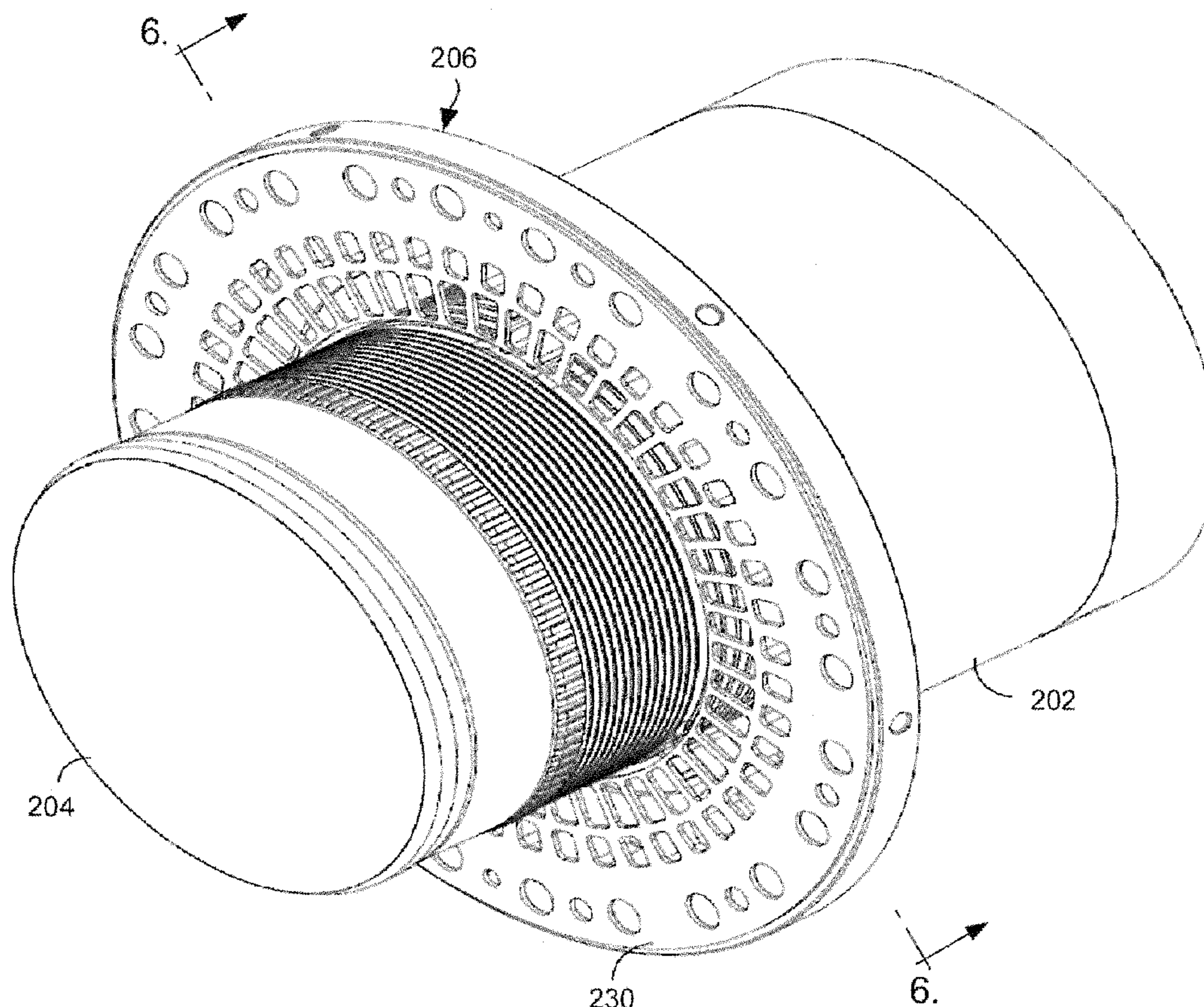
(57) **ABSTRACT**

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.

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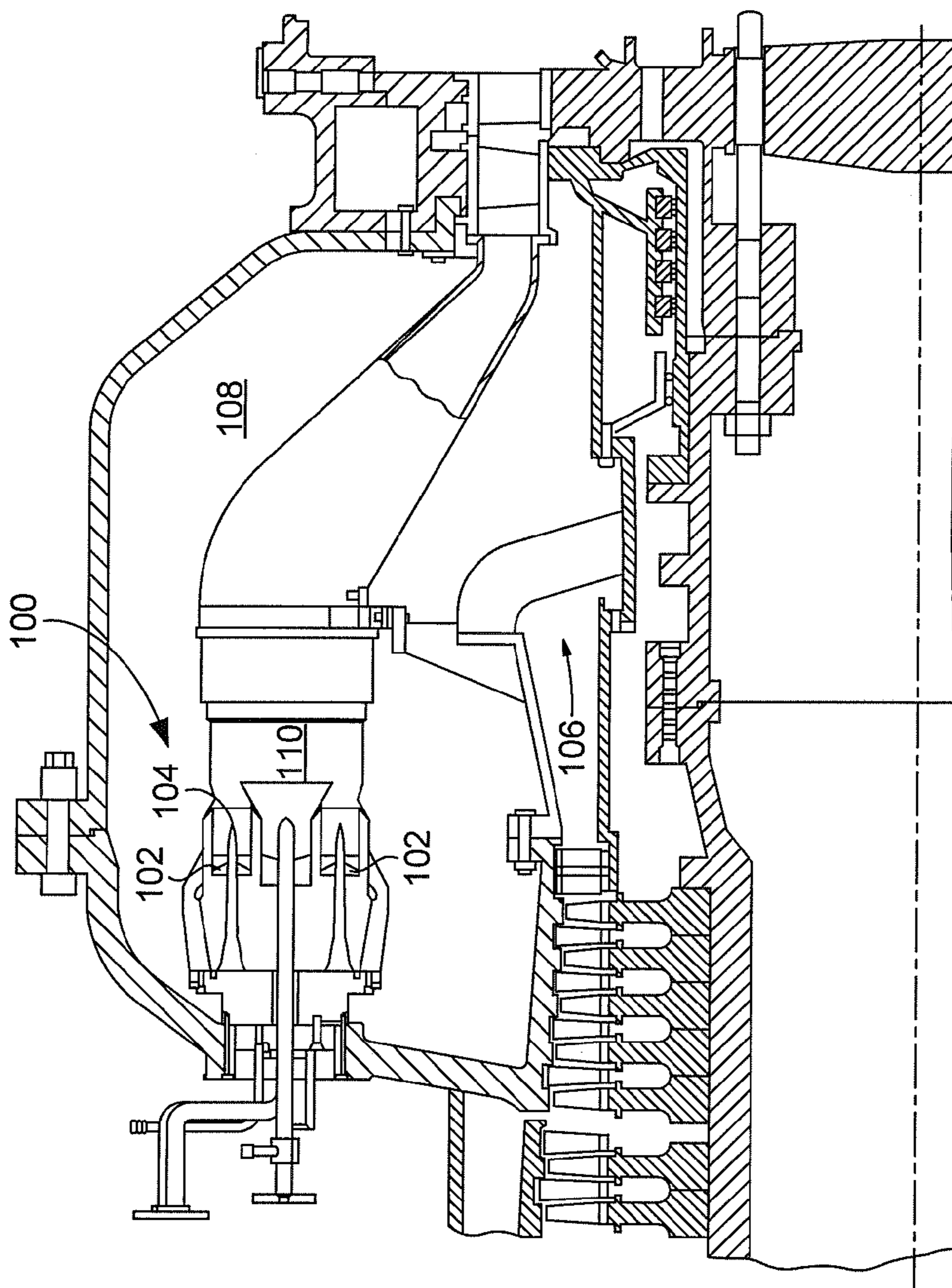


FIG. 1.
PRIOR ART

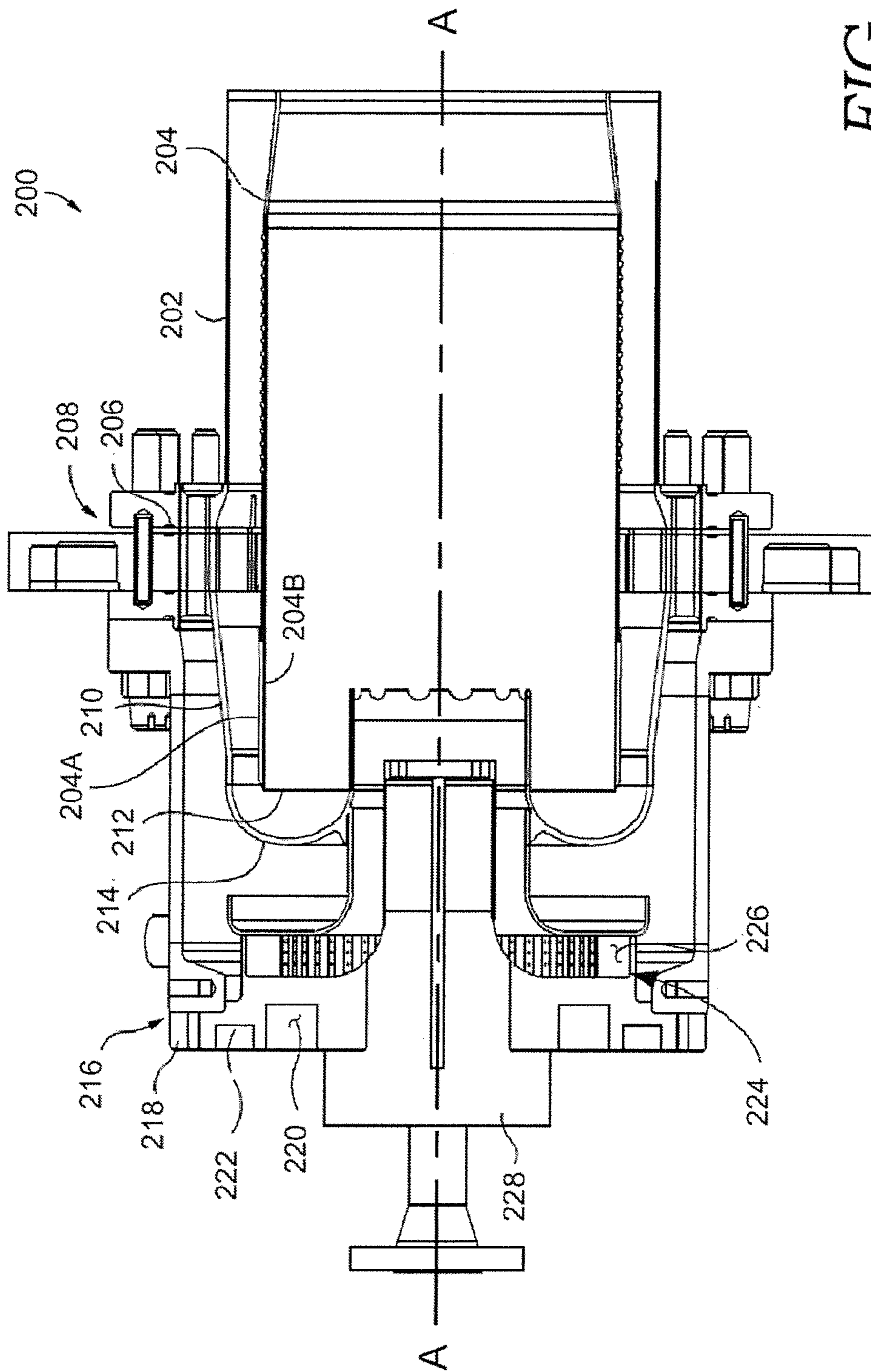


FIG. 2.

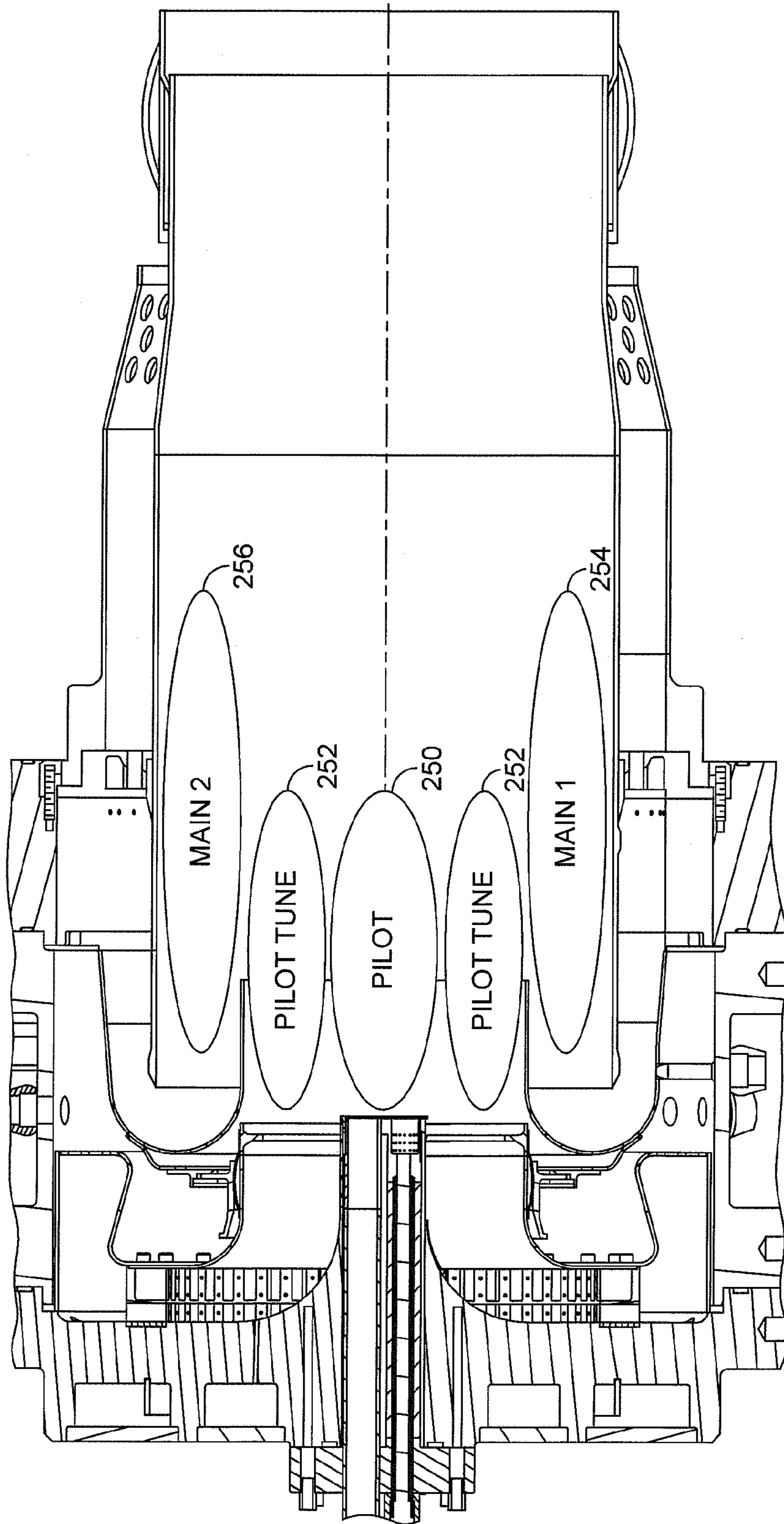
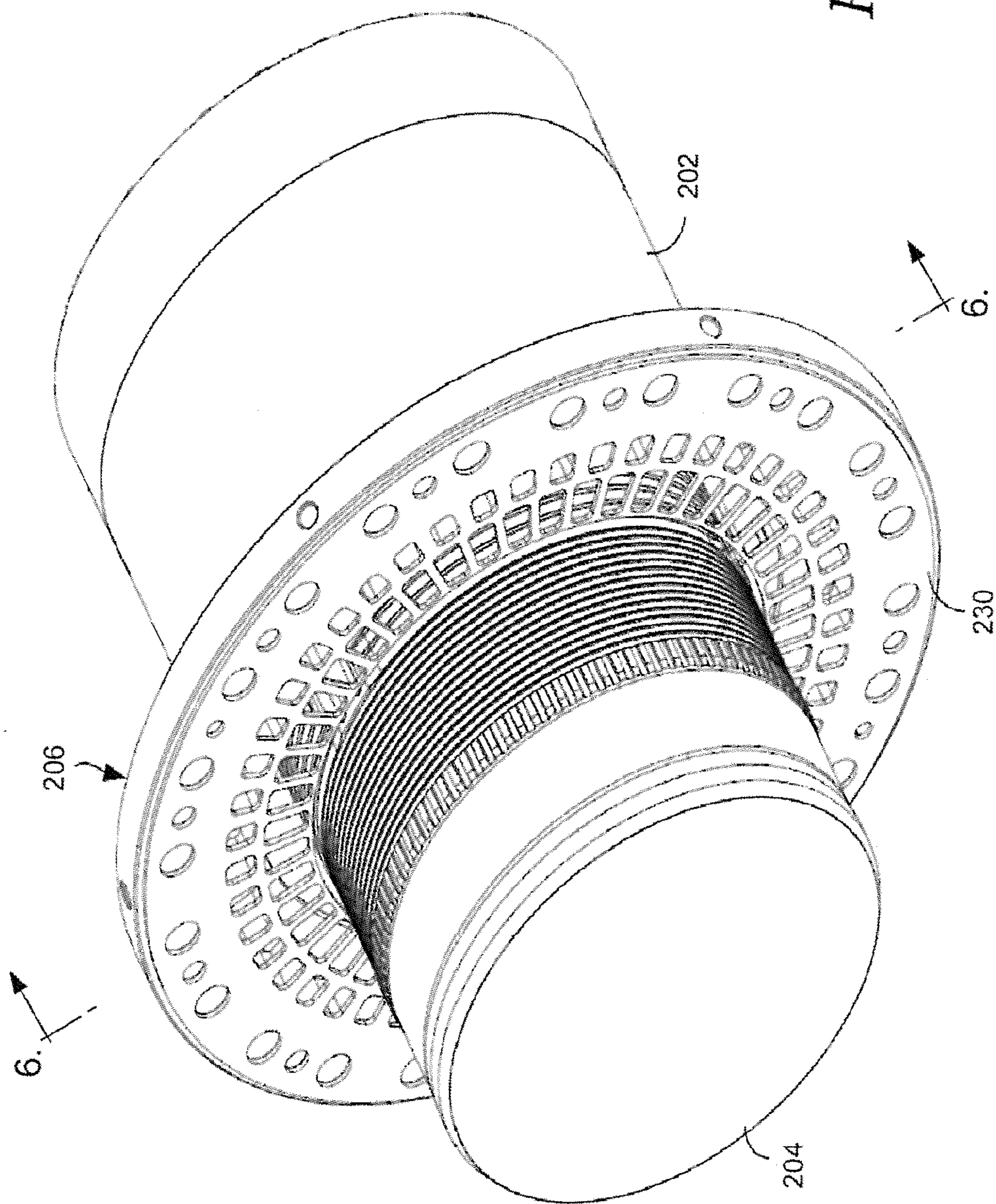


FIG. 3.



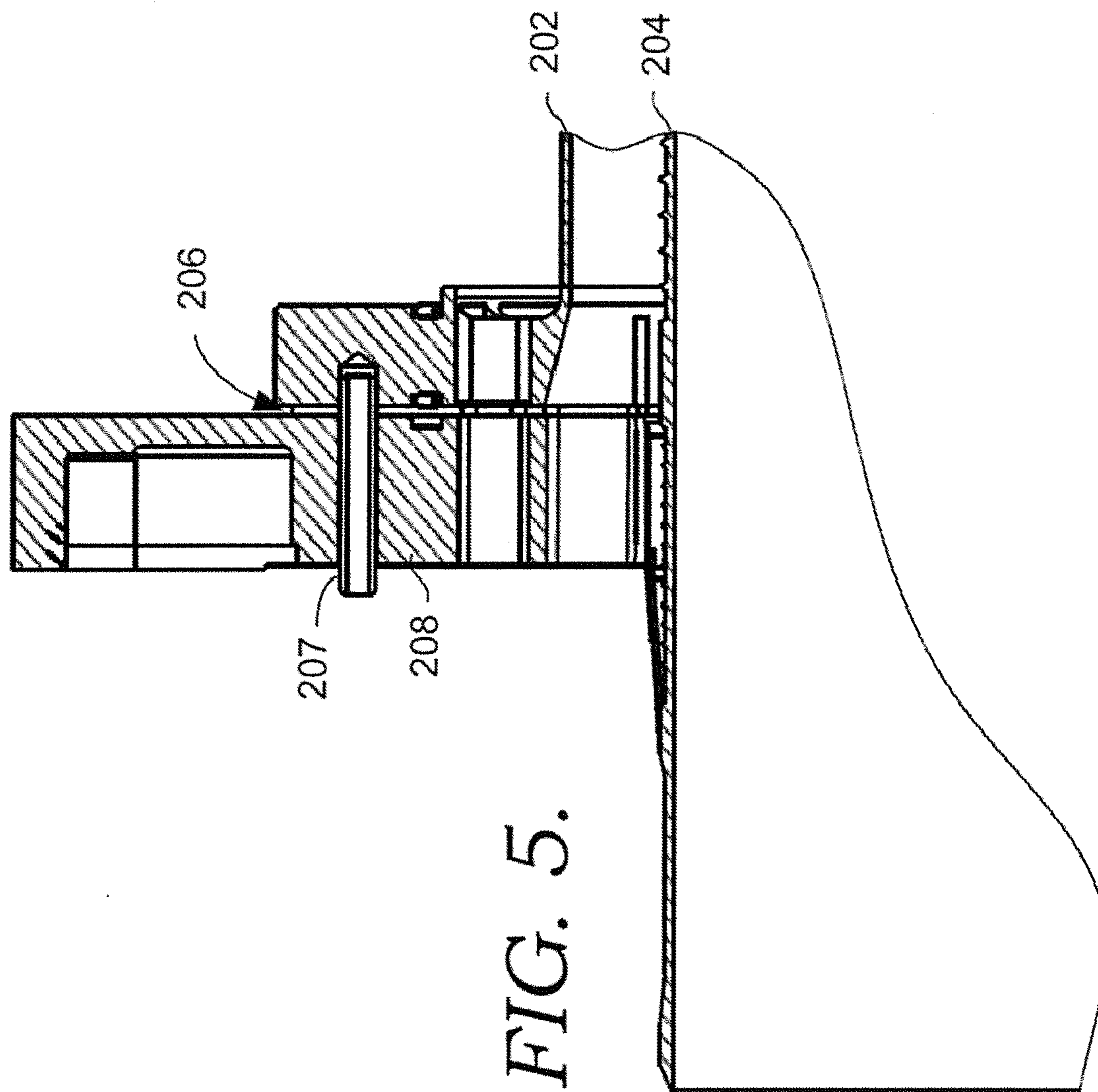


FIG. 5.

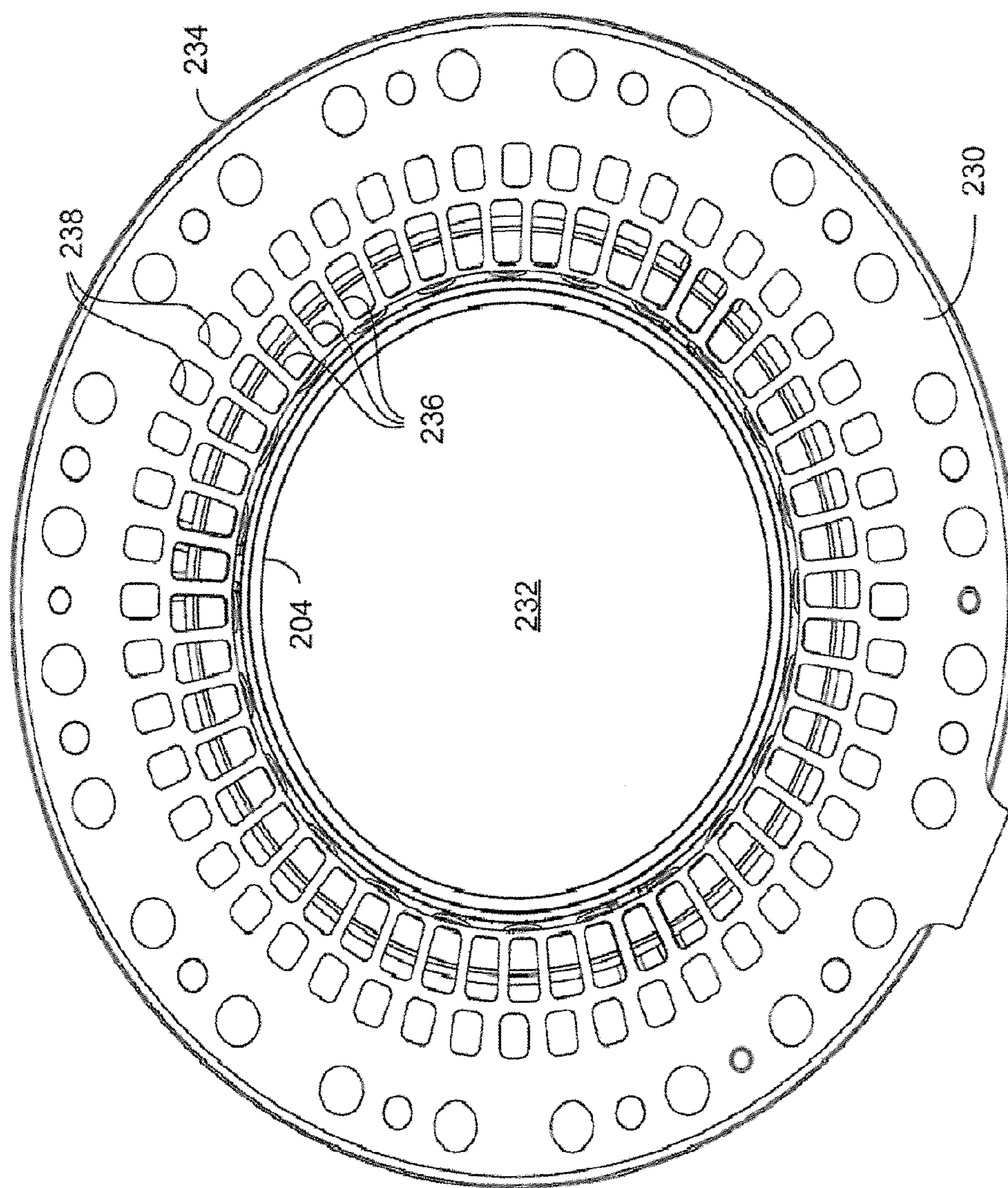


FIG. 6.

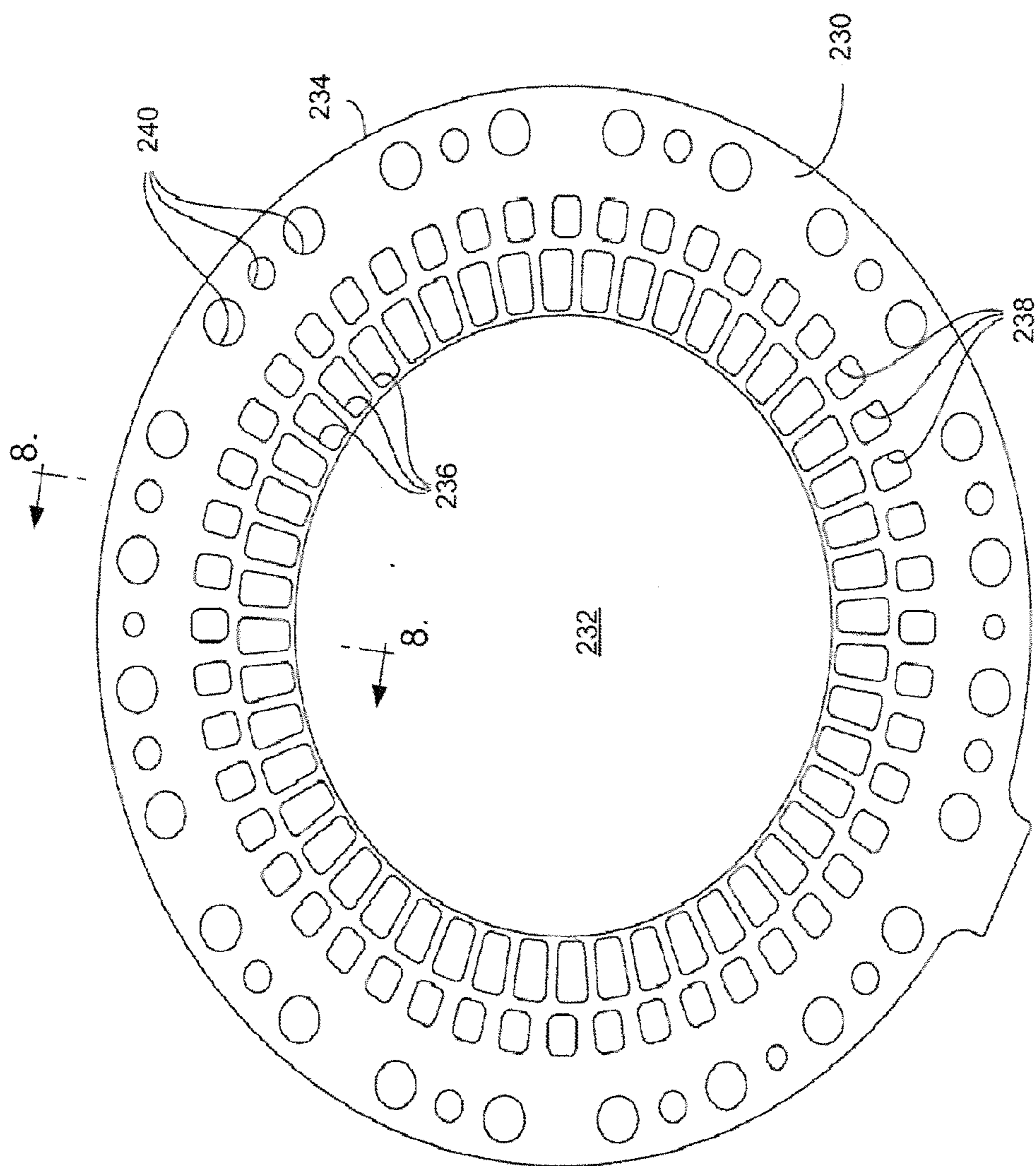
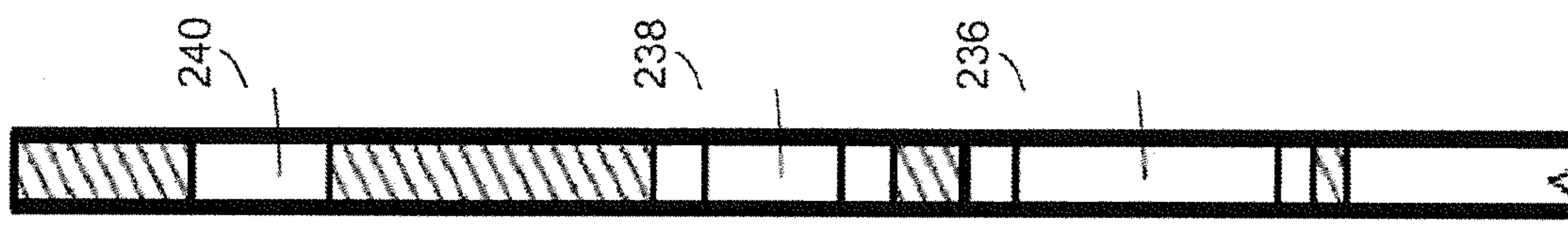


FIG. 7.

FIG. 8.



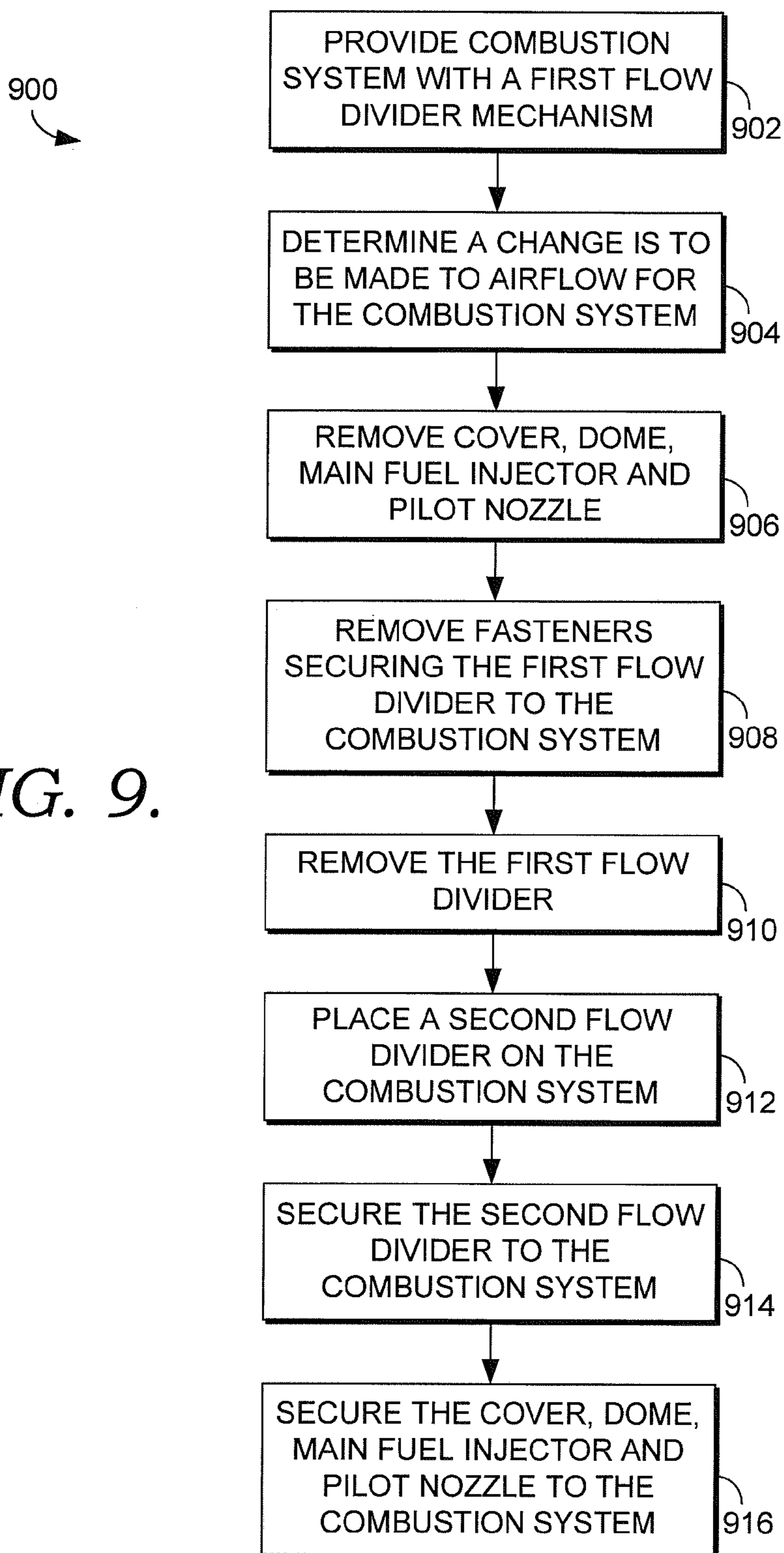


FIG. 9.

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 (NO_x) 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 NO_x 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 com-

burner 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 204A 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 204B 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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