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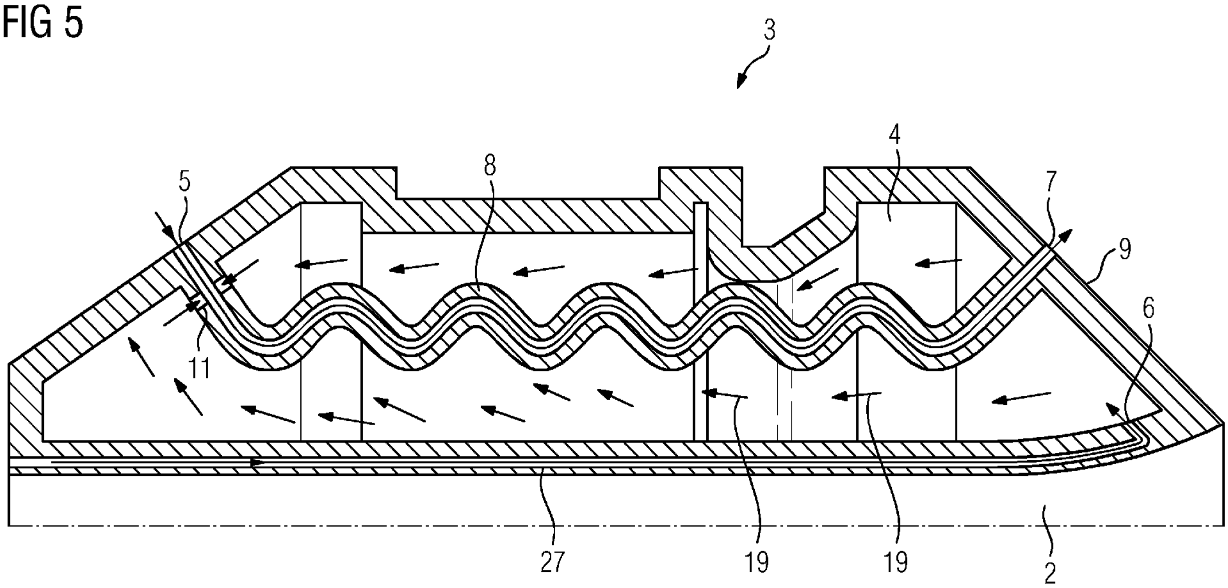
(54) GAS TURBINE BURNER WITH PILOT FUEL-AIR MIXING

(57) The invention relates to burner (1) with a burner head comprising a main mixing tube (2) for premixing combustion air and fuel, wherein the main mixing tube (2) is provided with a pilot burner system (3) in its downstream part, wherein the pilot burner system (3) comprises an annular mixing cavity (4) with an entrance (5) for air in its upstream end, with an entrance (6) for pilot fuel and with an outlet nozzle (7) in its downstream end, wherein a pilot mixing tube (8) extends inside the mixing cavity (4) between the air entrance (5) and the outlet nozzle (7) with a pilot mixing tube (8) length exceeding a distance between the upstream and the downstream ends of the mixing cavity (4).

FIG 5



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Description

FIELD OF THE INVENTION

[0001] The invention relates to a burner according to the features of the preamble of claim 1.

BACKGROUND OF THE INVENTION

[0002] Such burners are preferably used for firing the combustion chamber of a gas turbine. Such burners are known from EP 1 389 713 B1 and comprise a swirl generator and a downstream mixing tube. The burner head is provided with a pilot burner system to support the main flame. The pilot burner system comprises a mixing cavity for mixing pilot fuel and assist air. The mixing cavity of the known burner is of a pure circumferential shape. Since such a design bears the risk for the pilot flame to burn inside the mixing cavity EP 2 268 975 B1 proposes a solution with swirler wings being arranged in the vicinity of the pilot fuel/air mix outlet nozzles.

[0003] The mixing of fuel and air is mainly due to the tangential interaction of fuel and air streams. But still the pilot fuel-air mixing is limited, and fuel rich pockets are directed towards the combustion chamber. Therefore, the pilot flame is an external air assisted diffusion like flame that has inherent flame stability but can also create high NO_x emission due to this diffusion mode combustion.

[0004] Further, the combustor dump locations contribute to flame stabilization as will be shown in Figure 3.

[0005] The object of the present invention is to improve a burner of the above type in such a way that NO_x emission is reduced.

SUMMARY OF THE INVENTION

[0006] The present invention solves the above problem by providing a burner with a burner head comprising a main mixing tube for premixing combustion air and fuel, wherein the main mixing tube is provided with a pilot burner system in its downstream part, wherein the pilot burner system comprises an annular mixing cavity with an entrance for air in its upstream end, with an entrance for pilot fuel and with an outlet nozzle in its downstream end, wherein a pilot mixing tube extends inside the mixing cavity between the air entrance and the outlet nozzle with a pilot mixing tube length exceeding a distance between the upstream and the downstream ends of the mixing cavity.

[0007] The non-premixed behavior of the pilot flame is one of the major sources of NO_x. The extended mixing path inside the mixing cavity of the inventive burner improves fuel and air mixing and reduces the formation of NO_x. Further premixing of the pilot stage is possible when the pilot flame has an additional flame stabilization point. The present invention is intended to increase the pilot fuel mixing and inherently to reduce the NO_x without affecting the flame stability.

[0008] According to a preferred embodiment of the invention the mixing cavity comprises a conical front surface facing away from the burner axis and the outlet nozzle is arranged in that conical front surface with an injection angle perpendicular to the front surface.

[0009] It is particularly advantageous when a pilot fuel entrance of the mixing cavity is in its downstream part and a pilot fuel entrance of the pilot mixing tube is in its upstream part.

[0010] According to a preferred embodiment, a cooling channel is arranged in at least a part of a radially outer wall and the downstream end of the mixing cavity.

[0011] Yet another preferred embodiment of the present invention is characterized in that the cooling channel opens out at the conical front surface at an inner position compared to the outlet nozzle as seen in a radial direction of the burner.

[0012] According to another preferred embodiment of the invention, the cooling channel begins at an upstream part of the mixing cavity.

[0013] According to a further embodiment of the invention the pilot mixing tube is a spiral tubing arrangement.

[0014] Alternatively, the pilot mixing tube comprises secondary tubes that merge before opening out into the outlet nozzle.

[0015] In another alternative embodiment, the pilot mixing tube comprises steps.

[0016] It is advantageous, when the pilot mixing tube is fully integrated with the mixing cavity, especially when the pilot burner system is additively manufactured.

[0017] The present invention additionally relates to an annular combustion chamber of a gas turbine, which is characterized in that at least two, preferably at least 10 burners as described above are arranged within the combustion chamber.

[0018] To sum up, the mixing of fuel and air can be improved by introducing additively manufactured pilot fueling arrangement with additional mixing length. With the invention mixing at the pilot burner stage exit can be controlled more efficiently. The overall fuel-air mixing is improved. The enhanced mixing can produce lower NO_x emission without affecting the combustion stability. A variable mixing length is possible for different fuels. Variable location fuel injection possibility can widen the fuel flexibility of the pilot stage combustion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Embodiments of the invention are now described, by way of example only, with reference to the accompanying drawings, of which:

Figure 1 shows a pilot fuel-air mixing arrangement in prior art design;

Figure 2 shows a burner arrangement with pilot injection holes;

Figure 3 shows a pilot flame stabilization process due to dump plane;

Figure 4 shows a cut through of a double cone burner with mixing tube in prior art design indicating the position of the pilot burner system in its downstream part highlighted by the rectangular box;

Figure 5 shows a cut through a simplified sketch of the annular mixing cavity according to the invention;

Figure 6 shows a cut through an alternative embodiment of the annular mixing cavity with more safety features or film air to protect the metal;

Figure 7 shows a spiral tubing arrangement possible inside the mixing cavity;

Figure 8 shows a multiple pilot tube arrangement and

Figure 9 shows a pilot fuel arrangement where secondary tubes combine inside the mixing cavity.

[0020] The illustration in the drawings is in schematic form. It is noted that in different figures, similar or identical elements may be provided with the same reference signs.

DESCRIPTION OF THE DRAWINGS

[0021]

Figure 1 shows a pilot fuel-air mixing arrangement in prior art design according to EP 2 268 975 B1. Pilot fuel 19 is provided through a gas channel 16. The gas channel 16 emerges into a mixing cavity 17. Assist air 20 for burning the pilot fuel 19 is led into the mixing cavity 17 through air channels (not shown) and is deflected by swirler vanes 18. As can be seen fuel and air mixing is mainly due to a tangential interaction of fuel and air streams. Due to a relatively short mixing length, the mixing is limited, and a center rich pilot jet is directed toward the combustion chamber.

Figure 2 shows a burner arrangement in an annular combustion chamber 15 with pilot injection holes 21 arranged in a conical front surface 9 of a downstream part of the respective burner 1.

Figure 3 shows a pilot flame stabilization process due to dump plane in a double cone burner 1. Fuel and air enter the main mixing tube 2 through tangential slots 22 of a swirler prior entering the combustion chamber 15. Due to the broadening a main recirculation zone 23 of the main flame 26 forms with a forward stagnation point 24 at the entry level of the combustion chamber 15. Pilot fuel 19 and air are added to the combustion chamber 15 radially outwardly with respect to the main air and fuel, the pilot fuel 19 and air forming external recirculation zones 25 with opposite direction of rotation compared to the main recirculation zone 23.

Figure 4 shows a cut through of a prior art double cone burner 1 with a burner head comprising a main mixing tube 2 for premixing combustion air and fuel, wherein the main mixing tube 2 is provided with a pilot burner system 3 in its downstream part. The pilot burner system 3 is highlighted by a rectangular box and shows the prior art design that has already been presented in Figure 1.

[0022] The relatively small partially premixed pilot arrangement of the prior art can be replaced with a cavity filled with fuel and tube arrangements according to the invention.

[0023] The invention is explained in Figure 5 showing a cut through a simplified sketch of the mixing cavity 4 of the pilot burner system 3, the pilot burner system 3 comprising an annular mixing cavity 4 with an entrance 5 for air in its upstream end, with an entrance 6 for pilot fuel and with an outlet nozzle 7 in its downstream end. A pilot mixing tube 8 extends inside the mixing cavity 4 between the air entrance 5 and the outlet nozzle 7. The pilot mixing tube 8 length exceeds a distance between the upstream and the downstream ends of the mixing cavity 4 which is achieved by a meandering pilot mixing tube 8. Further, the pilot mixing tube 8 is fully integrated with the mixing cavity 4 and given the geometry is suitable for being additively manufactured.

[0024] The mixing cavity 4 comprises a conical front surface 9 facing away from the burner axis 10 (see figure 3). The outlet nozzle 7 is arranged in that conical front surface 9 with an injection angle perpendicular to the front surface 9.

[0025] Under operating conditions pilot fuel 19 is provided through a channel 27 arranged in the wall of the main mixing tube 2 which is also the radially inner wall of the mixing cavity 4 and enters the mixing cavity 4 at its downstream part where it travels in the opposite direction and enters the pilot mixing tube 8 in its upstream part so that the pilot mixing tube 8 carries the air and the fuel. The fuel supply is indicated by lines and arrows in figure 5. The fuel injection holes at the pilot fuel entrance 11 of the pilot mixing tube 8 can be of different cross section like oval/triangular or circular to get the penetration. Additionally, swirl can also be introduced in the fuel holes if required.

[0026] Figure 6 shows a cut through an alternative embodiment of the annular mixing cavity 4 for supplying fuel and air in the pilot burner system 3 with more safety features or film air to protect the metal. Figure 6 shows a cooling channel 12 arranged in at least a part of a radially outer wall 13 and the downstream end of the mixing cavity 4 for a small stream of air. The cooling channel 12 opens out at the conical front surface 9 at an inner position compared to the outlet nozzle 7 as seen in a radial direction of the burner 1. The cooling channel 12 begins at an upstream part of the mixing cavity 4. Further, the front surface 9 is cooled by the fuel which is then introduced inside the mixing cavity 4 for mixing.

[0027] Different tubing arrangements for increasing the fuel-air mixing are possible inside the mixing cavity 4. Figure 7 shows the pilot mixing tube 8 realized as a spiral tubing arrangement inside the mixing cavity 4.

[0028] Figure 8 shows a multiple pilot tube arrangement where the pilot mixing tubes 8 comprise steps. The step type tubing can be in X-Y or X-Z plane. The X-Z plane, which is parallel to the burner outer surface, opens many possibilities to place the pilot mixing tube bundles.

[0029] Figure 9 shows a pilot fuel arrangement where secondary tubes 14 combine inside the mixing cavity 4 before opening out into the outlet nozzle 7.

[0030] From the examples shown in Figures 7 to 9 it becomes clear that single or multiple pilot mixing tube 8 arrangements can be incorporated based on design requirements. The location of the entrance for pilot fuel of the mixing cavity 4 can be varied to achieve a specific degree of mixing of fuel and air.

[0031] Although the present invention has been described in detail with reference to the preferred embodiment, it is to be understood that the present invention is not limited by the disclosed examples, and that numerous additional modifications and variations could be made thereto by a person skilled in the art without departing from the scope of the invention.

Claims

1. A burner (1) with a burner head comprising a main mixing tube (2) for premixing combustion air and fuel, wherein the main mixing tube (2) is provided with a pilot burner system (3) in its downstream part, wherein the pilot burner system (3) comprises an annular mixing cavity (4) with an entrance (5) for air in its upstream end, with an entrance (6) for pilot fuel and with an outlet nozzle (7) in its downstream end, **characterized in that** a pilot mixing tube (8) extends inside the mixing cavity (4) between the air entrance (5) and the outlet nozzle (7) with a pilot mixing tube (8) length exceeding a distance between the upstream and the downstream ends of the mixing cavity (4) .

2. The burner (1) according to claim 1, wherein the mixing cavity (4) comprises a conical front surface (9) facing away from a burner axis (10) and wherein the outlet nozzle (7) is arranged in that conical front surface (9) with an injection angle perpendicular to the front surface (9).

3. The burner (1) according to claim 1 or claim 2, wherein a pilot fuel entrance (6) of the mixing cavity (4) is in its downstream part and a pilot fuel entrance (11) of the pilot mixing tube (8) is in its upstream part.

4. The burner (1) according to claims 1 to 3, wherein a cooling channel (12) is arranged in at least a part of a radially outer wall (13) and the downstream end of the mixing cavity (4).

5. The burner (1) according to claim 4, wherein the cooling channel (12) opens out at the conical front surface (9) at an inner position compared to the outlet nozzle (7) as seen in a radial direction of the burner (1).

6. The burner (1) according to claims 4 or 5, wherein the cooling channel (12) begins at an upstream part of the mixing cavity (4).

7. The burner (1) according to one of the preceding claims, wherein the pilot mixing tube (8) is a spiral tubing arrangement.

8. The burner (1) according to one of claims 1 to 6, wherein the pilot mixing tube (8) comprises secondary tubes (14) that merge before opening out into the outlet nozzle (7).

9. The burner (1) according to one of claims 1 to 6, wherein the pilot mixing tube (8) comprises steps.

10. The burner (1) according to one of the preceding claims, wherein the pilot mixing tube (8) is fully integrated with the mixing cavity (4).

11. The burner (1) according to one of the preceding claims, wherein the pilot burner system (3) is additively manufactured.

12. Annular combustion chamber (15) of a gas turbine, **characterized in that** at least two, preferably at least 10 burners (1) according to the preceding claims are arranged within the combustion chamber (15).

FIG 1

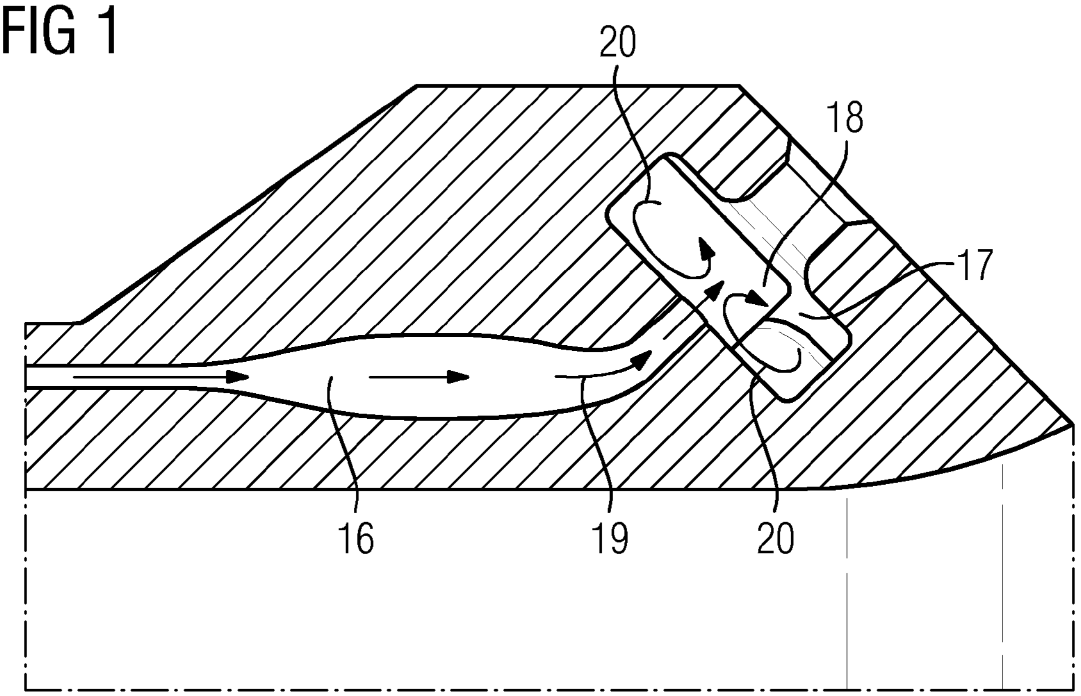
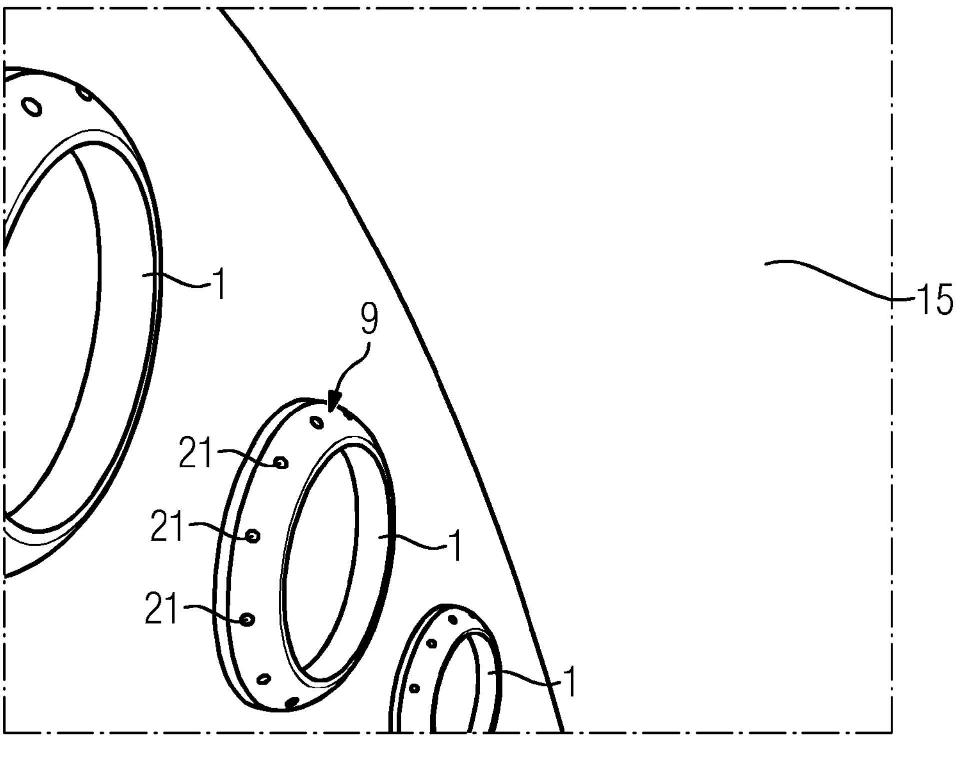


FIG 2



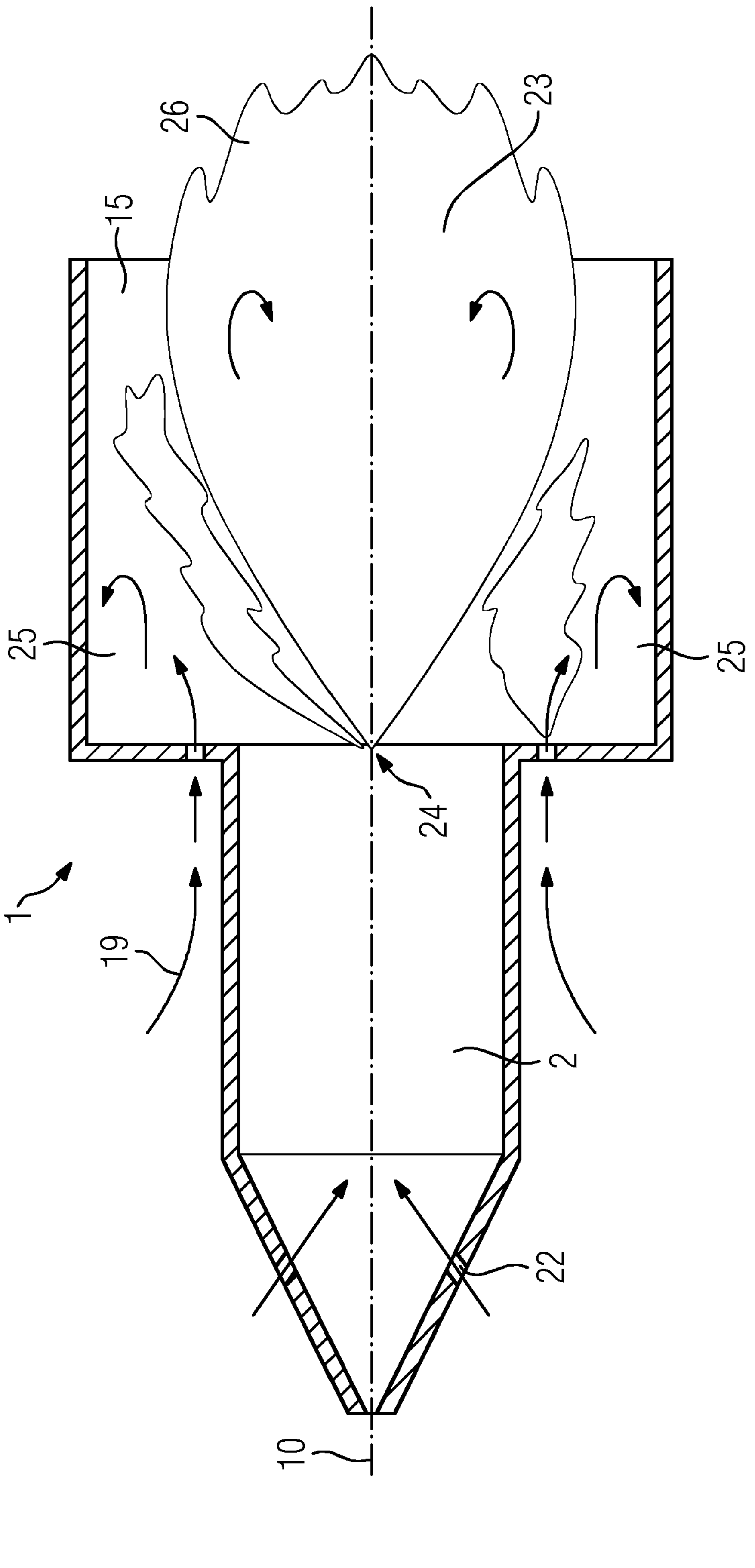


FIG 3

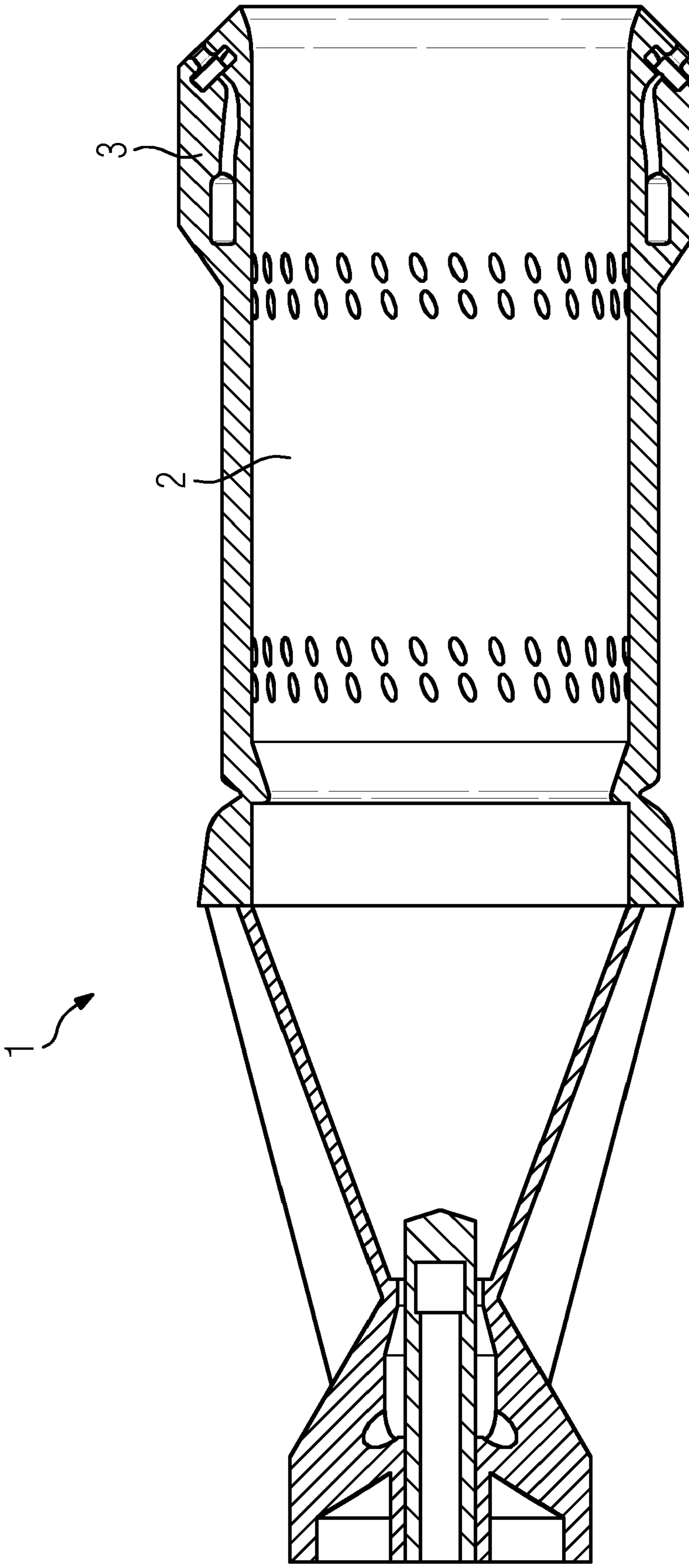


FIG 4

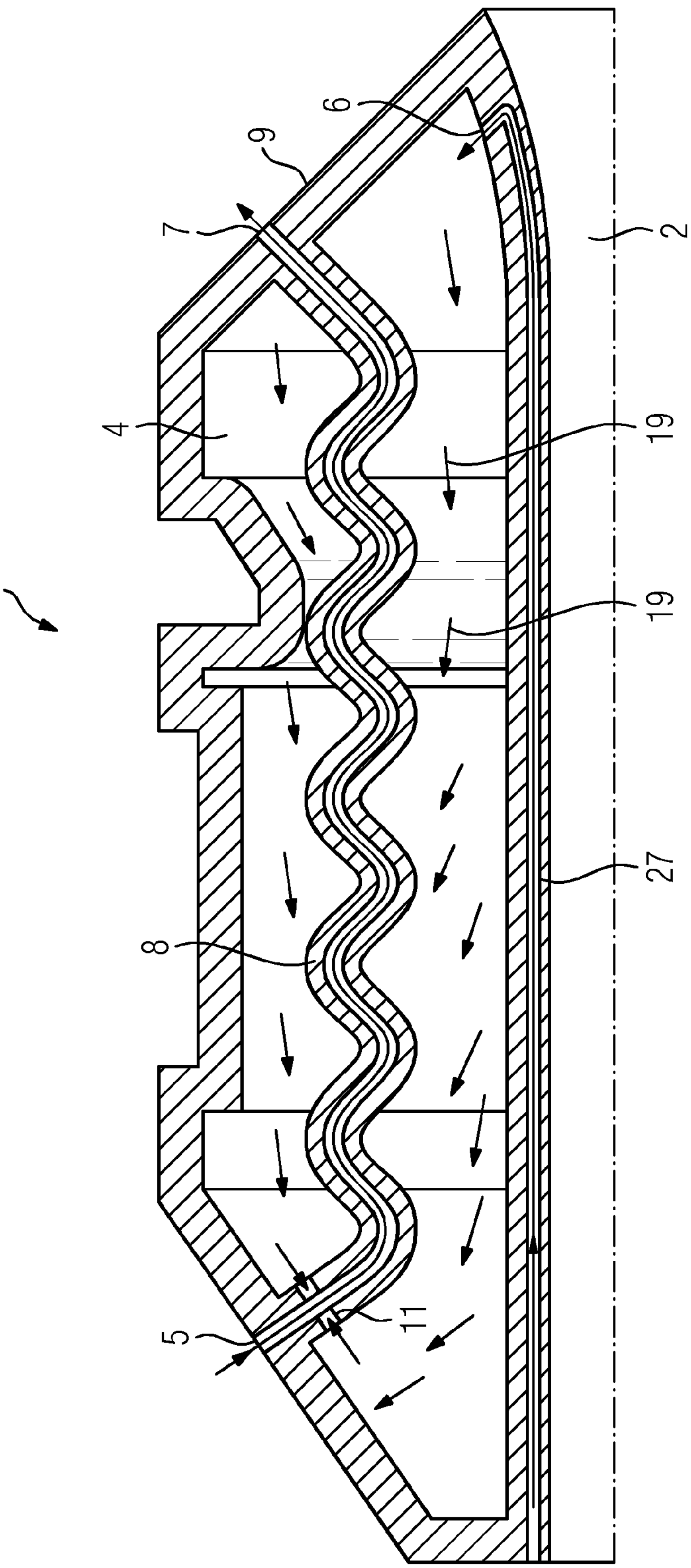


FIG 5

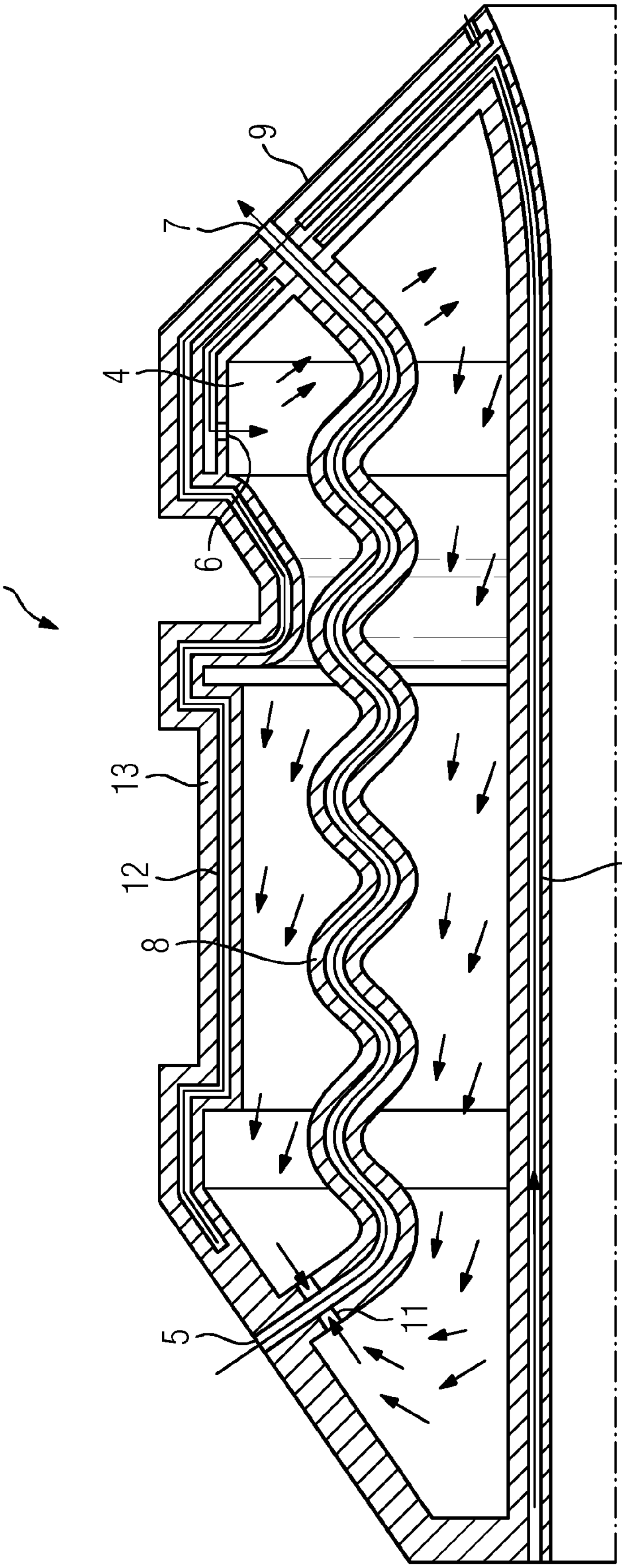


FIG 6

FIG 7

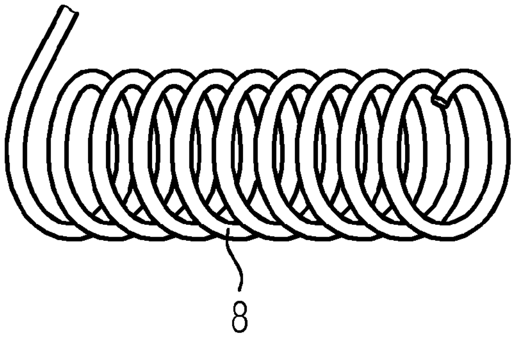


FIG 8

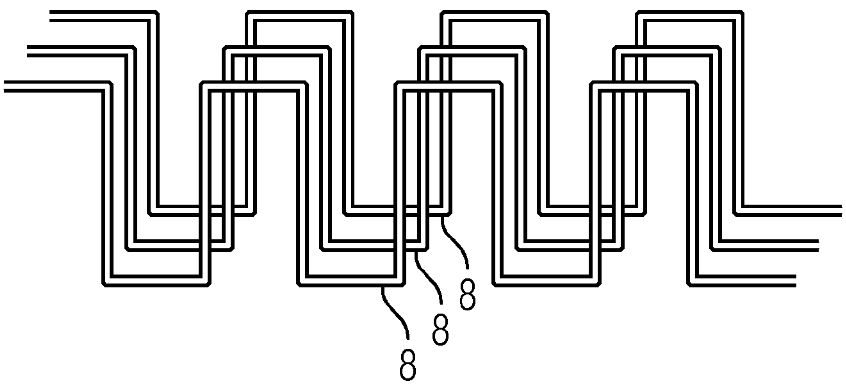
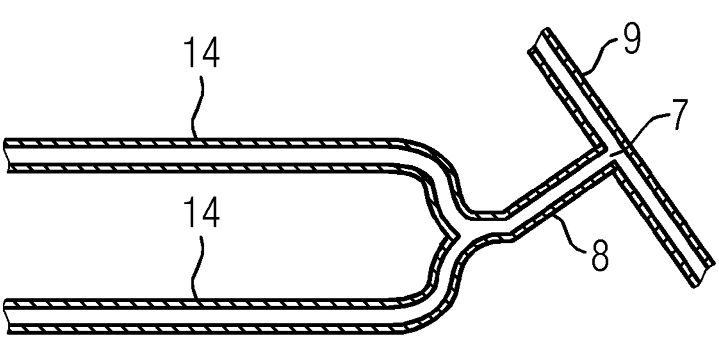


FIG 9



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EUROPEAN SEARCH REPORT

Application Number
EP 18 19 3084

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	EP 3 290 804 A1 (SIEMENS AG [DE]) 7 March 2018 (2018-03-07) * paragraphs [0056], [0057], [0059] * * figures 7, 8 * -----	1,2,11, 12	INV. F23R3/28 F23R3/34 F23R3/50 F23D11/10 F23D11/40 F23D14/02
A,D	EP 1 389 713 A1 (ALSTOM SWITZERLAND LTD [CH]) 18 February 2004 (2004-02-18) * the whole document * -----	1,2,11, 12	
A,D	EP 2 268 975 B1 (SIEMENS AG [DE]) 14 December 2016 (2016-12-14) * the whole document * -----	1,2,11, 12	

TECHNICAL FIELDS SEARCHED (IPC)

F23R
F23D
F23C

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	15 February 2019	Vogl, Paul

CATEGORY OF CITED DOCUMENTS

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15-02-2019

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- EP 2268975 B1 **[0002] [0021]**