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(54) **COMBUSTOR AND METHOD OF OPERATING A COMBUSTOR**

BRENNKAMMER UND VERFAHREN ZUM BETRIEB EINER BRENNKAMMER

CHAMBRE DE COMBUSTION ET MÉTHODE D'UTILISATION D'UNE CHAMBRE DE COMBUSTION

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## Description

**[0001]** The present invention relates to a combustor comprising in flow series a burner, a transition piece and a combustion chamber being of larger diameter than the transition piece, the combustion chamber being connected to the transition piece via a dome portion. In addition, the invention relates to a method of operating a combustor, especially a combustor of a gas turbine.

**[0002]** Modern gas turbine engines, such as the one known from US 2004/0137395 A, use the concept of premixing air and fuel in lean stoichiometry before the combustion of the fuel/air mixture. Usually, the pre-mixing takes place by injecting fuel into an air stream in a swirling zone of a combustor which is located upstream from the combustion zone. The swirling leads to a mixing of fuel and air before the mixture enters the combustion zone.

**[0003]** US 6,532,726 B2 describes a gas turbine engine system having a combustor with a burner head having injection arrangements for gas- and liquid-fuel operations. During both gas- and liquid-fuel operations the flame front face is located close to the burner head and, during liquid-fuel operations, air is forced across the downstream face to cool the head.

**[0004]** The aerodynamics in the combustor dome comprise of a annular recirculation bubble that has a helical flow pattern in the circumferential sense. This recirculation bubble is driven by the swirling flow emerging from the pre-chamber. Currently, it is known that at low machine loads the highest combustion efficiency can be achieved if the flame front is fully stabilised in the dome recirculation bubble. Poor efficiency is associated with a flame front stabilised in the central recirculation bubble, which is predominantly located in the pre-chamber area. At high machine loads, the central recirculation bubble has sufficient swirl and intensity for the flame front to be fully held.

**[0005]** However, the combustion system has relatively poor combustion efficiency at low loads and at starting conditions. This problem exists for liquid and gas operation, although it is most noticeable on liquid.

**[0006]** With respect to the mentioned state of the art it is an objective of the invention to provide a combustor, in particular a gas turbine combustor, and a method of operating a combustor, especially a gas turbine combustor which is advantageous in providing a combustion efficiency at low loads and starting.

**[0007]** This objective is solved by a combustor according to claim 1 and a method according to claim 8. The dependent claims describe advantageous developments of the invention.

**[0008]** The inventive combustor comprises in flow series a burner, a transition piece and a combustion chamber being of larger diameter than the transition piece. The combustion chamber is connected to the transition piece via a dome portion. Air injection openings are located in the dome portion. In particular, the transition piece may also be referred to as a pre-chamber in regard to the combustion chamber.

**[0009]** It is believed that the state of the art dome recirculation bubble strength is only marginally insufficient and that limited additional air directed the appropriate way will improve the efficiency of the combustion system. To improve the dome recirculation efficiency where a machine would be operating predominantly in the low load regime, it is therefore proposed that air is introduced across the dome to supplement the existing aerodynamics and enhance stability.

**[0010]** According to the present invention the openings comprise a first row of openings being positioned at a circle of a first radius of the dome portion and at least one further row of openings being positioned at at least one further circle of a second radius of the dome portion being different to the first radius. The openings have an elongated shape with a long direction and a short direction. Especially, the openings have a shape of an ellipse. However, the openings can be of any other shape.

**[0011]** The openings of the first and the at least one further row can have a defined orientation e.g. such as the openings being positioned at an innermost circle of the dome portion are oriented tangentially with their elongated direction and the openings being positioned at the outermost circle of the dome portion have no tangential component in their elongated direction. The orientation of openings being arranged in further rows lying between the rows being positioned at the innermost and the outermost radius may be then dependent on the radius at which they are positioned. The tangential component proportion of an openings long direction increases as nearer the opening is positioned at the innermost radius of the dome portion and decreases as nearer the opening is positioned at the outermost radius of the dome portion. In addition duct portions of ducts for feeding the air to the opening adjoining the air injection openings are designed so that they have angles of inclination to the surface normal of the dome surface greater than 45 degrees and less than 80 degrees. When angled jets have angles of inclination to the surface front to which they emerge of less than 11 degrees (i.e. of more than 80 degrees relative to the surface normal) it will be difficult to attach them to the surface of the surface.

**[0012]** With the described configuration of the openings, an air jet streaming through an opening of a row being positioned at the outermost radius of the dome portion has no tangential component. Air jets flowing through openings of the other rows have tangential components that increase with decreasing radial position.

**[0013]** Advantageously, the first row of openings is arranged close to a dome edge, where the dome portion is adjacent the transition piece.

**[0014]** The number of openings of the first row may be greater than the number of openings of the at least one further row. The higher number of openings ensures a sufficient introduction of air near the transition piece due to provision of greater air penetration.

**[0015]** Further, the openings of the first row are advantageously each smaller than openings of the at least one further row. Due to the greater number and the smaller diameter of these openings, an even introduction of air to the partially premixed gases leaving the transition piece is achieved.

**[0016]** The inventive combustor is particularly adapted to perform the inventive method.

**[0017]** The inventive method of operating a combustor which comprises in flow series a burner, a transition piece and a combustion chamber being of larger diameter than the transition piece and being connected to it via a dome portion comprises the step of introducing air from the dome portion of the combustor.

**[0018]** In an advantageous embodiment of the present invention, the air is introduced by an inclination angle to the surface normal of the dome surface greater than 45 degrees and less than 80 degrees.

**[0019]** Further features, properties and advantages of the present invention will become clear from the following description of embodiments of the invention in conjunction with the accompanying drawings.

Figure 1 shows a combustor according to the invention;

Figure 2 shows a dome plate according to the present invention; and

Figure 3 shows another dome plate according to the present invention.

**[0020]** Figure 1 shows a combustor according to the invention. The combustor comprises in flow direction series a burner 10 with swirler portion 12 and a burner-head portion 11 attached to the swirler portion 12, a transition piece being referred as combustion pre-chamber 13 and a main combustion chamber 4. The main combustion chamber 4 has a diameter being larger than the diameter of the pre-chamber 13. The main combustion chamber 4 is connected to the pre-chamber 13 via a dome portion 30 comprising a dome plate 38. In general, the transition piece 13 may be implemented as a one part continuation of the burner 10 towards the combustion chamber 4, as a one part continuation of the combustion chamber 4 towards the burner 10, or as a separate part between the burner 10 and the combustion chamber 4.

**[0021]** The combustor is adapted to be operated with either liquid or gaseous fuel and comprises a gas-fuel injection system, a liquid-fuel injection system and an air injection system.

**[0022]** The gas-fuel injection system comprises main gas-fuel openings 23 and a pilot gas system. The main gas-fuel openings 23 are located at an air-inlet region of a burner head face 16, i.e. of the swirler portion 12, i.e. adjacent a radially outer part of passages 14 which are defined between a number of vanes of the swirler portion 12 and are fed from connectors 24. The pilot gas system comprises in flowing direction of pilot gas a connector 18 at the burner head 11, an annular gallery 19, gas outlets 32, a lip 20 extending radially inwards towards the longitudinal axis 21 of the combustor, and a central part 22 being arranged on a burner head face 16.

**[0023]** The liquid-fuel injection system comprises liquid-fuel pilot openings 25 and main liquid-fuel openings 27. The liquid-fuel pilot openings 25 can inject liquid fuel fed from connections 26 through appropriate ducts extending through the burner head 11 into the pre-chamber 13. The pilot openings 25 are positioned in the central part 22 of the burner head face 16 outside the outer circumference of the combustion flames front FF. The main liquid-fuel openings 27 are fed from fuel connectors 28 through appropriate passageways extendingthrough the burner head 11. The main liquid-fuel openings 27 are situated in the burner head face 16 at or near the air-exit region of the swirler 12, i.e., near a radially inner portion of the swirler passages 14.

**[0024]** The air injection system comprises air ducts 36 leading to openings 40, 42, 44 in the dome plate 38. The exit parts of the ducts, i.e. the parts adjoining the openings, are inclined with respect to the surface normal of the dome pate 38 by an inclination angle $\alpha$.

**[0025]** In operation, compressed air 15 is supplied to the burner 10 and streams through the swirler passages 14. The in streaming air mixes with fuel injected into the compressed air streams through the passages from injection openings located in a peripheral section of the burner head face 16. On arriving in the pre-chamber 13, the mixture is ignited by an igniter unit 17. Once lit, the flame continuous to burn so that a further ignition is not required.

**[0026]** When the engine is started in gas-fuel mode of operation, the pilot gas supplied through the connector 18 at the burner head 11 streams through passages in the burner head 11 arriving at the annular gallery 19. From there the pilot gas is directed via the gas outlets 32 to the underside of a directing means in the form of the lip 20 extending radially inwards towards the longitudinal axis 21 of the combustor. The lip 20 deflects the pilot gas across the central portion 22. However, as engine load and speed increase, the pilot gas supply is reduced and the main gas-fuel supply is increased. The main gas-fuel exits the main gas-fuel openings 23. The main gas-fuel and the air mix together as they pass the swirler passages 14 on their way to a combustion flame within pre-chamber 13 and main-chamber 4.

**[0027]** Further, air jets 34 are supplied by the air openings 36 into main combustion chamber 4. Therein, they mix in dependence of engine load with either with the pilot gas, the fuel-air mixture and/or the combustion products of them so as to improve the dome recirculation efficiency by providing sufficient swirl and intensity for the flame front. The injected air jets 34 have an inclination angle $\alpha$ in relation to the surface normal of the dome surface being shown as dashed line.

**[0028]** When the engine is started in the liquid-fuel mode of the combustor, pilot liquid-fuel is injected from pilot openings 25 into the pre-chamber 13 in an axial direction which is at least approximately parallel to the central longitudinal axis 21, where it mixes with air 15 exiting the swirler passages 14. The obtained mixture of air and fuel is ignited by the igniter unit 17. And further mixtures of air and fuel are fed to the so obtained flame F.

**[0029]** Additionally, the air jets 34 are supplied by the air openings 36 into the main combustion chamber 4. Therein, they mix with the mixture which leaves the pre-chamber 13. This mixture can comprise the pilot fuel, the air-fuel mixture being introduced into the combustor and/or their combustion products. Due to the orientation of the exit parts of the ducts 36 the air jets 34 have an inclination angle $\alpha$ in relation to the surface normal of the dome surface being shown as dashed line to compliment the existing aerodynamics and enhance the stability, especially, when the gas turbine is operating in the low load regime.

**[0030]** As engine load increases from start-up to approximately 70 % full load, the supply of liquid pilot fuel is reduced, and main liquid fuel is introduced from the main liquid-fuel openings 27 which are located on the burner face in the air exit region of the swirler passages 14 and inject main liquid fuel in a direction approximately perpendicular to the air stream flow 15. The supply of air jets 34 can either be continued or stopped.

**[0031]** Fig. 2 shows a dome portion according to the present invention. The dome portion comprises a plate 200 having a first row of openings 202, a second row of openings 204 and a third row of openings 206. All openings have an elongated shape defining a long direction of the openings.

**[0032]** The openings 202 are positioned at the innermost radius of the plate 200 and closest to the dome edge 208. They are oriented near tangential to the dome edge 208 with their long direction. The openings 204 are arranged at radius being greater than the previous radius. Their orientation is less tangential than that of the openings 202 of the first row. The openings 206 are situated at the outermost radius and are oriented radially inwards with no tangential component of their long direction.

**[0033]** Through openings 202, 204 and 206 air is introduced in the dome of the combustor. The air jets stream out the openings 202, 204 and 206 have an inclination in regard to a surface normal of a dome surface from which they emerge (see Fig. 1). The inclination angle $\alpha$ lies in the range of $45° < \alpha < 80°$. The jets streaming out openings 206 do not have a tangential component in regard to the dome edge 208, while the others have a tangential component. The flow direction of the air jets is shown by arrows.

**[0034]** Fig. 3 shows another dome portion according to the present invention. The dome portion comprises a plate 300 having a first row of openings 302, a second row of openings 304 and a third row of openings 306.

**[0035]** The openings 302 are positioned at the innermost radius of the plate 300 and closest to the dome edge 308 and are oriented near tangential to the dome edge 308. The openings 304 are arranged at radius being greater than the previous radius and are oriented less tangential than the openings 302. The openings 306 are situated at the outermost radius and are oriented radially inwards with no circumferential component.

**[0036]** The number of openings 302 is greater as the number of openings 304 or the number of openings 306 Further, the diameters of the openings 302 are smaller than the diameters of the openings 304 or 306. Thereby, an even introduction of air to the fuel and/or gases being introduced in the dome portion of the combustor is ensured and a greater air penetration is provided.

**[0037]** Through openings 302, 304 and 306 air is introduced in the dome of a combustion system. The air jets stream out the openings 302, 304 and 306 by an inclination angle $\alpha$, wherein $45° < \alpha < 80°$, wherein $\alpha$ is defined in regard to a surface normal of a dome surface front from which the air jets emerge (see Fig. 1). The jets streaming out openings 306 do not have a tangential component in regard to the dome edge 308.

## Claims

1. A combustor for a gas turbine comprising in flow series a burner (10), a transition piece (13) and a combustion chamber (4) being of larger diameter than the transition piece (13), the combustion chamber (4) being connected to the transition piece (13) via a dome portion (30), and air injection openings (40, 42, 44, 202, 204, 206, 302, 304, 306) being located in the dome portion, the air injection openings (40, 42, 44, 202, 204, 206, 302, 304, 306) comprising a first row of openings being positioned on a circle of a first radius and at least one further row of openings being positioned on at least one further circle of a second radius being different to the first radius, wherein the openings (202, 204, 206, 302, 304, 306) have an enlarged shape with a long direction and a short direction, the long direction of the first row being oriented tangential or near tangential to the dome edge (208, 308) and wherein the tangential component portion of an opening's long direction increases as nearer the opening is positioned at the innermost radius of the dome portion.

2. The combustor, as claimed in claim 1, wherein the first row of openings (202, 302) is arranged at a dome edge (208, 308) which is adjacent the transition piece (13).

3. The combustor, as claimed in claim 1, wherein the number of openings (302) of the first row is greater than the number of openings (304, 306) of the at least one further row.

4. The combustor, as claimed in claim 3, wherein the openings (302) of the first row have a diameter being smaller than a diameter of the openings (304, 306)

of the at least one further row.

5. The combustor, as claimed in claim 4, wherein duct portions of ducts (36) for feeding the air to the openings adjoining the air injection openings are designed such that they have angles of inclination (α) to the surface normal greater than 45 degrees and less than 80 degrees.

6. A method of operating a combustor for a gas turbine according to claim 1, wherein air is introduced from the dome portion (30) by means of air jets, wherein an air jet without any tangential component streams through an opening of a row being positioned at the outermost radius of the dome portion and wherein air jets with tangential components that increase with decreasing radial position flow through openings of the other rows.

7. The method, as claimed in claim 6, wherein the air is introduced with an inclination (α) to the surface normal of the dome portion (30) greater than 45 degrees and less than 80 degrees.

**Patentansprüche**

1. Verbrennungsanlage für eine Gasturbine, die in Flussfolge hintereinander geschaltet Folgendes umfasst: einen Brenner (10), ein Übergangsteil (13) und eine Brennkammer (4), die einen größeren Durchmesser aufweist als das Übergangsteil (13), wobei die Brennkammer (4) mit dem Übergangsteil (13) durch einen kuppelförmigen Teil (30) verbunden ist, und Lufteinspritzöffnungen (40, 42, 44, 202, 204, 206, 302, 304, 306), die in dem kuppelförmigen Teil angeordnet sind, wobei die Lufteinspritzöffnungen (40, 42, 44, 202, 204, 206, 302, 304, 306) eine erste Reihe von Lufteinspritzöffnungen, die in einem Kreis mit einem ersten Radius angeordnet sind, sowie mindestens eine weitere Reihe von Öffnungen, die in mindestens einem weiteren Kreis mit einem zweiten Radius, der von dem ersten Radius verschieden ist, angeordnet sind, umfassen, wobei die Lufteinspritzöffnungen (202, 204, 206, 302, 304, 306) eine vergrößerte Form mit einer langen Richtung und einer kurzen Richtung aufweisen, wobei die lange Richtung der ersten Reihe tangential oder beinahe tangential zu der Kante (208, 308) des kuppelförmigen Teils ausgerichtet ist und wobei der tangentiale Komponententeil der langen Richtung einer Lufteinspritzöffnung größer wird, je näher die Lufteinspritzöffnung an dem innersten Radius des kuppelartigen Teils angeordnet ist.

2. Verbrennungsanlage gemäß Anspruch 1, wobei die erste Reihe von Lufteinspritzöffnungen (202, 302) an einer Kante (208, 308) des kuppelförmigen Teils angeordnet ist, die am Übergangsteil (13) angrenzt.

3. Verbrennungsanlage gemäß Anspruch 1, wobei die Anzahl der Lufteinspritzöffnungen (302) in der ersten Reihe größer ist als die Anzahl der Lufteinspritzöffnungen (304, 306) in der mindestens einen weiteren Reihe.

4. Verbrennungsanlage gemäß Anspruch 3, wobei die Lufteinspritzöffnungen (302) in der ersten Reihe einen Durchmesser haben, der geringer ist als ein Durchmesser der Lufteinspritzöffnungen (304, 306) in der mindestens einen weiteren Reihe.

5. Verbrennungsanlage gemäß Anspruch 4, wobei Kanalteile von Kanälen (36) zum Zuführen von Luft in die Lufteinspritzöffnungen, die an die Lufteinspritzöffnungen angrenzen, derart ausgeführt sind, dass sie Neigungswinkel (α) zur Flächennormale aufweisen, die größer als 45 Grad und kleiner als 80 Grad sind.

6. Verfahren zum Betrieb einer Verbrennungsanlage für eine Gasturbine gemäß Anspruch 1, wobei Luft aus dem kuppelförmigen Teil (30) mithilfe von Luftstrahlen zugeführt wird, wobei ein Luftstrahl ohne Tangentialkomponente durch eine Lufteinspritzöffnung einer Reihe strömt, die am äußersten Radius des kuppelförmigen Teils angeordnet ist, und wobei Luftströme mit Tangentialkomponenten, die mit abnehmender Radialposition größer werden, durch Lufteinspritzöffnungen der anderen Reihen strömen.

7. Verfahren gemäß Anspruch 6, wobei die Luft mit einem Neigungswinkel (α) zur Flächennormale des kuppelförmigen Teils (30), der größer als 45 Grad und kleiner als 80 Grad ist, zugeführt wird.

**Revendications**

1. Dispositif de combustion pour une turbine à gaz comprenant, en série dans le sens du flux, un brûleur (10), une pièce de transition (13) et une chambre de combustion (4) étant d'un diamètre plus grand que la pièce de transition (13), la chambre de combustion (4) étant connectée à la pièce de transition (13) par l'intermédiaire d'une partie en dôme (30), et des ouvertures d'injection d'air (40, 42, 44, 202, 204, 206, 302, 304, 306) étant situées dans la partie en dôme, les ouvertures d'injection d'air (40, 42, 44, 202, 204, 206, 302, 304, 306) comprenant une première rangée d'ouvertures étant positionnées sur un cercle d'un premier rayon et au moins une autre rangée d'ouvertures étant positionnées sur au moins un autre cercle d'un deuxième rayon étant différent du premier rayon, dans lequel les ouvertures (202, 204,

206, 302, 304, 306) ont une forme élargie avec un sens long et un sens court, le sens long de la première rangée étant orienté tangentiellement ou presque tangentiellement au bord (208, 308) du dôme et dans lequel la partie composante tangentielle du sens long d'une ouverture augmente plus l'ouverture est positionnée proche du rayon le plus interne de la partie en dôme.

**2.** Dispositif de combustion, selon la revendication 1, dans lequel la première rangée d'ouvertures (202, 302) est agencée au niveau d'un bord (208, 308) du dôme qui est adjacent à la pièce de transition (13).

**3.** Dispositif de combustion, selon la revendication 1, dans lequel le nombre d'ouvertures (302) de la première rangée est plus grand que le nombre d'ouvertures (304, 306) de l'au moins une autre rangée.

**4.** Dispositif de combustion, selon la revendication 3, dans lequel les ouvertures (302) de la première rangée ont un diamètre étant plus petit qu'un diamètre des ouvertures (304, 306) de l'au moins une autre rangée.

**5.** Dispositif de combustion, selon la revendication 4, dans lequel des parties de conduite de conduites (36) pour amener de l'air jusqu'aux ouvertures jouxtant les ouvertures d'injection d'air sont conçues de telle manière qu'elles ont des angles d'inclinaison ($\alpha$) par rapport à la normale de la surface supérieurs à 45 degrés et inférieurs à 80 degrés.

**6.** Procédé d'exploitation d'un dispositif de combustion pour une turbine à gaz selon la revendication 1, dans lequel de l'air est introduit à partir de la partie en dôme (30) au moyen de jets d'air, dans lequel un jet d'air sans aucune composante tangentielle s'écoule à travers une ouverture d'une rangée étant positionnée au niveau du rayon le plus extérieur de la partie en dôme et dans lequel des jets d'air ayant des composantes tangentielles qui augmentent avec la diminution de la position radiale affluent à travers des ouvertures des autres rangées.

**7.** Procédé, selon la revendication 6, dans lequel l'air est introduit avec une inclinaison ($\alpha$) par rapport à la normale de la surface de la partie en dôme (30) supérieure à 45 degrés et inférieure à 80 degrés.

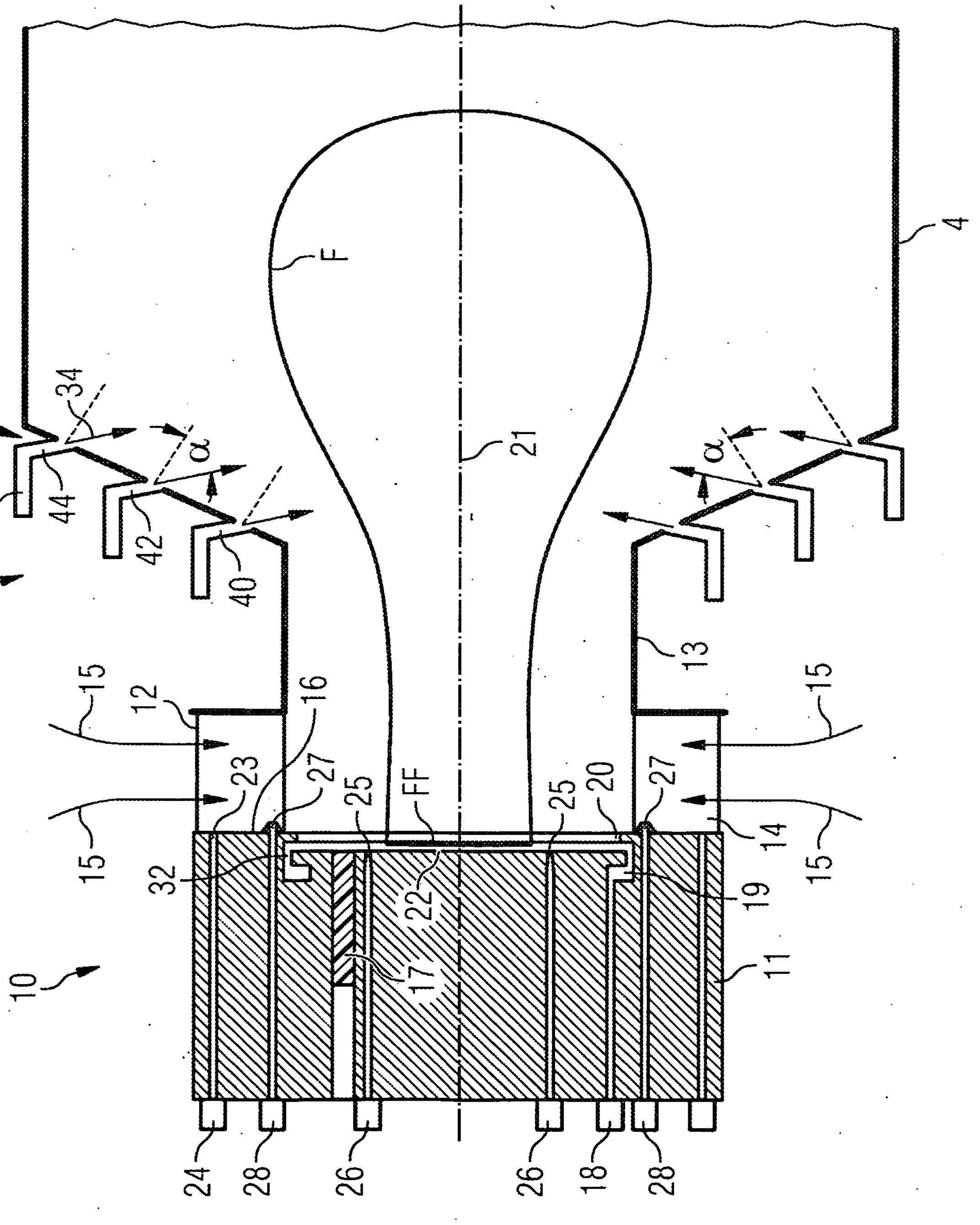
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FIG 1

FIG 2

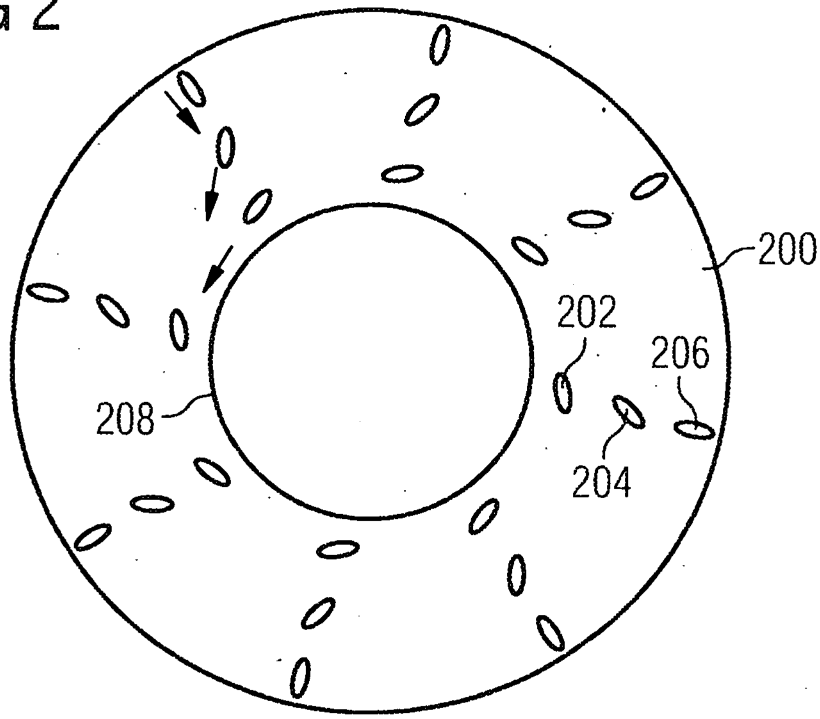
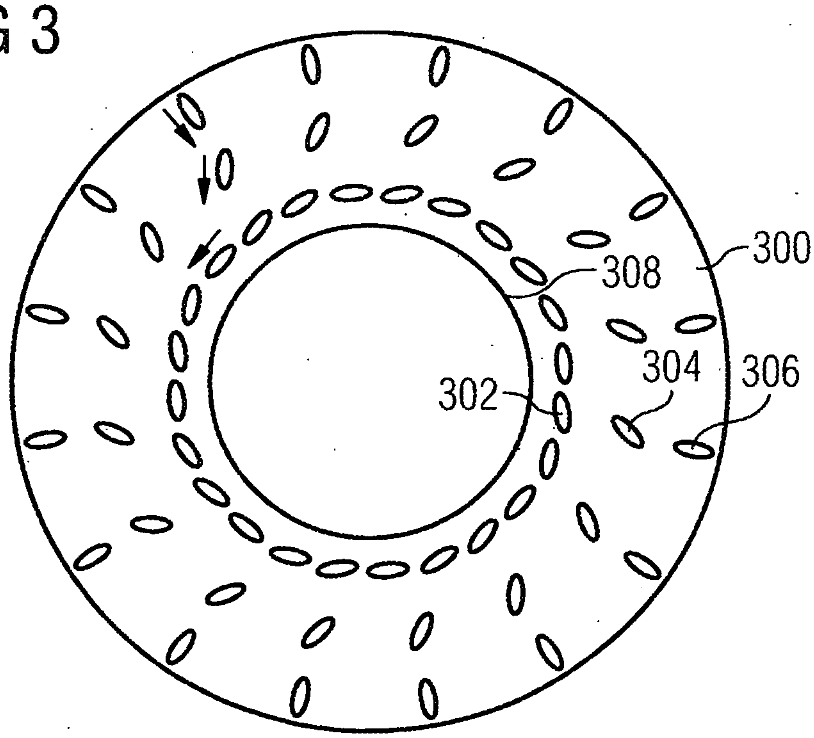



FIG 3



## REFERENCES CITED IN THE DESCRIPTION

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