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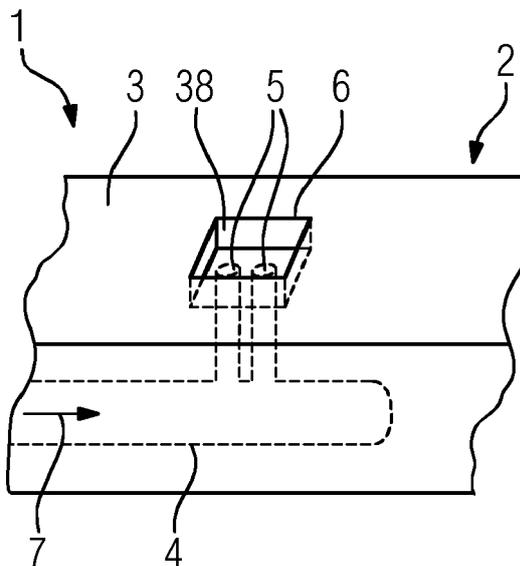
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(54) **SWIRLER, BURNER AND COMBUSTOR FOR A GAS TURBINE ENGINE**

(57) The invention relates to a swirler for use in a combustor of a gas turbine engine, comprising a plurality of generally radially inwardly extending passages arranged circumferentially staggered in a circle, each passage having a radially outer inlet end, a radially inner outlet end, first and second generally radially inwardly extending lateral surfaces, and a base surface and top surface, in use of the swirler fuel and air travelling along

the passages from their inlet ends to their outlet ends so as to create adjacent to the outlet ends a swirling fuel/air mixture, wherein at least one surface of at least one passage comprises at least one gas fuel injection hole, characterized in that the surface, having the gas fuel injection hole, comprises at least one counterbore radially surrounding the gas fuel injection hole, wherein the gas fuel injection hole is arranged at a base of the counterbore.

**FIG 2**



## Description

**[0001]** The invention relates to a swirler for use in a combustor of a gas turbine engine, comprising a plurality of generally radially inwardly extending passages arranged circumferentially staggered in a circle, each passage having a radially outer inlet end, a radially inner outlet end, first and second generally radially inwardly extending lateral surfaces, and a base surface and top surface, in use of the swirler fuel and air travelling along the passages from their inlet ends to their outlet ends so as to create adjacent to the outlet ends a swirling fuel/air mixture, wherein at least one surface comprises at least one gas fuel injection hole.

**[0002]** Moreover, the invention relates to a burner for a gas turbine engine.

**[0003]** Furthermore, the invention relates to a combustor for a gas turbine engine.

**[0004]** A gas turbine engine comprises an ambient air supply duct, a compressor, a combustor, an expander, i.e. a turbine, and an exhaust gas duct.

**[0005]** It is desired to reduce the polluting emissions, in particular nitrogen oxide ( $\text{NO}_x$ ), carbon monoxide (CO), unburned hydro carbons (UHC), smoke and particle emissions, of gas turbine engines.

**[0006]** One way to reduce polluting emissions is to provide a burner in a combustor of a gas turbine engine with a swirler. The swirler is arranged in a passage through which compressed air is supplied to a combustion chamber of the combustor via the burner. The swirler is connected to a gas fuel supply device. The swirler gives the supplied air a tangential direction rotating the flow i.e. providing a swirling air flow to the combustion chamber. Simultaneously, gas fuel is introduced in the air through internal gas fuel passages arranged in the swirler. The swirling air/gas fuel mixture is supplied to the combustion chamber of the combustor. The swirling of the air/gas fuel mixture leads to a highly homogeneous air/gas fuel mixture in form of a lean gas fuel mixture. Such lean gas fuel mixtures burn at a lower combustion temperatures than rich gas fuel mixtures. Reduced combustion temperatures particularly lead to reduced nitrogen oxide emissions.

**[0007]** It is an object of the invention to further reduce polluting emissions, in particular nitrogen oxide emissions, associated with the operation of gas turbine engines.

**[0008]** This object is solved by the independent claims. Advantageous embodiments are disclosed in the dependent claims which either by taken alone or in any combination with each other may relate to an aspect of the invention.

**[0009]** The swirler according to the invention for use in a combustor of a gas turbine engine comprises a plurality of generally radially inwardly extending passages arranged circumferentially staggered in a circle, each passage having a radially outer inlet end, a radially inner outlet end, first and second generally radially inwardly

extending lateral surfaces, and a base surface and top surface, in use of the swirler fuel and air travelling along the passages from their inlet ends to their outlet ends so as to create adjacent to the outlet ends a swirling fuel/air mixture, wherein at least one surface of at least one passage comprises at least one gas fuel injection hole, wherein the surface, having the gas fuel injection hole, comprises at least one counterbore radially surrounding the gas fuel injection hole, and wherein the gas fuel injection hole is arranged at a base of the counterbore.

**[0010]** According to the invention the gas fuel injection hole is not arranged, as conventionally known, directly at the surface of the passage, but in the counterbore of the surface which defines a cavity in the surface. Through this, a low velocity region is created in the cavity, i.e. the counterbore, to reduce the momentum of a gas fuel jet exiting the gas fuel injection hole. Thereby, the incoming cross flow of air inside the cavity will mix with local recirculation in the cavity to enhance mixing of air and gas fuel. This enhanced or tailored mixing is attended by lower polluting emissions. Additionally, the enhanced or tailored mixing results in a reduction of the number of hot spots to further reduce pollution emissions.

**[0011]** Particularly, the cross flow velocity of compressed air streaming along the surface of the passage comprising the counterbore reduces the momentum of the gas fuel stream exiting the gas fuel injection hole by recirculation of air with low pressure inside the counterbore. Through this, the aerodynamics for mixing gas fuel and air are improved.

**[0012]** In contrast, known swirlers comprise passages with gas fuel injection holes directly arranged for example at a lateral surface which is defined by a lateral surface plane of a vane of the swirler without providing an inventive counterbore. This leads to less efficient and/or controlled mixing of gas fuel and air because the gas fuel streams coming from the gas fuel injection holes travel toward an expansion region of the combustion chamber of the combustor without being effectively influenced by mixing.

**[0013]** The inventive swirler can have one or more passages designed according to the invention. Especially, all passages of the swirler can be designed accordingly. The cross section of at least one passage can be rectangular, squared, circular, elliptical or the like.

**[0014]** The surface of the at least one swirler passage according to the invention can have two or more gas fuel injection holes. Each gas fuel injection hole communicates with at least one internal gas supply passage of the swirler. At least one surface can be flat-shaped, leaning, facet-shaped, curved-shaped or the like.

**[0015]** The counterbore can be optimized with respect to its mixing characteristics. For example the dimensions of the counterbore, such as its depth, diameter or the like, can be adapted to a specific use of the swirler in order to optimize the mixing characteristics of the swirler.

**[0016]** Preferably, the counterbore is rectangular-shaped, oval-shaped, elliptical-shaped or circular-

shaped. Other shapes of the counterbore are also possible to improve the mixing characteristics of the counterbore.

[0017] Preferably, at least one surface comprises at least two gas fuel injection holes and at least one counterbore, the counterbore radially surrounding both gas fuel injection holes, wherein the gas fuel injection holes are arranged at a base of the counterbore. According to this, all gas fuel injection holes of a surface can be arranged in a common single counterbore of that surface.

[0018] Preferably, wherein at least one surface comprises at least two gas fuel injection holes and at least two counterbores, wherein each gas fuel injection hole is radially surrounded by its own counterbore and is arranged at a base of this counterbore. According to this embodiment, more than one counterbore is arranged on one single surface of the swirler passage, each counterbore surrounding at least one gas fuel injection hole.

[0019] Preferably, the surface, having the at least one gas fuel injection hole and the at least one counterbore, is a lateral surface. The lateral surface can be defined by a lateral surface of a vane of the swirler.

[0020] Preferably, the surface, having the at least one gas fuel injection hole and the at least one counterbore, is the base surface.

[0021] The burner according to the invention for a gas turbine engine comprises at least one swirler according to any one of the preceding embodiments or any combination thereof. The above mentioned advantages connected with the swirler are correspondingly connected with the inventive burner.

[0022] The combustor according to the invention for a gas turbine engine comprises at least one burner according to the invention. The above mentioned advantages connected with the swirler are correspondingly connected with the inventive combustor.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The above mentioned attributes and other features and advantages of this invention and the manner of attaining them will become more apparent and the invention itself will be better understood by reference to the following description of embodiments of the invention taken in conjunction with the accompanying drawings, wherein

FIG. 1 shows part of a turbine engine in a sectional view,

FIG. 2 shows a perspective transparent drawing of a detail of an embodiment of the inventive swirler,

FIG. 3 shows a sectional view of the swirler shown in FIG.2,

FIG. 4 shows a perspective transparent drawing of a detail of a further embodiment of the inventive swirl-

er,

FIG. 5 shows a perspective transparent drawing of a detail of a further embodiment of the inventive swirler, and

FIG. 6 shows a perspective transparent drawing of a detail of a further embodiment of the inventive swirler.

### DETAILED DESCRIPTION OF INVENTION

[0024] Figure 1 is a schematic illustration of a general arrangement of a gas turbine engine 10 having an inlet 12, a compressor 14, a combustor system 16, a turbine system 18, an exhaust duct 20 and a twin-shaft arrangement 22, 24. The gas turbine engine 10 is generally arranged about an axis 26 which for rotating components is their rotational axis. The arrangements 22, 24 may have the same or opposite directions of rotation.

[0025] The combustion system 16 comprises an annular array of combustor units, i.e. burner 36, only one of which is shown. In one example, there are six burners 36 evenly spaced about the engine 10.

[0026] The turbine system 18 includes a high-pressure turbine 28 drivingly connected to the compressor 14 by a first shaft 22 of the twin-shaft arrangement 22, 24. The turbine system 18 also includes a low-pressure turbine 30 drivingly connected to a load (not shown) via a second shaft 24 of the twin-shaft arrangement.

[0027] The term axial is with respect to the axis 26. The terms upstream and downstream are with respect to the general direction of gas flow through the engine 10 and as seen in FIG.1 is generally from left to right.

[0028] The compressor 14 comprises an axial series of stator vanes and rotor blades mounted in a conventional manner. The stator or compressor vanes may be fixed or have variable geometry to improve the airflow onto the downstream rotor or compressor blades.

[0029] Each turbine 28, 30 comprises an axial series of stator vanes and rotor blades mounted via rotor discs arranged and operating in a conventional manner. A rotor assembly comprises an annular array of rotor blades or blades and the rotor disc.

[0030] In operation air 32 is drawn into the engine 10 through the inlet 12 and into the compressor 14 where the successive stages of vanes and blades compress the air before delivering the compressed air into the combustion system 16. In a combustion chamber of the combustion system 16 the mixture of compressed air and fuel is ignited. The resultant hot working gas flow is directed into, expands and drives the high-pressure turbine 28 which in turn drives the compressor 14 via the first shaft 22. After passing through the high-pressure turbine 28, the hot working gas flow is directed into the low-pressure turbine 30 which drives the load via the second shaft 24.

[0031] The low-pressure turbine 30 can also be referred to as a power turbine and the second shaft 24 can

also be referred to as a power shaft. The load is typically an electrical machine for generating electricity or a mechanical machine such as a pump or a process compressor. Other known loads may be driven via the low-pressure turbine 30. The fuel may be in gaseous and/or liquid form.

[0032] The turbine engine 10 shown and described with reference to FIG.1 is just one example of a number of engines or turbomachinery in which this invention can be incorporated. Such engines can be gas turbines or steam turbine and include single, double and triple shaft engines applied in marine, industrial and aerospace sectors.

[0033] Figure 2 shows a perspective transparent drawing of a detail of an embodiment of the inventive swirler 1 for use in a combustor of a gas turbine engine.

[0034] The swirler 1 comprises a plurality of generally radially inwardly extending passages 2 arranged circumferentially staggered in a circle, wherein only one passage 2 is shown in FIG.2. Each passage 2 having a radially outer inlet end and a radially inner outlet end, which are not shown in FIG.2. Each passage 2 is defined by surfaces 3, wherein only one surface 3 is shown in FIG. 2. This surface 3 may be a lateral surface, a base surface or a top surface. In use of the swirler 1 fuel and air travelling along the passages 2 from their inlet ends to their outlet ends so as to create adjacent to the outlet ends a swirling fuel/air mixture.

[0035] The surface 3 comprises two gas fuel injection holes 5 communicating with an internal gas fuel supply passage 4 of the swirler 1. Additionally, the surface 3 comprises a rectangular-shaped, in particular box-shaped, counterbore 6 radially surrounding the gas fuel injection holes 5. The gas fuel injection holes 5 are arranged at a base 38 of the counterbore 6. Therefore, the common counterbore 6 radially surrounds both gas fuel injection holes 5. The flow of gas fuel through the gas fuel supply passage 4 is indicated by the arrow 7.

[0036] Figure 3 shows a section view of the swirler 1 shown in FIG.1. The air streaming along the surface 3 is indicated by the arrow 8. The spirally-shaped lines 9 indicate how air circulates in said counterbore 6, thereby reducing the momentum of a gas fuel jet exiting the gas fuel injection holes 5. The incoming cross flow of air inside the counterbore 6 will mix with these local recirculation in the counterbore 6, thereby enhancing the mixing of air and gas fuel.

[0037] Figure 4 shows a perspective transparent drawing of a detail of a further embodiment of the inventive swirler 1. This embodiment differs from the embodiment shown in FIG.2 only in that the counterbore 6 is oval-shaped.

[0038] Figure 5 shows a perspective transparent drawing of a detail of a further embodiment of the inventive swirler 1. This embodiment differs from the embodiment shown in FIG.2 only in that the counterbore 6 is circular-shaped.

[0039] Figure 6 shows a perspective transparent

drawing of a detail of a further embodiment of the inventive swirler 1. This embodiment differs from the embodiments shown in FIG.2 to FIG.5 in that the surface 3 comprises two gas fuel injection holes 5 and two counterbores 6, wherein each gas fuel injection hole 5 is radially surrounded by its own counterbore 6 and is arranged at a base 38 of this counterbore 6.

[0040] In the described embodiments, the gas fuel injection holes 5 are arranged in a row with respect to the flow direction, indicated by the arrow 8, of air streaming along the surface 3. Alternatively, the gas fuel injection holes 5 may be arranged in a crosswise direction with respect to said flow direction.

[0041] Although the invention has been explained and described in detail in connection with the preferred embodiments it is noted that the invention is not limited to the disclosed embodiments. A person skilled in the art can derive from these embodiments other variations without leaving the scope of protection of the invention.

## Claims

1. A swirler (1) for use in a combustor of a gas turbine engine (10), comprising a plurality of generally radially inwardly extending passages (2) arranged circumferentially staggered in a circle, each passage (2) having a radially outer inlet end, a radially inner outlet end, first and second generally radially inwardly extending lateral surfaces (3), and a base surface (3) and top surface (3), in use of the swirler (1) fuel and air travelling along the passages (2) from their inlet ends to their outlet ends so as to create adjacent to the outlet ends a swirling fuel/air mixture, wherein at least one surface (3) of at least one passage (2) comprises at least one gas fuel injection hole (5), **characterized in that** the surface (3), having the gas fuel injection hole (5), comprises at least one counterbore (6) radially surrounding the gas fuel injection hole (5), wherein the gas fuel injection hole (5) is arranged at a base (38) of the counterbore (6).
2. The swirler (1) according to claim 1, wherein the counterbore (6) is rectangular-shaped, oval-shaped, elliptical-shaped or circular-shaped.
3. The swirler (1) according to claim 1 or 2, wherein at least one surface (3) comprises at least two gas fuel injection holes (5) and at least one counterbore (6), the counterbore (6) radially surrounding both gas fuel injection holes (5), wherein the gas fuel injection holes (5) are arranged at a base (38) of the counterbore (6).
4. The swirler (1) according to claim 1 or 2, wherein at least one surface (3) comprises at least two gas fuel injection holes (5) and at least two counterbores (6), wherein each gas fuel injection hole (5) is radially

surrounded by its own counterbore (6) and is arranged at a base (38) of this counterbore (6).

5. The swirler (1) according to any one of the claims 1 to 4, wherein the surface (3), having the at least one gas fuel injection hole (5) and the at least one counterbore (6) is a lateral surface (3) . 5
6. The swirler (1) according to any one of the claims 1 to 4, wherein the surface (3), having the at least one gas fuel injection hole (5) and the at least one counterbore (6) is the base surface (3). 10
7. A burner (36) for a gas turbine engine (10), **characterized by** at least one swirler (1) according to any one of the preceding claims. 15
8. A combustor for a gas turbine engine (10) comprises at least one burner (36) according to claim 7. 20

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FIG 1

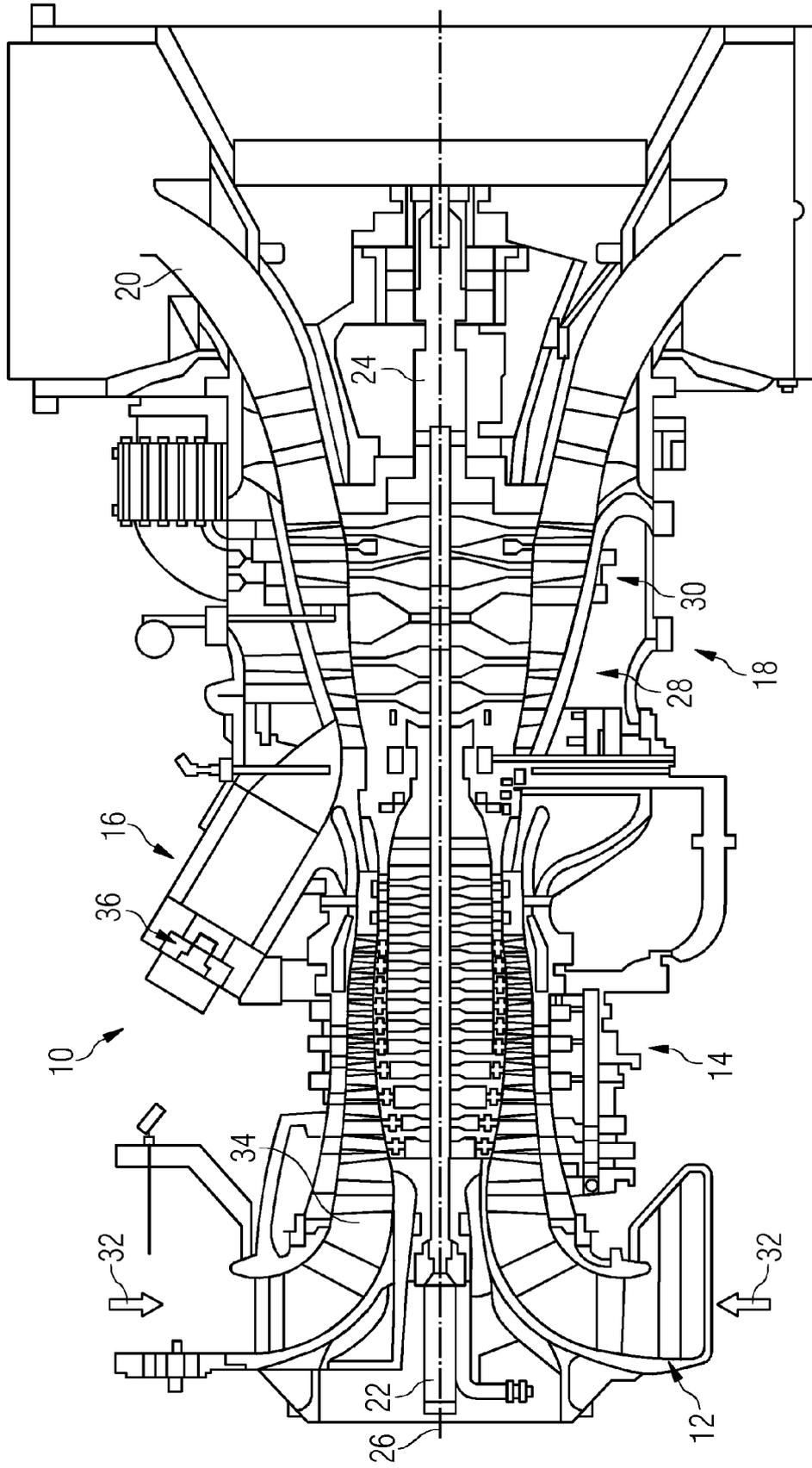


FIG 2

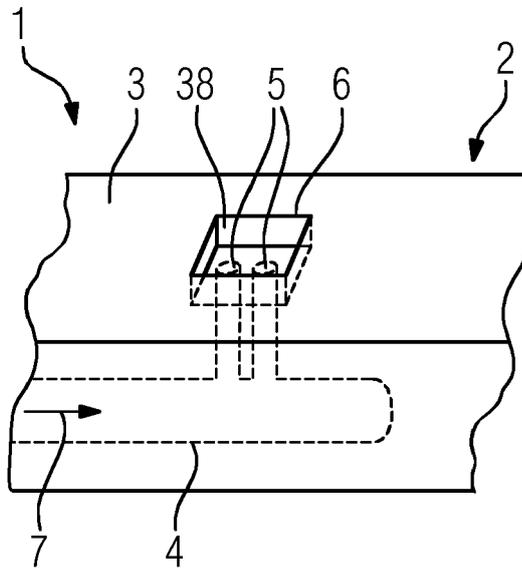


FIG 3

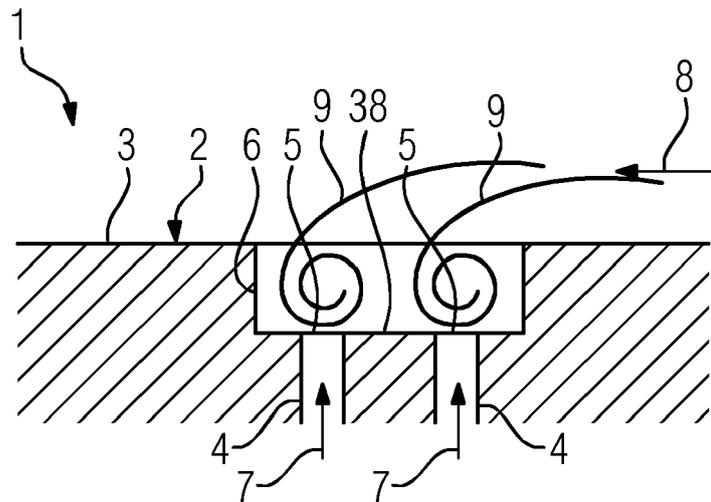


FIG 4

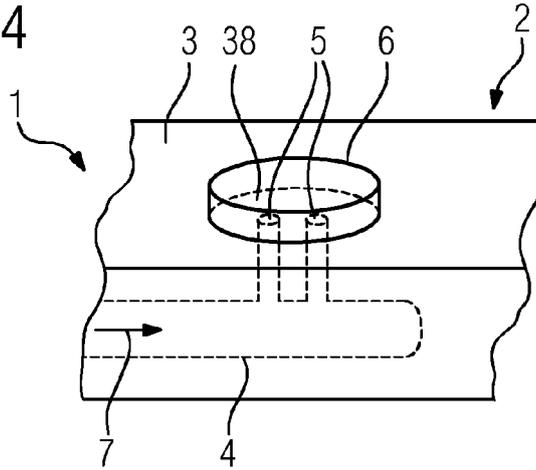


FIG 5

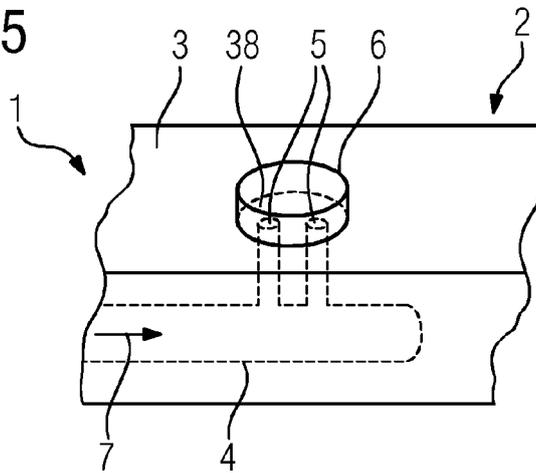
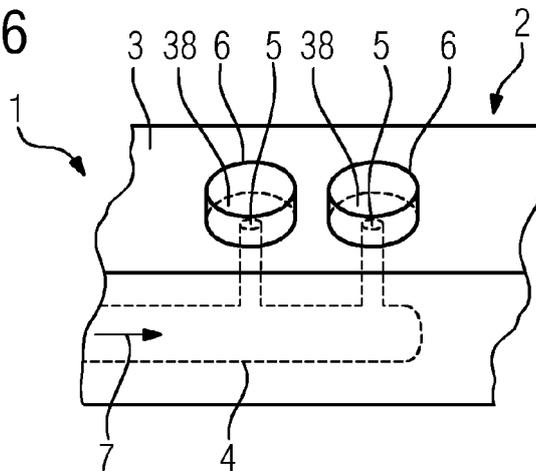


FIG 6





EUROPEAN SEARCH REPORT

Application Number  
EP 15 16 2154

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			F23R F23C F23D
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 28 August 2015	Examiner Villar Fernández, R
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT  
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
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