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(54) GAS TURBINE WITH COMBINED CAN-TYPE AND ANNULAR COMBUSTOR AND METHOD OF OPERATING A GAS TURBINE

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(57) **ABSTRACT**

A gas turbine is provided which has a combustor comprising a plurality of can-type combustor elements and an annular element. Isolated combustion takes place in the can-type combustor thereby generating individual component hot gas streams. The component hot gas streams are merged in the annular part. Combustion oscillations are substantially avoided by decoupling combustion flames. Accordingly, temperature and pressure homogenization as well as combustion stabilization by cross-ignition is effected.

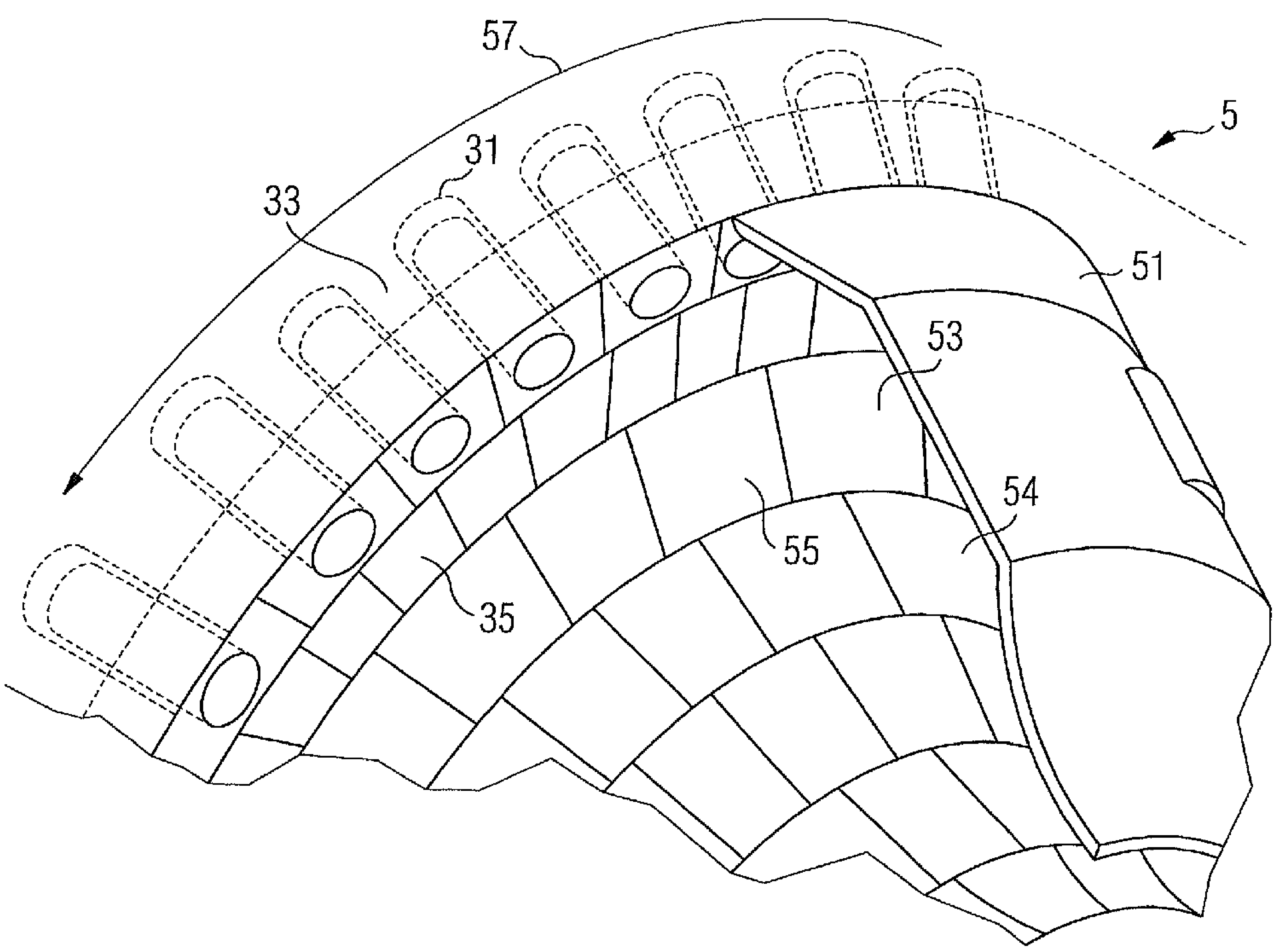


FIG 1

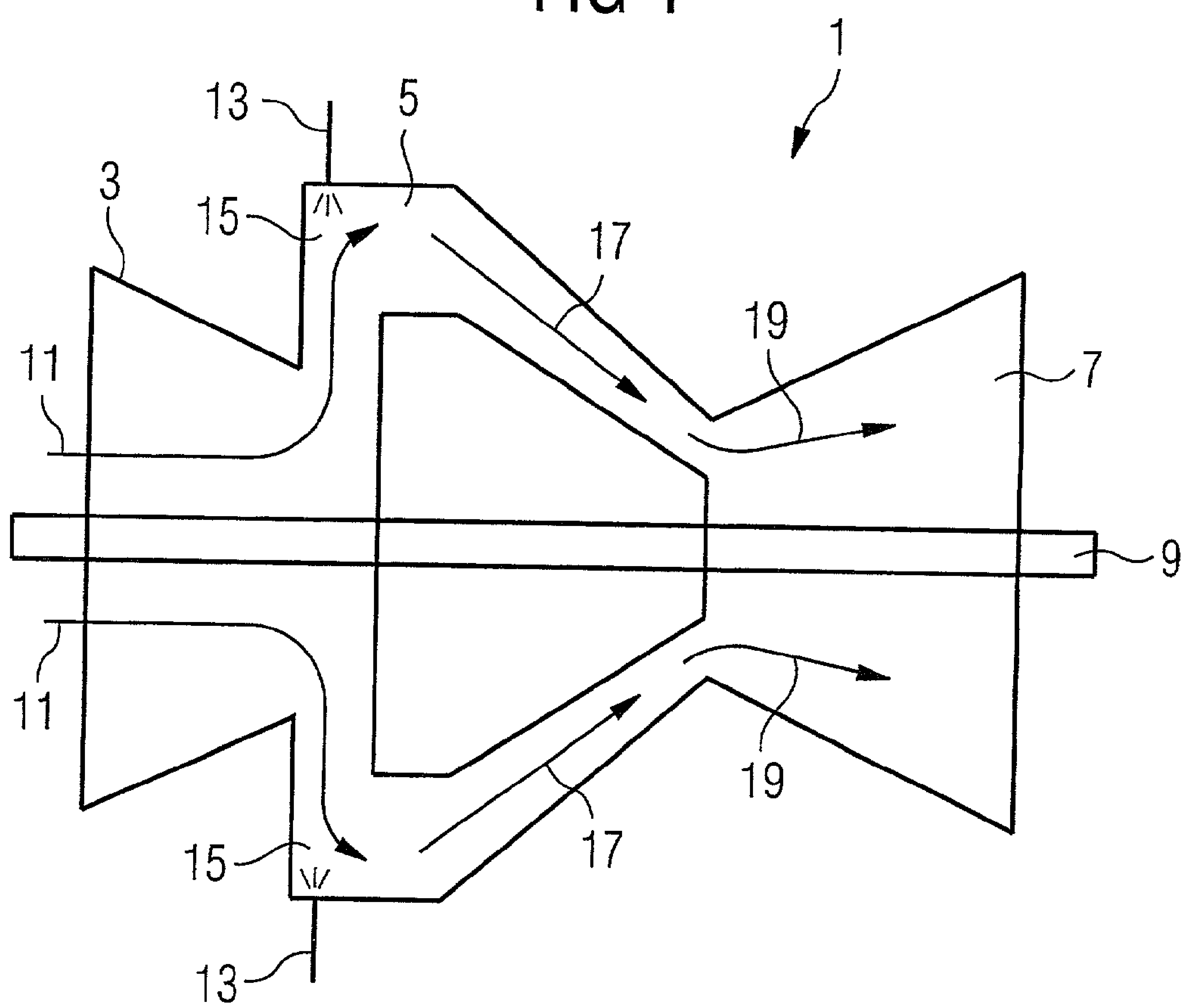


FIG 2 PRIOR ART

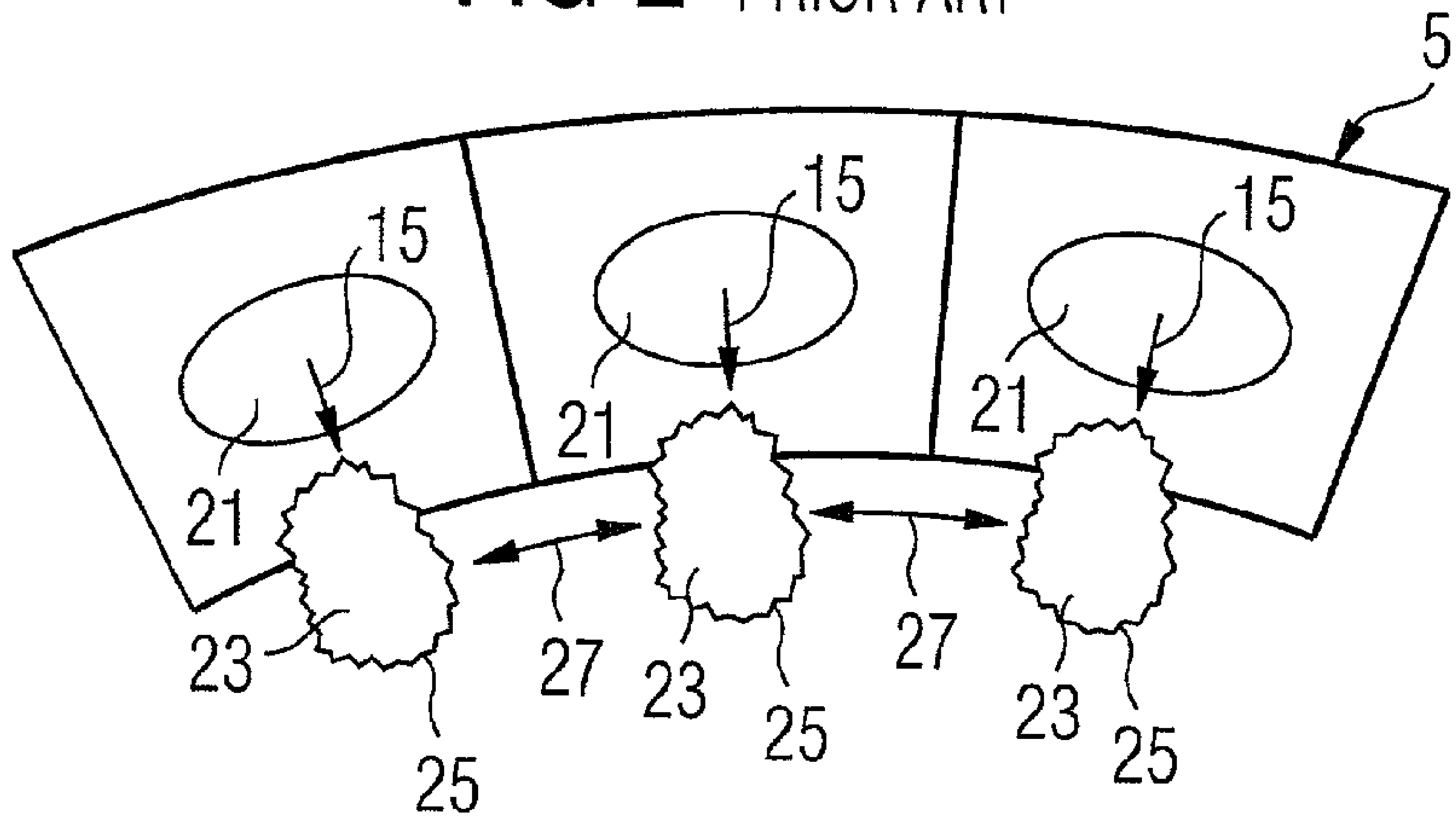
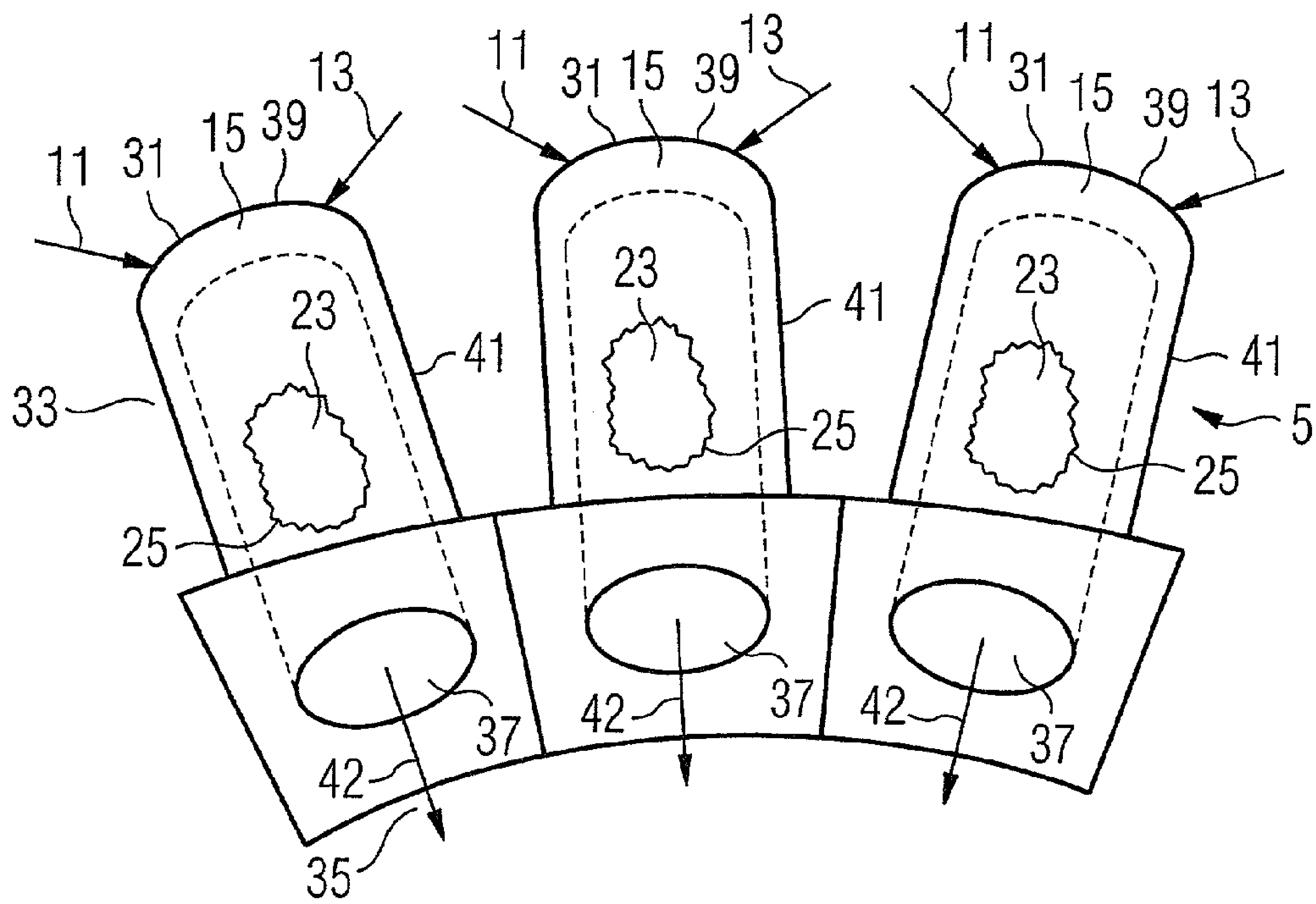


FIG 3



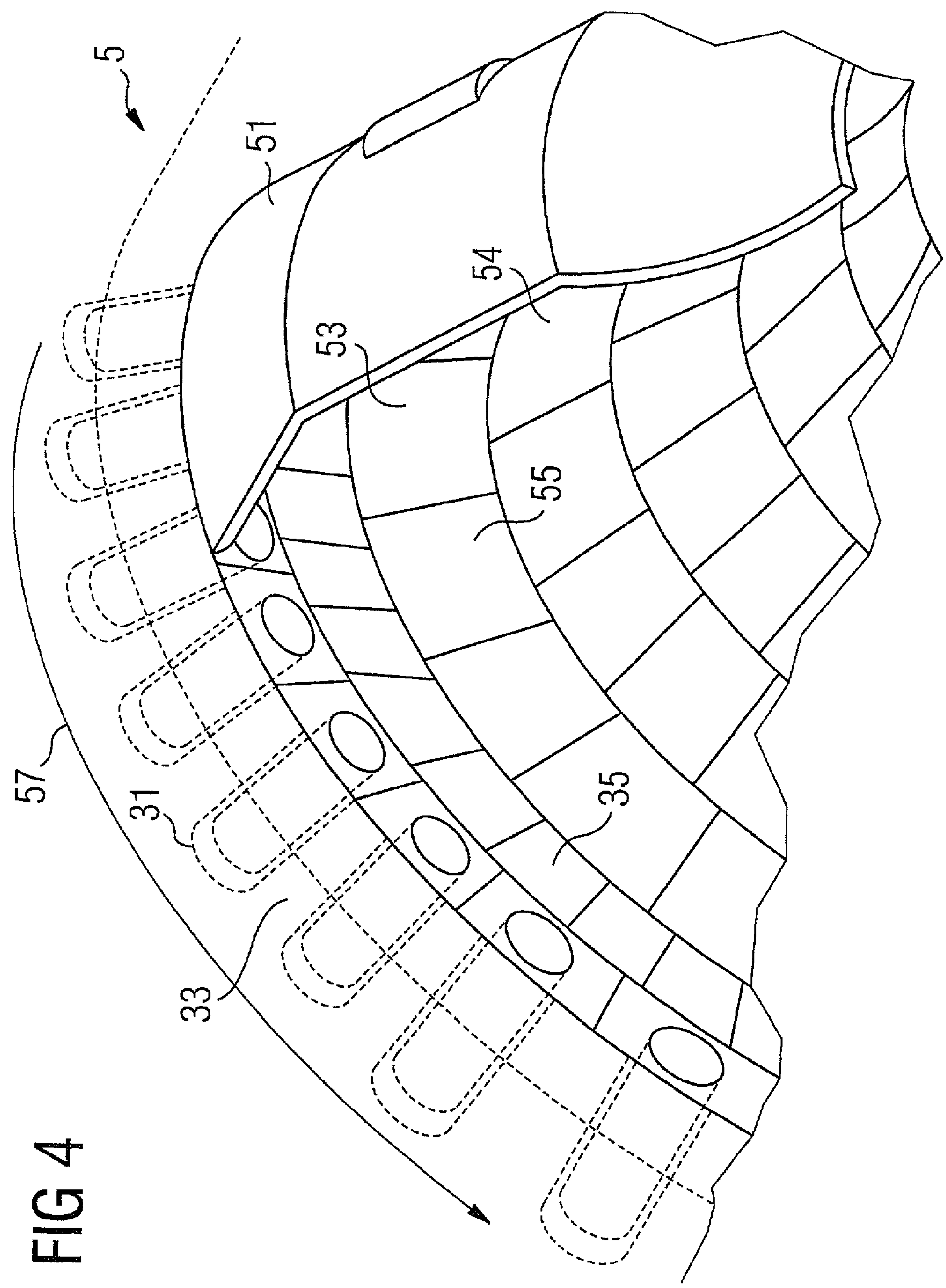


FIG 4

FIG 5

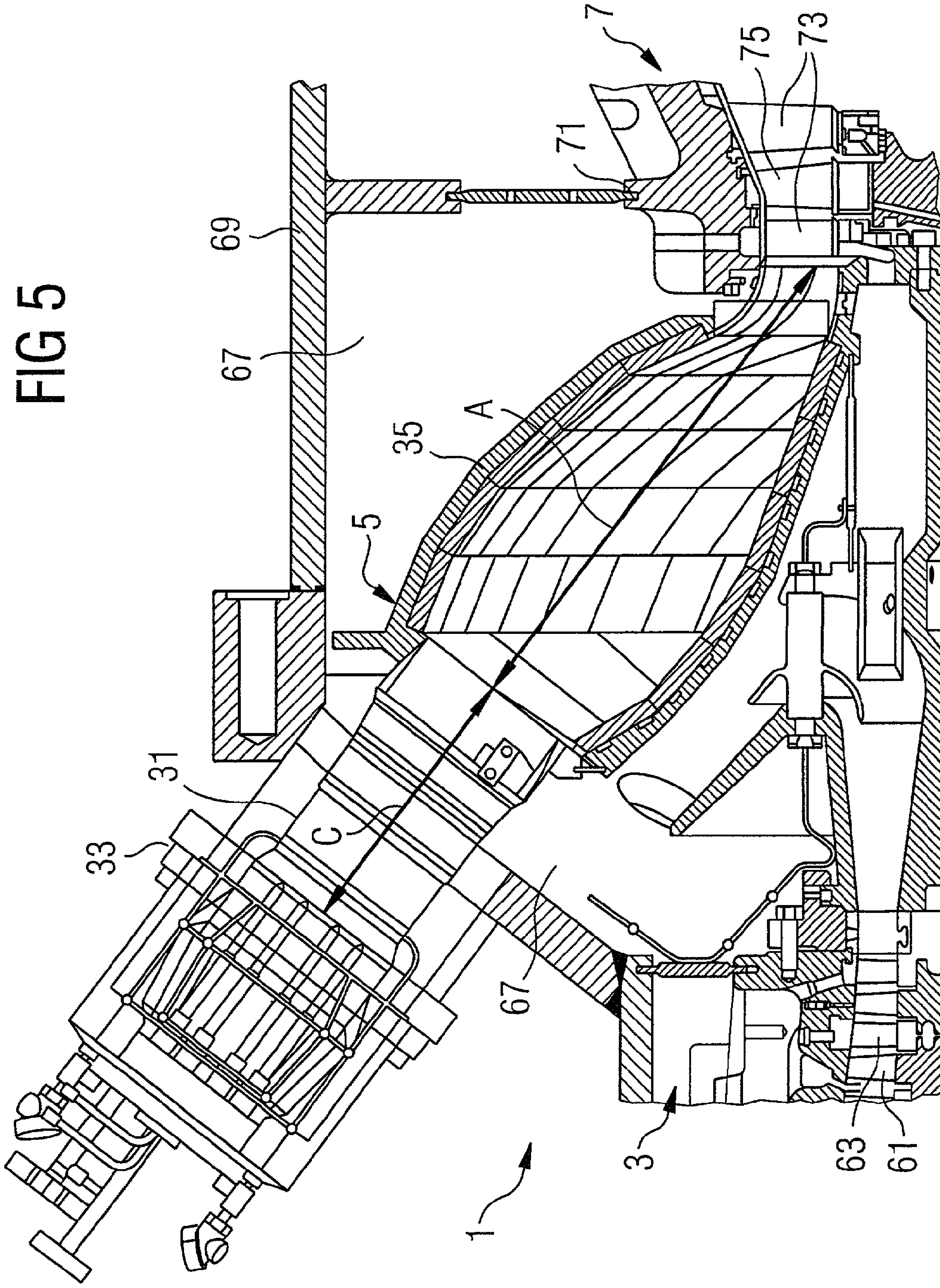
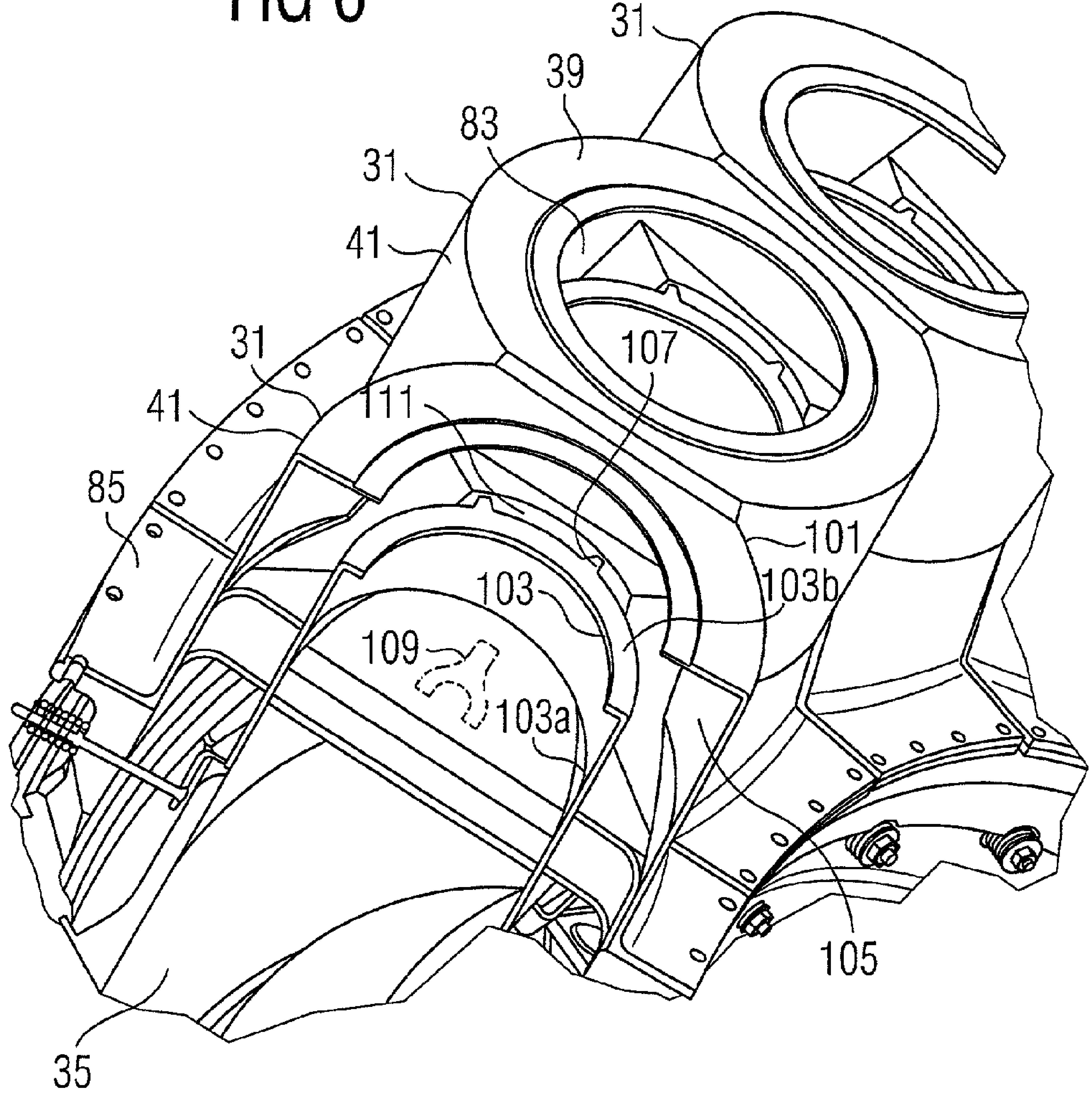


FIG 6



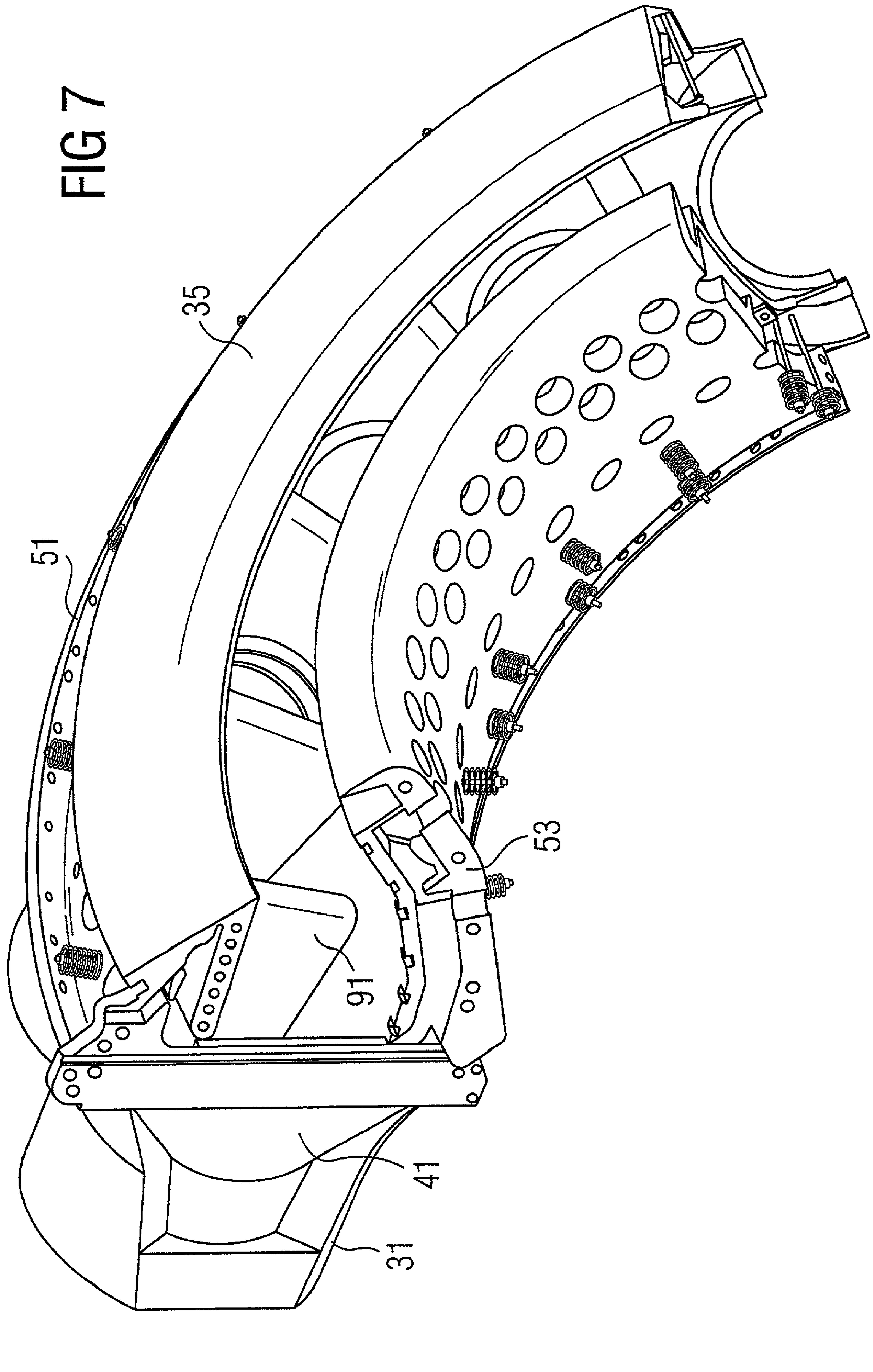


FIG 7

GAS TURBINE WITH COMBINED CAN-TYPE AND ANNULAR COMBUSTOR AND METHOD OF OPERATING A GAS TURBINE

BACKGROUND OF THE INVENTION

[0001] The invention is related to the field of gas turbines and, more particularly, to operating conditions of gas turbines, where combustion oscillations may occur.

[0002] Gas turbines are widely used for power generation as well as in jet engine aircrafts. In a gas turbine, air and fuel are incinerated in a combustor, leading to the generation of a hot gas stream which expands in a turbine part, thereby rotating a shaft. A part of the so generated rotational energy is used for driving a compressor and providing compressed air for the combustor.

[0003] Efforts for reducing emissions, in particular nitrogenmonoxide NO_x, have led to the concept of lean combustion, where air and fuel are not mixed directly in the combustion flame but rather in advance, i.e. in an area different from the actual combustion zone. After mixing, the well-homogenized mixture is subsequently conducted to the combustion zone. This premixing of fuel and air has the advantage that low fuel/air ratios could be achieved, resulting in low flame temperatures and, accordingly, low NO_x emissions. On the other hand, with the lean combustion process, flame instabilities are more likely to occur, which can in turn lead to combustion oscillations. Combustion oscillations are acoustical modes that arise from a positive coupling between pressure fluctuations caused by flame instabilities and acoustical reflections from combustor walls. The combustion oscillations produce high noise emissions and may lead to extensive damage to gas turbine parts.

[0004] German published patent application DE 43 39 094 A1 sets out a method of suppressing combustion oscillations in a gas turbine by injecting an inert fluid into the combustion zone, thereby redistributing the combustion zone and disturbing the mechanism that establishes the combustion oscillation. This method is applied to an annular combustor which is specifically susceptible to combustion oscillations because of the large space usually defined by this geometry. The method belongs to the category of active instability control, because combustion oscillations are monitored and suppressed with a closed loop active control cycle. However, active instability control is a complex and expensive method, introducing a significant cost increase for the equipment needed to operate the gas turbine.

[0005] WO 00/12939 sets out a gas turbine with an annular combustor, to which a plurality of burners are connected. Here, the problem of combustion oscillations in the annular combustor is avoided by a passive measure: Cylindrical means are installed around the orifices of several of the burners, which leads to a shift of the flame position and therefore to a detuning of acoustical modes occurring in the combustor. Passive measures are generally less expensive than active instability control, however, only certain frequency bands are normally suppressed by the static means.

[0006] U.S. Pat. No. 5,309,710 sets out a can-type combustor for a gas turbine. Can-type combustors are less prone to combustion oscillations. However, the can-type construction is more complex and expensive and not as easy to service as an annular combustor. Moreover, an annular combustor provides a more homogenous temperature and pressure distribution at the turbine inlet, which is unavailable in the can-type combustors.

BRIEF SUMMARY OF THE INVENTION

[0007] In view of the foregoing, the present invention provides a gas turbine and a method of operating a gas turbine which substantially avoids combustion oscillations. The present invention also advantageously provides a gas turbine and a method of operating a gas turbine which leads to a homogenous pressure and temperature distribution of a hot gas stream at a turbine inlet. Additionally, the present invention provides a gas turbine and a method of operating a gas turbine which is easy to service. It is another advantage of the invention to provide a method which can be implemented so as to enable mass production at reasonable engineering effort and expense and with maximally replicable component characteristics. As a further advantage, the present invention provides a gas turbine and a method of operating a gas turbine which requires comparably low cooling. The present invention further advantageously provides a gas turbine and a method of operating a gas turbine which requires comparably low complexity of construction and therefore leads to lower costs. Additionally, the present invention provides a gas turbine and a method of operating a gas turbine which is comparably stable in operation. As a further advantage, the invention provides a gas turbine and a method of operating a gas turbine which lowers sealing requirements for sealing against the hot gas.

[0008] More particularly, the present invention provides a gas turbine, comprising a combustor for combustion of an air/fuel-mixture, thereby generating a hot gas stream, and a turbine with a turbine inlet through which the hot gas stream is conducted, wherein the combustor comprises an annular part, located next to the turbine inlet and a can-type part, comprising a plurality of can-type combustors, each connected to the annular part and opened to the annular part through a respective can outlet. The combination of a can-type combustor with an annular combustor combines advantages of the respective single concepts, thereby avoiding disadvantages of the respective single concepts. In particular, separate combustion within the can-type part avoids coupling of flame instabilities, thereby avoiding combustion oscillations. Moreover, resulting from the annular part, the temperature and pressure at the turbine inlet is homogenized. Additionally, cross-ignition within the annular combustor assures stable operation with all operating conditions. Furthermore, the overall surface of the combustor that needs to be cooled is smaller compared to a can-type combustor or element thereby resulting in decreased cooling requirements.

[0009] Preferably, the can-type combustors each have a head-part and a sidewall extending from said head-part to said can outlet. Through the head part fuel and air is introduced into the can-type combustors. A main combustion zone is defined as being the zone of a visible flame. The extension of the sidewall of each can-type combustor is preferably sized such that each can-type combustor encloses essentially a complete main combustion zone. In another preferred embodiment, the extension of the sidewall of each can-type combustor is sized such that it does not significantly exceed the main combustion zone. By enclosing essentially all of the main combustion zones, a high degree of decoupling between the different flames is achieved. In that the sidewalls do not significantly exceed the main combustion zones, unnecessary enlargement of the combustor is avoided, thereby keeping cooling requirements and construction costs low.

[**0010**] The annular part has an annular part axial extension, measured along the direction of said hot gas stream and the can-type part has a can-type part axial extension, measured along the direction of the hot gas stream and the annular part axial extension is preferably at least a half of the can-type part axial extension. This assures a sufficient merger of the individual hot gas streams from the can-type combustors, resulting in a high degree of homogenization of temperature and pressure.

[**0011**] The turbine inlet is at least partially formed by a vane support structure, carrying vanes located in the turbine and the annular part is preferably connected to and thereby supported by the vane support structure. As a main advantage, sealing of clearances between the combustor and the turbine come out to be comparably easy because of lack of relative movement of these parts against one another.

[**0012**] Each of the can-type combustors is preferably connected to the annular part and thereby supported by the annular part. Accordingly, sealing of clearances between the can-type combustors and the annular part come out to be comparably easy because of lack of relative movement of these parts against one another. Moreover, the support of the can-type combustors is less complex compared to combustors which have only cans, because those usually require support from an outer casing. Accordingly, costs are reduced. In a further preferred embodiment, each of the connections of the can-type combustors to the annular part is designed in such a manner that each of the can-type combustors is individually easily removable from the annular part, thereby leading to a construction that is easy to service by simply exchanging single can-type combustors.

[**0013**] The can-type combustors are preferably equally distributed along the circumference of the annular part, thereby defining hollow spaces between respective sidewalls of adjacent can-type combustors. The hollow spaces can be used for introducing a cooling fluid for cooling of the can-type combustors.

[**0014**] The annular part is preferably designed with a radically outward located outer shell and a radially inward located inner shell, wherein ribs, extending from the outer shell to the inner shell, are located next to the can-type part and wherein each of said can-type combustors is connected with its side wall to at least one of said ribs.

[**0015**] Preferably, the sidewalls are diffuser-shaped; thereby diffusing the hot gas stream discharged from the can-type combustors into the annular part.

[**0016**] Also, the present invention provides a gas turbine with a combustor for combustion of an air/fuel-mixture, thereby generating a main hot gas stream and a turbine with a turbine inlet through which the main hot gas stream is conducted, wherein the combustor comprises a first stage in which individual hot gas streams are generated in distinct main combustion zones, which are defined to be the region of a visible flame, each combustion zone being separated from another, wherein the first region of the combustor is followed by a second region in which the individual hot gas streams are brought together to form the main hot gas stream. The second region is preferably designed to assure appropriate intermixing of the individual hot gas streams, thereby homogenizing the temperature distribution in the main hot gas stream.

[**0017**] Also, the present invention provides a method for reducing combustion oscillations in a gas turbine, the method comprising the following steps: conducting air and fuel to a plurality of distinct combustion zones, incinerating the air and fuel in the distinct combustion zones which isolated from one another, thereby generating individual hot gas streams and thereby substantially avoiding acoustical coupling of flame instabilities occurring in the distinct combustion zones, merging the individual hot gas streams to a main hot gas stream thereby substantially homogenizing the temperature and pressure distribution and feeding the main hot gas stream through a turbine inlet. The advantages of this method correspond to the foregoing described advantages of the gas turbine.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[**0018**] Some of the features, advantages, and benefits of the present invention having been stated, others will become apparent as the description proceeds when taken in conjunction with the accompanying drawings in which:

[**0019**] **FIG. 1** is a schematic view on a gas turbine,

[**0020**] **FIG. 2** illustrates combustion in an annular combustor,

[**0021**] **FIG. 3** illustrates schematically an improvement of the present invention over that shown in **FIG. 2**,

[**0022**] **FIG. 4** illustrates a plurality of can-type combustors connected to an annular combustor

[**0023**] **FIG. 5** illustrates in a longitudinal section a gas turbine with a can-type combustor connected to an annular combustor.

[**0024**] **FIGS. 6 and 7** illustrate in a three dimensional view can-type combustors connected to an annular combustor.

DETAILED DESCRIPTION OF THE INVENTION

[**0025**] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the illustrated embodiments set forth herein. Rather, these illustrated embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

[**0026**] **FIG. 1** illustrates schematically a gas turbine **1**. The gas turbine **1** comprises of a compressor **3**, a combustor **5** and a turbine **7**. The turbine **7** is mounted on a shaft **9** together with the compressor **3**. Within the compressor **3**, air **11** is compressed and conducted to the combustor **5**. Also, fuel **13** is conducted to the compressor **5**, being mixed with the air **11** to give an air/fuel mixture **15**. The air/fuel mixture **15** is incinerated, thereby generating a hot gas stream **17**. The hot gas stream **17** is conducted through a turbine inlet **19** into the turbine **7**, where through an arrangement of vanes and blades (not shown) energy is transferred to the shaft **9** which rotates. The rotational energy is partly used for driving the compressor **3**. Another part of the rotational energy could be used, for instance, for driving an electric generator.

[**0027**] **FIG. 2** illustrates an annular combustor **5**. Burners **21** function as suppliers of air/fuel mixtures **15** which are incinerated in a visible flame **25**, defining a main combustion zone **23**. Flame instabilities can occur, resulting in pressure pulses which in turn can induce more flame instabilities. In particular, adjacent burners **21** can have mutually acoustic coupling, thereby mutually inducing flame instabilities indicated by arrows **27**. By reflection of pressure pulses from the combustor wall, stable combustion oscillations can arise from the flame instabilities.

[**0028**] **FIG. 3** illustrates a novel concept for the combustor **5**. The combustor **5** comprises a can-type part **33** and an annular part **35**. The can-type part **33** comprises of a plurality of can-type combustors **31**, each connected to the annular part **35** and opened to the annular part **35** through respective can outlets **37**. Through respective head-parts **39** of each can-type combustor **31**, air **11** and fuel **13** is introduced, thereby forming an air/fuel mixture **15**. A sidewall **41** extends from the head part of each can-type combustor **31** to the respective can outlet **37**. The air/fuel mixture **15** is incinerated in the main combustion zones **23**, defined by visible flames **25**, in each of the can-type combustors **31**, thereby each generating an individual hot gas stream **42**. The individual or component hot gas streams **42** are merged in the annular part **35** to form the main hot gas stream **17**. As a consequence, the temperature and pressure of the main hot gas stream **17** turns out to be well homogenized before entering the turbine **7**. Additionally, cross-ignition between the different flames **23** is established which results in improved stability of operation, even under extreme lean combustion conditions. Preferably, the air **11** and fuel **13** undergo at least in part a premixing to form the air/fuel mixture **15**, thereby achieving a lean combustion which is, if appropriate, stabilized by a diffusion flame.

[**0029**] The sidewalls **41** are sized such that they fully enclose the respective combustion zones **23**. This results in an acoustical decoupling of the flames **25** and, accordingly, an avoidance of combustion oscillation. However, the sidewalls **41** do not exceed substantially the extensions of the combustion zones **23**, thereby keeping the can-type part **33** reasonable small.

[**0030**] **FIG. 4** illustrates in a three-dimensional view more particularly the assembly of the annular part **35**. It is formed of an outer shell **51** and an inner shell **53** which enclose an annular shaped space **54**. The inner surface of the outer shell **51** as well as the inner shell **53** is covered by heat shield elements **55** for protection against hot gas. The can-type combustors **31** of the can-type part **33** may be distributed substantially equally along a circumferential direction **57** of the annular part **35**.

[**0031**] **FIG. 5** illustrates a longitudinal section of the combustor **5** supported in the gas turbine **1**. The compressor **3** has blades **61** and vanes **63** which, from a rotation of the shaft **9**, compress and conduct air **11** through a compressor diffuser **65** to a space **67** that is formed from an outer casing **69**. The compressed air **11** is mainly conducted to the combustor **5** but a part of the air **11** is used for cooling the combustor **5** and turbine **7**. The outer casing **69** also encloses a vane support structure **71** of the turbine **7**. This vane support structure **71** supports vanes **73**. Between two respective rows of vanes **73**, blades **75** are mounted on the shaft **9**. The vane support structure **71** also supports the annular part **35** of the combustor **5** which is attached to the vane support structure **71**. Accordingly, very little relative movement between the annular part **35** and the turbine **7** occurs which leads to an easy sealing against discharge of hot gas out of clearances between the annular part **35** and the turbine **7**. Moreover, the can-type combustors **31** are attached to the annular part **35** which again leads to very little relative movement between the annular part **35** and the can-type combustors **31** and, accordingly, to an easy sealing against discharge of hot gas out of clearances. Furthermore, without the need of supporting the combustor **5** from the outer casing **69**, a less complex and less expensive construction is achieved. In a direction of the hot gas stream, the can-type part **33** has an can-type part extension C and the annular part **35** has an annular part extension A which is at least one half of the can-type part extension C.

[**0032**] FIGS. **6** and **FIG. 7** illustrate in a three-dimensional view, the connection of the can-type combustors **31** to the annular part **35**. The annular part **35** has ribs **91**, extending from the outer shell **51** to the inner shell **53**. The can-type combustors **31** are connected to these ribs **91** with their sidewalls **41**. The sidewalls **41** are diffuser shaped and have flanges **85** with which they are connected to the annular part **35**. Every single can-type combustor **31** is easily removable for service. The head parts **39** have openings **83** in which a burner can be mounted.

[**0033**] **FIG. 6** illustrates furthermore the can-type combustors **31** having a double wall structure which comprises an outer wall **101** and an inner wall **103**, enclosed by the outer wall **101**. Between the outer wall **101** and the inner wall **103** hollow space or opening **105** is formed which provides for conduction of a cooling fluid. In particular, steam could be used as a cooling fluid, separated in a closed cooling cycle from the hot gas inside the combustor. The inner wall **103** may be manufactured as a cylinder **103**a with an on welded flange **103***b*. The inner wall **103** is mounted within the outer wall **101** by guidance elements **107** and fixation in a fork-like support **109**. Between adjacent can-type combustors **31**, the space **105** for cooling fluid is narrowed. Accordingly, an impingement cooling is provided in this area **111** in order to improve cooling effectiveness. The low cost design and easy mounting of the inner wall **103** allows complete exchange of this inner wall **103** during a service cycle.

[**0034**] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

What is claimed is:

1. A gas turbine, comprising:

a combustor for generating a stream of hot gas, said combustor comprising a plurality of can-type elements for accommodating combustion of air and fuel therein, and a single annular element for annularly orienting said plurality of can-type elements and merging said combustion such that combustion oscillations are substantially avoided.

2. The gas turbine according to claim 1, further comprising a compressor for generating compressed air and means for directing said air to said can-type element.

3. The gas turbine according to claim 2, wherein said merging of said combustion results in a stream of hot gas, and wherein said gas turbine further comprising a turbine for converting said stream of hot gas into mechanical energy.

4. The gas turbine according to claim 3, wherein said turbine comprises an intake for receiving said stream of hot gas.

5. The gas turbine according to claim 3, further comprising a shaft mechanically connecting said turbine, combustor and compressor.

6. The gas turbine according to claim 1, wherein said can-type elements comprise a head having intakes for receiving fuel and air, an outlet exhausting said stream of gas, and a side wall connecting said head and outlet.

7. The gas turbine according to claim 6, wherein said can-type element comprises a first area defining a combustion zone defined as a second area of a visible flame of said combustion.

8. The gas turbine according to claim 7, wherein said first area substantially equals said second area.

9. The gas turbine according to claim 6, wherein said annular element and can-type elements comprise an axial extension extending in the direction of flow of said stream of hot gas and wherein said annular element axial extension comprises at least half of the overall area of said can-type axial extensions.

10. The gas turbine according to claim 4, wherein said intake of said turbine is partially formed by a vane support structure, said structure accommodating vanes thereon and located within said turbine, and said annular element is connected to and supported by said vane support structure.

11. The gas turbine according to claim 1, wherein said can-type elements are supported by said annular element.

12. The gas turbine according to claim 11, wherein said can-type elements are individually removable from said annular element.

13. The gas turbine according to claim 12, wherein each said can-type elements are connected to said annular element by at least one connector facilitating removal of said can-type elements.

14. The gas turbine according to claim 6, wherein said can-type elements are equally distributed along the circumference of said annular part and define hollow spaces between respective sidewalls of adjacent can-type elements.

15. The gas turbine according to claim 6, wherein said annular element includes an outer shell, an inner shell located within said outer shell, ribs extending from said outer shell to said inner shell such that said can-type combustors are connected to said annular element side wall by at least one of said ribs.

16. The gas turbine according to claim 6, wherein said sidewalls are diffuser-shaped.

17. The gas turbine according to claim 1, wherein said can-type elements and annular element are arranged such that acoustic decoupling is substantially effected and combustion oscillations are substantially avoided.

18. The gas turbine according to claim 1, wherein each of said can-type combustors includes a double wall, said double wall comprising an outer wall, an inner wall, and a hollow space defined by cooperating outer and inner walls, said hollow space conducting cooling fluid in between said outer wall and said inner wall.

19. A Gas turbine, comprising:

a combustor for combustion of an air and fuel mixture in the production of a main hot gas stream, said combustor comprising a first and second region, said first region defining an area wherein individual combustion and production of component hot gas streams occurs, said first region having an area substantially defined by a visible flame of said combustion, and said second region defining an area wherein said component hot gas streams are combined to form said main hot gas stream before entering the turbine inlet, thereby generating a substantially homogeneous main gas stream temperature distribution; and

a turbine with a turbine inlet for receiving and conducting said main hot gas stream.

20. The gas turbine according to claim 19, wherein the second region is substantially annular.

21. The gas turbine according to claim 20, wherein said first region comprises a plurality of individual combustion regions substantially equally distributed about said second region.

22. A method for reducing combustion oscillations in a gas turbine, comprising the steps:

conducting air and fuel into a plurality of distinct combustion zones,

incinerating said air and fuel in said distinct combustion zones,

generating individual hot gas streams in said zones thereby substantially avoiding acoustical coupling of flame instabilities occurring in said distinct combustion zones, and

merging said individual hot gas streams into a main hot gas stream, thereby substantially homogenizing said temperature distribution of merged individual hot gas streams.

23. The method according to claim 22, further comprising the step of feeding said main hot gas stream through a turbine inlet.

24. The method according to claim 22, wherein pressure of said main hot gas stream is substantially homogenized by said step of merging.

* * * * *