(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 933 559 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
21.10.2015 Bulletin 2015/43

(51) Int Cl.:
F23R 3/20 (2006.01) *F23D 99/00* (2010.01)
F23R 3/34 (2006.01)

(21) Application number: **14164859.2**

(22) Date of filing: **16.04.2014**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(71) Applicant: **ALSTOM Technology Ltd**
5400 Baden (CH)

(72) Inventors:
- **Knöpfel, Hanspeter**
  5605 Dottikon (CH)
- **Eroglu, Adnan**
  5417 Untersiggenthal (CH)

(74) Representative: **Alstom Technology Ltd**
CHTI Intellectual Property
Brown Boveri Strasse 7
5400 Baden (CH)

(54) Fuel mixing arragement and combustor with such a fuel mixing arrangement

(57) The present application relates to a fuel mixing arrangement (100) for mixing fuel and an oxidizing medium for combustion in a combustor of a gas turbine, with a flute fuel injection system comprising at least two streamline bodies (22) with at least one fuel nozzle wherein the streamline bodies (22) comprise either vortex generators or lobes and at least one body (22) is arranged parallel to the flow direction of the oxidizing medium. A better mixing is achieved by arranging the at least second other streamline body (22) inclined to the first one. A perpendicular arrangement of the streamline bodies (22) is preferred, so that a square arrangement occurs.

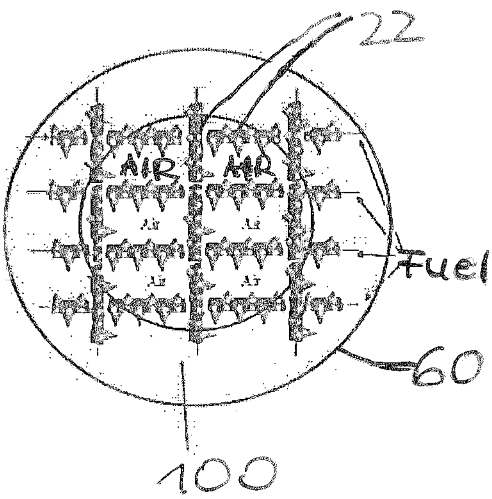


FIG. 5

EP 2 933 559 A1

Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to combustors of a gas turbine especially for a reheat system with sequential combustion or for a staged system which are proved to excel in achieving very low emissions at high firing temperatures. Although such combustion systems fulfil also a number of stringent requirements, such as low pressure drop, low cooling air consumption, long lifetime and fuel flexibility, an additional improvement of mixing quality of fuel with air and/or flue gas within a temperature range of 350 to 1500 °C should be achieved with a special fuel mixing arrangement.

PRIOR ART

[0002] It is well known that in order to achieve a high efficiency a high turbine inlet temperature is required in standard gas turbines. As a result, there arise high NOx emission levels and higher life cycle costs. These problems can be mitigated with a sequential combustion cycle, wherein the compressor delivers nearly double the pressure ratio of a conventional one. The main flow passes the first combustion chamber (e.g. using a burner of the general type as disclosed in EP 0 321 809 B1 or as in US 4,932,861 A, also called EV combustor, where the EV stands for environmental), wherein a part of the fuel is combusted. After expanding at the high-pressure turbine stage, the remaining fuel is added and combusted (e.g. using a burner of the type as disclosed in US 5,431,018 A or US 5,626,017 A or in US 2002/0187448 A1, also called SEV combustor, where the S stands for sequential). Both combustors contain premixing burners, as low NOx emissions require high mixing quality of the fuel and the oxidizer.

[0003] Since the second combustor is fed by expanded exhaust gas of the first combustor, the operating conditions allow self-ignition (spontaneous ignition) of the fuel air mixture without additional energy being supplied to the mixture. To prevent ignition of the fuel air mixture in the mixing region, the residence time therein must not exceed the auto ignition delay time. This criterion ensures flame-free zones inside the burner. This criterion poses challenges in obtaining appropriate distribution of the fuel across the burner exit area.

[0004] SEV-burners are currently designed for operation on natural gas and oil only. Therefore, the momentum flux of the fuel is adjusted relative to the momentum flux of the main flow so as to penetrate in to the vortices. This is done by using air from the last compressor stage (high-pressure carrier air). The high-pressure carrier air is bypassing the high-pressure turbine. The subsequent mixing of the fuel and the oxidizer at the exit of the mixing zone is just sufficient to allow low NOx emissions (mixing quality) and avoid flashback (residence time), which may be caused by auto ignition of the fuel air mixture in the mixing zone.

[0005] Well known is also a staged combustion system where for example lean premixed combustion of a hydrocarbon fuel and air is combined with lean direct injection of hydrocarbon fuel and carrier fluid into a combustor downstream of premixed reaction zone in order to achieve very low levels of NOx emissions (US 6,192,688 B1). EP 2 211 109 A1 discloses a burner of a gas turbine having a duct that comprises at least a vortex generator and downstream of it a plurality of nozzles for injection a fuel within the duct wherein the nozzles are arranged along the wall of the duct and are arranged for injecting fuel toward the inner of the duct.

[0006] The concepts developed up to now provide very good mixing levels and combustion performances. However, they rely either in high momentum flux ratios, complicated geometries or complex sealing systems between the fuel injector and the hot gas path (US 5,645,410 A, WO 2011 /037646 A1, US 5,351,474 A, US 6,192,688 B1, WO 2011/054757 A2, WO 2011/054766 A2, EP 2 211 109 A1).

[0007] Documents WO 2011/054757 A2, WO 2011/054766 A2 filed by the applicant of the present application describe multipoint injection systems which provide an effective way to mix fuel and hot gas with a minimal pressure drop. The multipoint injection scheme is supported by fluid-dynamic structure generated by dedicated vortex generators or lobes. Thanks to the strong inline component of the fuel injectors it is independent on the momentum flux ratio.

[0008] In WO 2011/054757 A2 is described the so called Flute Fuel Injection System with vortex generators, while in WO 2011/054766 A2 the Flute Fuel Injection System with lobes is described. Fig. 1 (inline fuel injection) and Fig. 2 (inclined fuel injection) show in detail the first concept according to two embodiments of WO 2011/054757 A2:

Fig. 1 a) shows in a first embodiment of WO 2011 /054757 A2 the streamlined body in a view opposite to the direction of the flow of oxidising medium with fuel injection parallel to the flow of oxidising medium, in Fig. 1b) a side view onto such a streamlined body is shown, in Fig. 1c) a cut perpendicular to the central plane of the streamlined body is shown, in Fig. 1d) a schematic sketch how the attack angle and a sweep angle of the vortex generator are defined, wherein in the upper representation a side elevation view is given, and in the lower representation a view onto the vortex generator in a direction perpendicular to the plane on which the vortex generator is mounted are given.

[0009] The first embodiment to this concept is to stagger the vortex generators 23 embedded on the streamlined bodies or flutes 22 as shown in Figure 1. The vortex generators 23 are located sufficiently upstream of the fuel injection location to avoid flow recirculation. The vortex generator attack and sweep angles are chosen to produce highest circulation rates at a minimum pressure drop.

[0010] Normally such vortex generators have an attack angle α in the range of 15-20° and/or a sweep angle β in the range of 55-65°, for a definition of these angles reference is made to Fig. 1d), where for an orientation of the vortex generator in the air flow 14 as given in Fig. 1 a) the definition of the attack angle α is given in the upper representation which is an elevation view, and the definition of the sweep angle β is given in the lower representation, which is a top view onto the vortex generator.

[0011] As illustrated the body 22 is defined by two lateral surfaces 33 joined in a smooth round transition at the leading edge 25 and ending at a small radius/sharp angle at the trailing edge 24 defining the cross-sectional profile 48. Upstream of trailing edge the vortex generators 23 are located. The vortex generators are of triangular shape with a triangular lateral surface 27 converging with the lateral surface 33 upstream of the vortex generator, and two side surfaces 28 essentially perpendicular to a central plane 35 of the body 22. The two side's surfaces 28 converge at a trailing edge 29 of the vortex generator 23, and this trailing edge is typically just upstream of the corresponding fuel nozzle 15. The lateral surfaces 27 but also the side surfaces 28 may be provided with effusion/film cooling holes 32. The whole body 22 is arranged between and bridging opposite the two walls of the combustor, so along a longitudinal axis 49 essentially perpendicular to the walls. Parallel to this longitudinal axis there is, according to this embodiment, the leading edge 25 and the trailing edge 24. It is however also possible that the leading edge 25 and/or the trailing edge are not linear but are rounded.

[0012] At the trailing edge the nozzles 15 for fuel injection are located. In this case fuel injection takes place along the injection direction 35 which is parallel to the central plane 35 of the body 22. Fuel as well as carrier air are transported to the nozzles 15 as schematically illustrated by arrows 30 and 31, respectively. Typically the fuel supply is provided by a central tubing, while the carrier air is provided in a flow adjacent to the walls 33 to also provide internal cooling of the structures 22. The carrier airflow is also used for supply of the cooling holes 32. Fuel is injected by generating a central fuel jet along direction 34 enclosed circumferentially by a sleeve of carrier air.

[0013] The staggering of vortex generators 23 helps in avoiding merging of vortices resulting in preserving very high net longitudinal vorticity. The local conditioning of fuel air mixture with vortex generators close to respective fuel jets improves the mixing. The overall burner pressure drop is significantly lower for this concept. The respective vortex generators produce counter rotating vortices which at a specified location pick up the axially spreading fuel jet.

[0014] Another second embodiment of this first concept is shown in Fig. 2, where the fuel is injected at a certain angle (can be increased up to 90°). In this case, the fuel is directed into the vortices and this has shown to improve mixing even further. More specifically in this case there are, along the row of nozzles 15, a first set of three nozzles 15, which are directing the fuel jet 34 out of plane 35 at one side of plane 35, and the second set of nozzles 15' directing the corresponding fuel jet out of plane at the other side of plane 35. The more the fuel jets 34 are directed into the vortices the more efficient the mixing takes place.

[0015] In WO 2011/054766 A2 the fuel injection system with lobes as a second concept is described. Fig. 3 shows the basic design of a lobed flute injector with inline fuel injection, wherein in Fig 3a) a cut of the flute 22 perpendicular to the longitudinal axis is shown, in Fig. 3b) a side view, in Fig. 3c) a view onto the trailing edge and against the main flow, and in Fig. 3d) a prospective view are shown.

[0016] The injector can be part of a burner, as already described elsewhere. The main flow is passing the lobed mixer, resulting in velocity gradients. These result in intense generation of shear layers, into which fuel can be injected. The lobe angles are chosen in such way to avoid flow separation. The streamlined body 22 has a leading edge 25 and a trailing edge 24. The leading edge 25 defines a straight line and in the leading edge portion of the shape the shape is essentially symmetric, so in the upstream portion the body has a rounded leading edge and no lobing. The leading edge 25 extends along the longitudinal axis 49 of the flute 22. Downstream of this upstream section the lobes successively and smoothly develop and grow as one goes further downstream towards the trailing edge 24. In this case the lobes are given as half circles sequentially arranged one next to the other alternating in the two opposite directions along the trailing edge, as particularly easily visible in Fig. 3c).

[0017] At each turning point 47 which is also located on the central plane 35, there is located a fuel nozzle which injects the fuel inline, so essentially along the main flow direction 14. In this case the trailing edge is not a sharp edge but has width w which is in the range of 5 to 10 mm. The maximum width W of the flute element 22 is in the range of 25-35 mm and the total height h of the lobing is only slightly larger than this width W. A blade for a typical burner in this case has a height H in the range of 100-200 mm. The periodicity λ is around 40-60 mm. The lobes could be staggered in order to improve the mixing performance and the lobe size can be varied to optimize both pressure drop and mixing. In one embodiment the burner wall has a converging portion and three lobed injectors 22 are arranged in this cavity. The central injector (body 22) is arranged parallel to the main flow direction 14, while the lateral injectors (bodies 22) are arranged in a converging manner adapted to the convergence of the two side walls of the burner/combustor.

[0018] Both documents, WO 2011/054757 A2 and WO 2011/054766 A2, are integral part of the present application;

that means all variants disclosed in these documents are integrated in the present application.

SUMMARY OF THE INVENTION

[0019] It is an object of the present invention to disclose a fuel mixing arrangement with multipoint fuel injection systems with dedicated vortex generators or lobes as described in WO 2011/054757 A2, WO 2011/054766 A2 or similar and providing excellent fuel/air mixing without the need of high momentum flux ratio and with fitting to different contours, for example to a cylindrical or a square burner. Such configuration should be well suited for annular combustion systems (as in the GT24/26 developed by the applicant) as well as for a can combustor configuration where the temperature at the inlet to the mixer is in a range of 350 to 1500 °C.

[0020] This and other objects are obtained by a fuel mixing arrangement according to claim 1. The fuel mixing arrangement for mixing fuel and an oxidizing medium, for example air, air and flue gas mixtures or flue gas, for combustion in a combustor of a gas turbine, comprises a flute fuel injection system with at least two streamline bodies with at least one fuel nozzle, wherein the streamline bodies comprise either vortex generators or lobes and at least one body is arranged parallel to the flow direction of the oxidizing medium. It is characterized in that the at least second other streamline body is arranged inclined to the at least first streamline body.

[0021] The disclosed fuel mixer arrangement has the following advantages:

- Improved mixing, which leads to less emission release
- Shortening of the mixing length, which leads to a compact design
- Reduced pressure drop
- Supplying multi fuel is possible, which leads to a more uniform mixing profile.

[0022] It is an advantage when the streamline bodies are arranged perpendicular to each other and when the fuel mixing arrangement comprises a plurality of streamline bodies which are placed in a square arrangement.

[0023] The fuel mixing arrangement can be placed as an advantage in a burner/mixer with a round or a square cross section. The fuel supply is very simple and not dependent on the contour of the burner/mixer.

[0024] In a preferred embodiment the fuel mixing arrangement according to the invention is placed in the main flow of the combustor or in a different embodiment it is placed in a by-pass passage in the wall of the combustor. Furthermore, an axial staging arrangement could also be used by placing at least two mixing arrangements one after another in the direction according to the main flow. These embodiments are also applicable in a combustor system for a gas turbine with two serial combustors.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The present invention is now to be explained more closely by means of different embodiments and with reference to the attached drawings.

Fig. 1 shows one embodiment of the flute fuel injection system with vortex generators and an inline fuel injection according to the prior art (WO 2011/054757 A2);

Fig. 2 shows a second embodiment of the flute fuel injection system with vortex generators and inclined fuel injection according to the prior art (WO2011/054757 A2);

Fig. 3 shows a third embodiment of the flute fuel injection system with lobes according to the prior art (WO 2011/054766 A2);

Fig. 4 shows an overview of additional injection systems;

Fig. 5 shows a first embodiment of the fuel injector arrangement (square arrangement) according to the invention in a round burner or mixer;

Fig.6 shows the embodiment (square arrangement of the fuel injectors) according to Fig.5 in a square burner or mixer;

Fig. 7 shows three embodiments of the general architecture of a combustor with the fuel mixing arrangement according to the invention and

Fig. 8 shows an additional embodiment with a mixing arrangement according to the invention integrated in a combustor system with two serial combustors.

[0026] The same reference numbers are used for the same details in the figures.

DETAILED DESCRIPTION OF DIFFERENT EMBODIMENTS OF THE INVENTION

[0027] As described above the present disclosure also relies on multipoint fuel injection device with a streamlined body and with dedicated vortex generators or lobes allowing a more homogeneous fuel distribution. The fuel injection system is applied to mixer configuration placed in approach medium within a temperature range of 350-1500 °C. The oxidizing medium could be air, an air/flue gas mixture or simply flue gas.

[0028] Fig.4a) to Fig. 4c) show as an overview three possible embodiments for the fuel injection devices, wherein on the axial direction A-A the shape of the body 22 of the injection device has an aerodynamic profile, similar to a symmetric airfoil of for example a turbine blade. The design is similar to the described in WO 2011/054757 A2 resp. WO 2011/054766 A2 (see Fig. 1-3). The only differences are the unequal size of the vortex generators 23 at the opposite lateral surfaces 33 of the body 22.

[0029] In Fig. 4a) the vortex generators (VG) 23 are coupled with inline injection of fuel: The injector nozzles are aligned with the main hot gas flow. Mixing is enhanced by dedicated VGs creating vertical structures helping the distribution of the fuel. The VGs on one lateral surface 33 are bigger than the VGs on the opposite lateral surface 33 of the body 22. The advantages of the inline injection are cheaper manufacturability, lower impact of momentum flux ratio on performances, higher flashback margin / fuel flexibility. In Fig. 4b) the vortex generators 23 are coupled with inclined injection of fuel: The injector nozzles 15 are inclined so that the fuel can better penetrate into the vertical structures created by VGs similar to the embodiment according to Fig. 4a). This can provide better mixing for lower NOx emissions. Also here, the VGs on one lateral surface 33 are bigger than the VGs on the opposite lateral surface 33 of the body 22. Fig. 4c) shows a lobed structure with inline fuel injection, which creates the velocity field necessary to optimize mixing of fuel and air. Lobes can achieve similar mixing levels with smaller pressure drop.

[0030] The core of the invention is that for further improving the mixing quality the fuel mixing arrangement 100 of the described fuel injectors is changed. So far the fuel injectors (streamline body 22 with the described VGs or lobed structure) are arranged parallel to the main flow direction 14, neighbouring injectors (bodies 22) are placed parallel or nearly parallel in a converging manner adapted to a possible convergence of the two side walls of a burner or combustor. According to the present invention, additional streamline bodies 22 are arranged inclined to the first ones, for example one embodiment is a square arrangement of the fuel injectors, where the additional streamline bodies 22 are arranged perpendicular to the first mentioned bodies 22.

[0031] Fig. 5 and Fig. 6 show such a square arrangement in a round burner or mixer 60 (Fig. 5) and in a square burner or mixer 70 (Fig. 6). For example, a triangle arrangement is of course also possible to use. Fuel is injected through the nozzles 15 into a gaseous medium, preferable air, an air and flue gas mixture or simply flue gas.

[0032] Fig. 7a) to Fig. 7c) describe the general architecture of a combustor 80 with walls 81 using the fuel injection arrangement 100 resp. mixer according to the present invention for operating a turbine 90 (schematically is shown only the turbine vane 1 of the turbine 90).

[0033] In Fig. 7a) is illustrated that the mixer with the fuel injector arrangement 100 is placed directly in the main flow 14 of the gaseous medium, for example air or flue gas, in the combustor 80. According to Fig. 5 and Fig. 6 the mixing arrangement 100 can fit to a round or a square cross section of the combustor 80. The fuel and the air/flue gas are mixed in a very good quality and then combusted. The combustion gases enter the inlet of the turbine 90, expand in the turbine thereby bringing/maintaining the turbine in rotation. The better mixing in the mixer arrangement 100 leads to a less emission release during combustion. As an additional advantage, the fuel supply could be easily realized and it is further independent on the contour of the combustor.

[0034] Fig. 7b) and Fig. 7c) show that the fuel injector arrangement 100 according to the invention is placed in a bypass passage to the main flow 14 in the wall 81 of the combustor 80. This has the advantage of a compact design and a less pressure drop of the fuel. According to Fig. 7c) more than one mixing arrangements 100 could be placed in axial direction (according to the main flow direction 14) one after another (axial staging).

[0035] Fig. 8 illustrates schematically a combustor system with two serial combustors 80, 80'. The fuel mixing arrangement 100 according to the invention is placed between the two combustors 80, 80' in the main flow 14. The temperature at the inlet of the mixer 100 is in the range of 350 to 1500 °C. After the second combustion in the combustor 80' the flue gases enter the inlet of a gas turbine 90. It is clear that - as an alternative - the suggested fuel mixing arrangement 100 could also be placed in the walls 81 of the second combustor 80' analogue to Fig. 7b) and Fig. 7c). Of course, round and square mixers are possible.

[0036] The disclosed fuel mixer arrangement 100 has the following advantages:

- Improved mixing, which leads to less emission release

- Shortening of the mixing length, which leads to a compact design
- Fitting a square or a cylindrical burner/combustor with a simple fuel supply independent on the combustor contour
- Reduced pressure drop
- Supplying multi fuel is possible, which leads to a more uniform mixing profile.

LIST OF REFERENCE NUMERALS

[0037]

14	flow of oxidising medium main flow direction	80, 80'	combustor
		81	wall of 80
15, 15'	fuel nozzle	90	turbine
22	streamlined body, flute	100	fuel mixing arrangement
23	vortex generator on 22		
24	trailing edge of 22	α	attack angle
25	leading edge of 22	β	sweep angle
27	lateral surface of 23	h	height of 42
28	side surface of 23	l	length of 22
29	trailing edge of 23	H	height of 22
30	fuel gas feed	w	width at trailing edge
31	carrier gas feed	W	maximum width of 22
32	effusion/film cooling holes		
33	lateral surface of 22		
34	ejection direction of fuel/carrier gas mixture		
35	central plane of 22/23		
42	lobes		
47	turning point		
48	cross section profile of 22		
49	longitudinal axis of 22		
60	burner/mixer with round cross section		
70	burner/mixer with square cross section		

Claims

1. Fuel mixing arrangement (100) for mixing fuel and an oxidizing medium for combustion in a combustor of a gas turbine, with a flute fuel injection system comprising at least two streamline bodies (22) with at least one fuel nozzle (15) wherein the streamline bodies (22) comprise either vortex generators (23) or lobes (42) and at least one body (22) is arranged parallel to the flow direction (14) of the oxidizing medium, **characterized in that** the at least second other streamline body (22) is arranged inclined to the first one.

2. Fuel mixing arrangement (100) according to claim 1, **characterized in that** the two bodies (22) are arranged perpendicular to each other.

3. Fuel mixing arrangement (100) according to claim 2, **characterized in that** the fuel mixing arrangement comprises a plurality of streamline bodies (22) which are placed in a square arrangement.

4. Fuel mixing arrangement (100) according to claim 3, **characterized in that** the fuel mixing arrangement is placed in a burner/mixer with a round (60) or a square (70) cross section.

5. Combustor (80) for a gas turbine, with a fuel mixing arrangement (100) according to one of the proceeding claims, **characterized in that** the fuel mixing arrangement (100) is placed in the main flow (14) of the combustor (80).

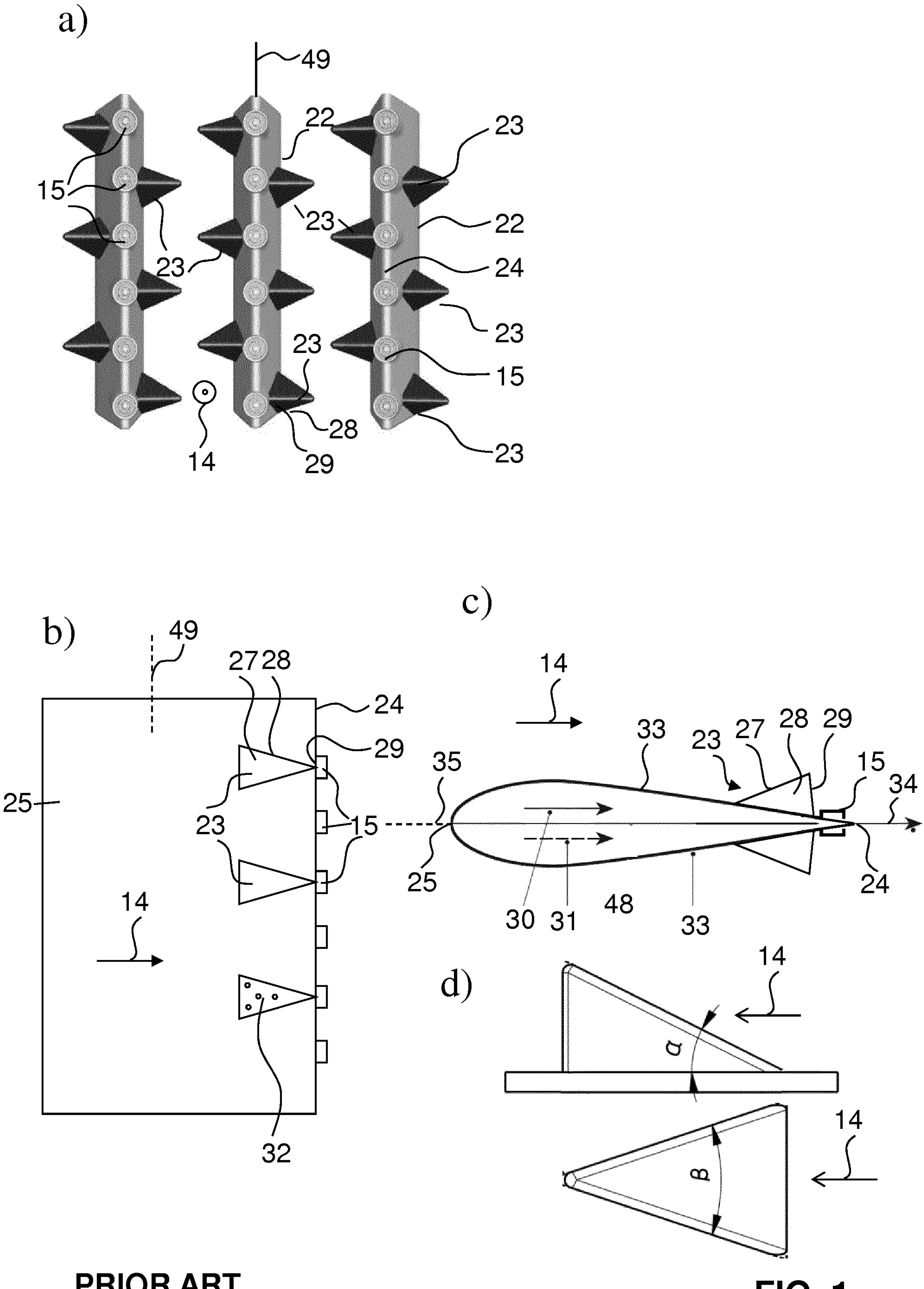
6. Combustor (80) for a gas turbine, with a fuel mixing arrangement (100) according to one of claims 1 to 4 and with walls (81), **characterized in that** the fuel mixing arrangement (100) is placed in a by-pass passage in the wall (81).

7. Combustor (80) according to claim 6, **characterized in that** at least two mixing arrangements (100) are placed one after another in the direction according to the main flow (14) for axial staging.

8. Combustor system with two serial combustors (80, 80') for a gas turbine and with a fuel mixing arrangement (100) according to one of claims 1 to 4, **characterized in that** the fuel mixing arrangement (100) is placed in the main flow (14) of the second combustor (80').

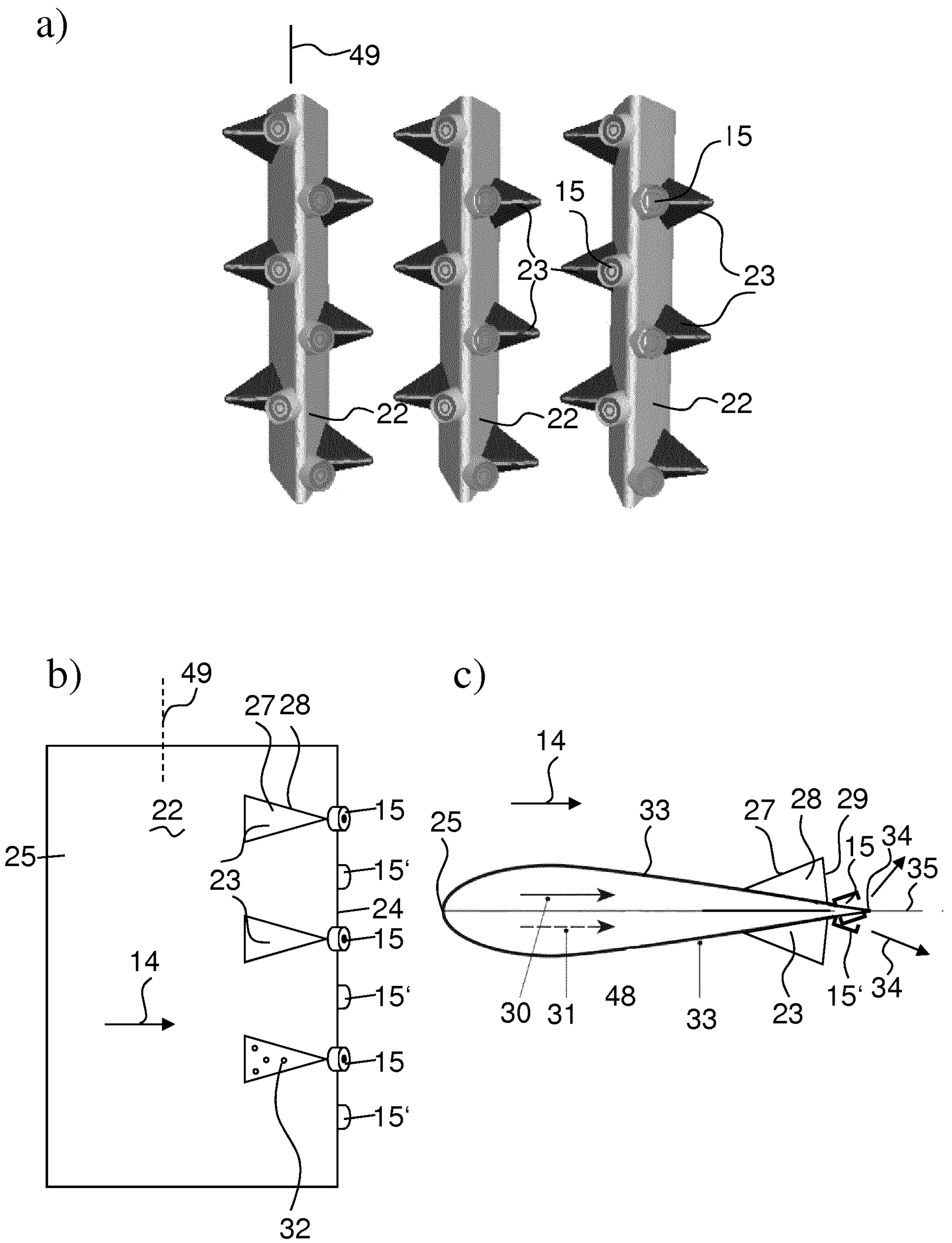
9. Combustor system with two serial combustors (80, 80') for a gas turbine and with a fuel mixing arrangement (100) according to one of claims 1 to 4 and with walls (81), **characterized in that** the fuel mixing arrangement (100) is placed is placed in a by-pass passage in the wall (81) of the second combustor (80').

10. Combustor system according to claim 9, **characterized in that** at least two mixing arrangements (100) are placed one after another in the direction according to the main flow (14) for axial staging.



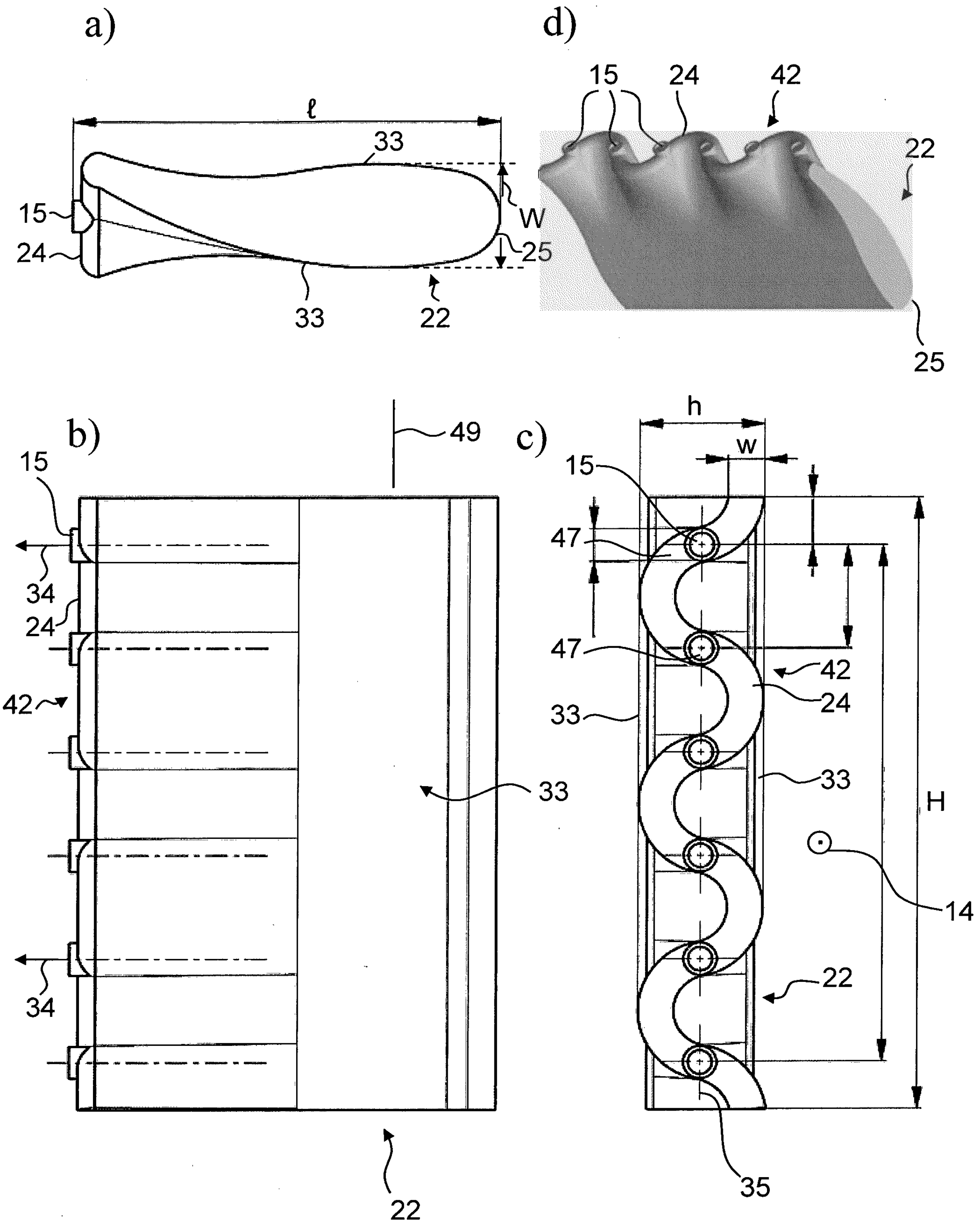
PRIOR ART

FIG. 1



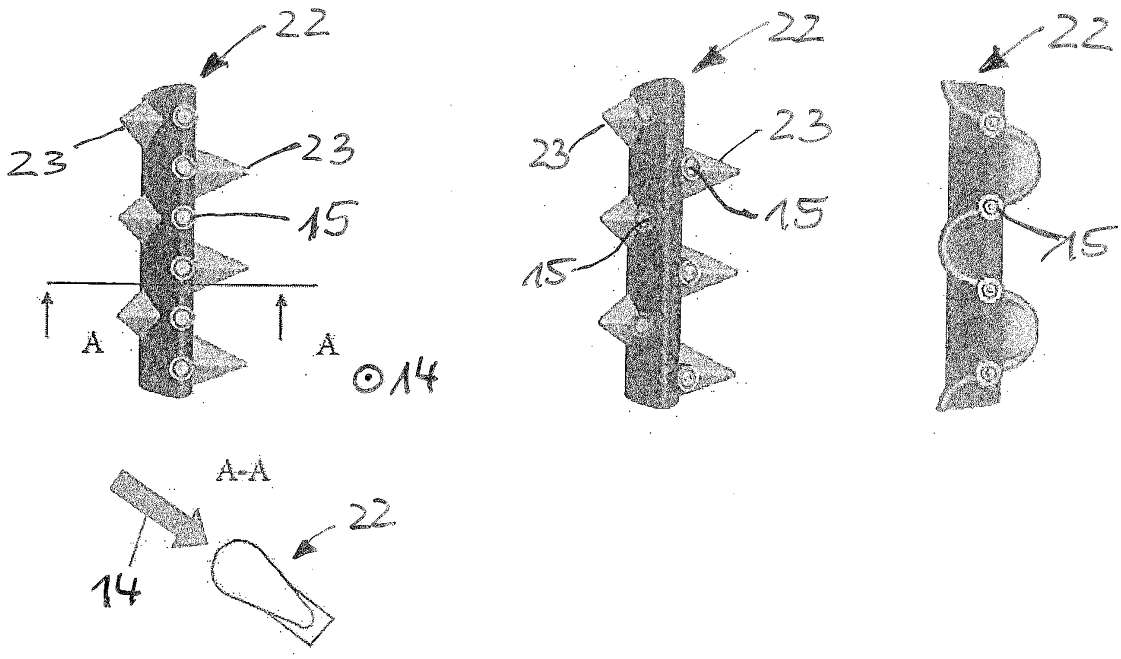
PRIOR ART

FIG. 2



PRIOR ART

FIG. 3



a) b) c)

FIG. 4

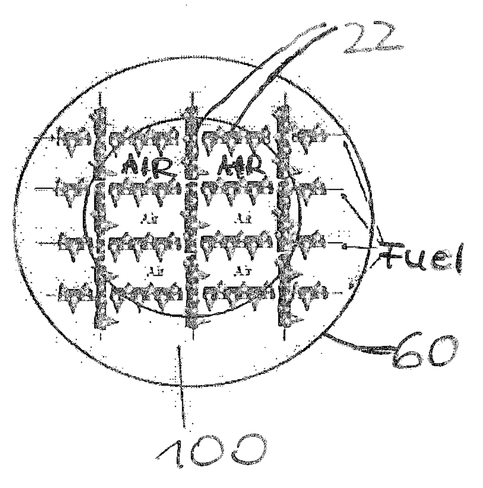


FIG. 5

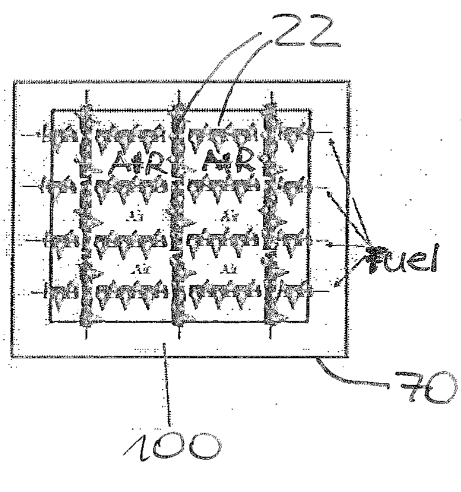


FIG. 6

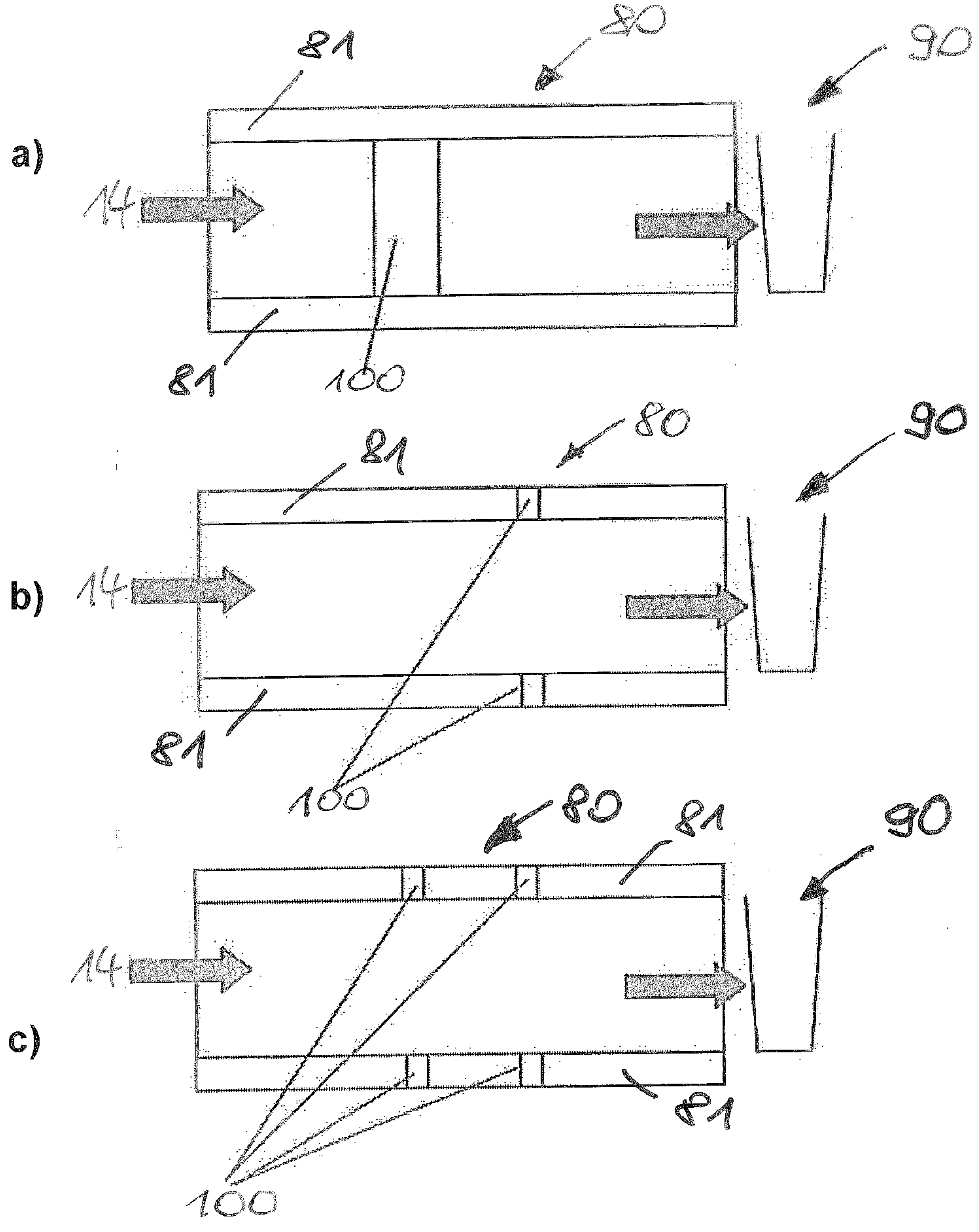


FIG. 7

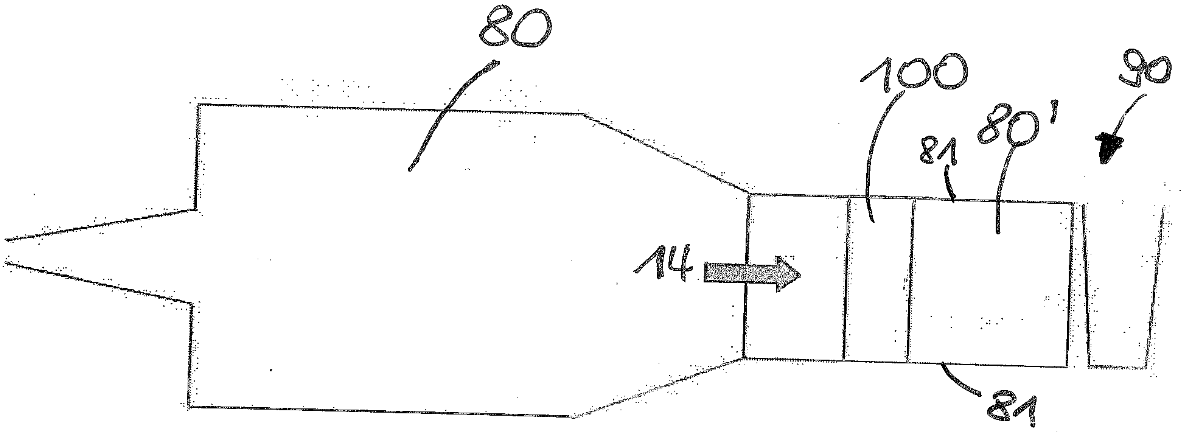


FIG. 8

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 14 16 4859

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2012/297787 A1 (POYYAPAKKAM MADHAVAN NARASIMHAN [CH] ET AL) 29 November 2012 (2012-11-29) * paragraphs [0045], [0141] - paragraph [0149]; figures 10-12 *	1,2,5,8 3,4	INV. F23R3/20 F23D99/00 F23R3/34
Y	EP 0 620 403 A1 (ABB MANAGEMENT AG [CH]) 19 October 1994 (1994-10-19) * column 7, line 4 - line 19; figures 6a, 6b *	3,4	
X	WO 97/17574 A1 (WESTINGHOUSE ELECTRIC CORP [US]) 15 May 1997 (1997-05-15) * column 7, line 8 - column 8, line 21; figures 3-5 *	1,2,6,7, 9,10	
A	EP 0 713 058 A1 (ABB MANAGEMENT AG [CH] ASEA BROWN BOVERI [CH]) 22 May 1996 (1996-05-22) * page 4, line 19 - line 34; figure 2 *	7,10	

TECHNICAL FIELDS SEARCHED (IPC)

F23R
F23D
B01F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	22 September 2014	Harder, Sebastian

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

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 14 16 4859

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

22-09-2014

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012297787 A1	29-11-2012	EP 2522912 A1	14-11-2012
		US 2012297787 A1	29-11-2012
EP 0620403 A1	19-10-1994	DE 59401177 D1	16-01-1997
		EP 0620403 A1	19-10-1994
		JP H0771757 A	17-03-1995
		US 5498155 A	12-03-1996
WO 9717574 A1	15-05-1997	CN 1211310 A	17-03-1999
		EP 0859937 A1	26-08-1998
		JP 2000500222 A	11-01-2000
		US 5647215 A	15-07-1997
		WO 9717574 A1	15-05-1997
EP 0713058 A1	22-05-1996	CN 1130741 A	11-09-1996
		DE 4441235 A1	23-05-1996
		EP 0713058 A1	22-05-1996
		JP H08219445 A	30-08-1996
		US 5645410 A	08-07-1997

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- EP 0321809 B1 **[0002]**
- US 4932861 A **[0002]**
- US 5431018 A **[0002]**
- US 5626017 A **[0002]**
- US 20020187448 A1 **[0002]**
- US 6192688 B1 **[0005] [0006]**
- EP 2211109 A1 **[0005] [0006]**
- US 5645410 A **[0006]**
- WO 2011037646 A1 **[0006]**
- US 5351474 A **[0006]**
- WO 2011054757 A2 **[0006] [0007] [0008] [0018] [0019] [0025] [0028]**
- WO 2011054766 A2 **[0006] [0007] [0008] [0015] [0018] [0019] [0025] [0028]**