



**EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**01.07.2020 Bulletin 2020/27**

(51) Int Cl.:  
**F23R 3/28 (2006.01) F23R 3/14 (2006.01)**

(21) Application number: **19219657.4**

(22) Date of filing: **24.12.2019**

(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**  
Designated Validation States:  
**KH MA MD TN**

(30) Priority: **25.12.2018 RU 2018146133**

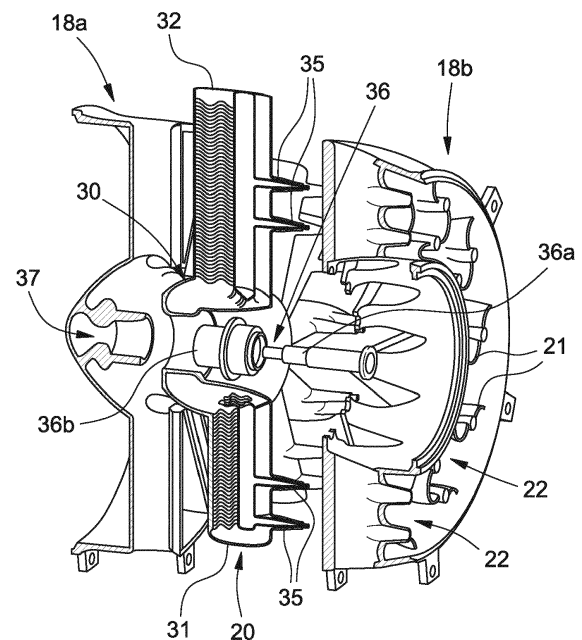
(71) Applicant: **Ansaldo Energia Switzerland AG**  
**5400 Baden (CH)**

(72) Inventors:  
• **GAUPP, Christoph**  
**8050 ZURICH (CH)**  
• **MAURER, Michael Thomas**  
**79713 BAD SAECKINGEN (DE)**  
• **BENZ, Urs**  
**5073 GIPF-OBERFRICK, AARGAU (CH)**  
• **MYATLEV, Alexander Sergeevich**  
**446112 CHAPAYEVSK, SAMARA REGION (RU)**

(74) Representative: **Bernotti, Andrea et al**  
**Studio Torta S.p.A.**  
**Via Viotti, 9**  
**10121 Torino (IT)**

(54) **MODULAR INJECTION HEAD FOR A COMBUSTOR OF A GAS TURBINE**

(57) An injection head for a gas turbine combustor, the injection head comprising a swirler (18) and a fuel insert (20) extending about a central axis (A). The swirler (18) comprises a plurality of streamlined hollow vanes (21), extending radially around the central axis (A), and flow channels (22) defined between adjacent vanes (21). The swirler (18) comprises a first shell (18a), defining a leading portion of the vanes (21) and a second shell (18b), defining a trailing portion of the vanes (21), the first shell (18a) and the second shell (18b) being joined to one another at a junction surface (S) transverse to the central axis (A). The fuel insert (20) comprises a plenum assembly (30) extending about the central axis (A) and a plurality of injector fingers (31, 32) extending radially outward from the plenum assembly (30) and provided each with at least a respective fuel nozzle (35). The injector fingers (31, 32) are at least in part enclosed within respective hollow vanes (21) and the fuel nozzles (35) are arranged through the second shell (18b).



**FIG. 4**

## Description

### CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This patent application claims priority from Russian patent application no. 2018146133 filed on December 25, 2018.

### TECHNICAL FIELD

**[0002]** The present invention relates to a modular injection head for a combustor of a gas turbine.

### BACKGROUND

**[0003]** As known, modern gas turbines may operate on a number of different fuels, such as various kinds of liquid and gaseous fuels, such as natural gas and diesel fuel. In general, the choice of operational fuel depends on the price, availability and operational parameters.

**[0004]** Several kinds of combustors have been designed to produce hot gas by burning gaseous or liquid fuel which is delivered in a compressed air through one or more fuel nozzles. One kind of combustor which proved to be effective comprises fuel nozzles arranged radially about a central axis and a fuel delivery system comprising nested fuel feed lines (at least one for each kind of fuel, but possibly two or more) with respective distributor rings and delivery pipes. The delivery pipes extend radially inward from the distributor rings and have respective outer ends connected thereto. The fuel nozzles may be provided at inner ends or on sidewalls of respective delivery pipes. Fuel, either gas or liquid, is supplied from the fuel feed lines to the distributor rings, that act as annular plena to equalize pressure and create uniform injection conditions at all the fuel nozzles.

**[0005]** Connection of the outer ends of the delivery pipes to the distributor rings is quite complicate and expensive, however. In fact, delivery pipes need to be individually connected and compensators are required at the outer end of each delivery pipe to damp vibrations and to accommodate stress caused by thermal expansion. Compensators may be e.g. in the form of bellows applied between the distributor rings and the delivery pipes. In any case, numerous additional components are necessary for the connections and corresponding welding seams must be accounted for, which may be critical under a mechanical standpoint and makes assembling process more complicate. Moreover, design of injection heads is often complicate and requires manufacturing of several components, in addition to complex assembling process involving numerous steps to connect the components trough seams, junctions and weldings.

### SUMMARY OF THE INVENTION

**[0006]** It is an aim of the present invention to provide an injection head for a combustor of a gas turbine, which

allows to overcome or at least to attenuate the limitations described.

**[0007]** According to the present invention, there is provided an injection head for a gas turbine combustor, the injection head comprising a swirler and a fuel insert extending about a central axis;

wherein the swirler comprises a plurality of streamlined hollow vanes, extending radially around the central axis, and flow channels defined between adjacent vanes;

wherein the swirler comprises a first shell, defining a leading portion of the vanes and a second shell, defining a trailing portion of the vanes, the first shell and the second shell being joined to one another at a junction surface transverse to the central axis;

wherein the fuel insert comprises a plenum assembly extending about the central axis and a plurality of injector fingers extending radially outward from the plenum assembly and provided each with at least a respective fuel nozzle;

and wherein the injector fingers are at least in part enclosed within respective hollow vanes and the fuel nozzles are arranged through the second shell.

**[0008]** Modular structure greatly simplifies the process of assembling of the injection head, since only a small number of components need to be connected to one another. The first shell, the fuel insert and the second shell may be individually manufactured as single bodies and the assembled to form the injection head. Conveniently, the first shell, the fuel insert and the second shell may be made by additive manufacturing techniques, which are flexible and allow integrating complex features in accordance with design preferences. Also maintenance process is improved, because disassembling the structure is as easy as assembling and because modular components may be individually replaced as the case be, while parts that do not need replacement may be kept.

**[0009]** According to an aspect of the invention, the injection head comprises a clamping bolt, extending along the central axis and clamping the first shell and the fuel insert together.

**[0010]** Central fixation of the first shell and of the fuel insert further simplifies assembling of the injection head and, in addition, connection of the whole injection head to the casing of the combustor. In fact, the first shell and of the fuel insert further may be solidly joined to each other and a single connection to the combustor structure, e.g. through one of the injector fingers, may give sufficient mechanical strength. Compensation of thermal stress may also be improved by a single connections. The clamping bolt may include a screw integral with one of the first shell and the fuel insert and passing through the other one.

**[0011]** According to an aspect of the invention, the second shell is fixed to the first shell at the junction surface, preferably by outer fastening members arranged around the first shell and the second shell and configured to retain the first shell and the second shell against one another or by welding.

**[0012]** All the components of the injection head can be thus easily assembled and connected to the structure of the burner.

**[0013]** According to an aspect of the invention, the first shell and the second shell have respective wall reinforcements extending in a radial direction at the junction surface and respective coupling members mutually engaging in a sealing manner.

**[0014]** According to an aspect of the invention, the second shell has an axial passage and the clamping bolt is selectively insertable and extractable through the axial passage.

**[0015]** According to an aspect of the invention, the plenum assembly is annular in shape and wherein an axial seat for the clamping bolt is defined in a space inside the plenum assembly.

**[0016]** The structure of the fuel insert advantageously exploits radial fuel distribution through the central plenum assembly. The annular plenum assembly easily accommodates the clamping bolt, thus allowing central fixation without significant increase in space occupied.

**[0017]** According to an aspect of the invention, the fuel insert comprises a primary fuel plenum, annular in shape and delimited by an inner tubular wall and an outer tubular wall, and a secondary fuel plenum, annular in shape and enclosed between the inner tubular wall and the outer tubular wall of the primary fuel plenum.

**[0018]** The nested arrangement of the primary fuel plenum and of the secondary fuel plenum favours the provision of effective, yet compact structure for the fuel insert.

**[0019]** According to an aspect of the invention, the fuel insert comprises primary fuel lines, fluidly coupled to the primary fuel plenum and delimited by walls of respective injector fingers, and secondary fuel lines, fluidly coupled to the secondary fuel plenum and extending radially outward inside respective primary fuel lines.

**[0020]** According to an aspect of the invention, the injector fingers include an inlet injector finger, configured for connection to a fuel feed manifold and comprising a primary inlet line, fluidly coupled to the primary fuel plenum, and a secondary inlet line, fluidly coupled to the secondary fuel plenum and enclosed within the primary inlet line.

**[0021]** Again, the injector head has a compact structure due to the nested arrangement of the primary and secondary fuel distribution systems. Fuel feed through a single injection finger greatly contributes to simplifying connection to the structure of the combustor. In particular, compensators to accommodate thermal stress and to damp mechanical vibrations are required only for the inlet injector finger, while the other injector fingers may simply be left with free ends. Moreover, the connection to the fuel feed manifold may be exploited also as a single fixation for the whole injection head, since sufficient mechanical strength is available.

**[0022]** According to an aspect of the invention, the inlet injector finger comprises at least one respective nozzle,

fluidly coupled to the primary inlet line and to the secondary inlet line, and a deflector, arranged in the primary inlet line upstream of the nozzle of the inlet injector finger and configured to reduce velocity of a primary fuel within the primary inlet line before the primary fuel reaches the at least one nozzle of the inlet injector finger, the deflector being preferably configured to create a vortex upstream of the at least one nozzle of the inlet injector finger.

**[0023]** The deflector favours similar injection conditions in all the injector fingers, including the inlet injector finger, to the benefit of efficient combustion.

**[0024]** According to an aspect of the invention, the injection head comprises radial reinforcing ribs extending radially inside the secondary inlet line.

**[0025]** Difference in pressure between the primary fuel line and the secondary fuel line may be quite high and cause severe stress. On account of such stress, the secondary fuel line tend to expand radially and may be deformed during operation. Such deformation is effectively prevented by the radial reinforcing ribs, which may be easily provided, especially if the fuel insert is made by additive manufacturing techniques.

**[0026]** According to an aspect of the invention, the radial reinforcing ribs connect opposite walls of the secondary inlet line and are configured to prevent expansion of the secondary inlet line in a circumferential direction on account of pressure excess in the secondary inlet line with respect to the primary inlet line.

**[0027]** According to an aspect of the invention, the injection head comprises further radial reinforcing ribs extending radially inside the secondary fuel lines of injector fingers other than the inlet injector finger, the further radial reinforcing ribs being configured to prevent expansion of the respective secondary fuel lines in a circumferential direction on account of pressure excess in the respective secondary fuel lines compared to the respective primary fuel lines.

**[0028]** According to an aspect of the invention, the injection head comprises circumferential reinforcing ribs extending circumferentially inside the secondary fuel plenum, wherein the circumferential reinforcing ribs connect opposite walls of the secondary inlet line and are configured to prevent expansion of the secondary fuel plenum in a radial direction on account of pressure excess in the secondary fuel plenum compared to the primary fuel plenum.

**[0029]** Similar to the secondary fuel lines, also the secondary fuel plenum may be subject to severe stress on account of pressure difference in respect of the primary fuel plenum and the to expand radially. The deformation is prevented by the circumferential reinforcing ribs

**[0030]** According to an aspect of the invention, the injection head a gas turbine combustor comprises at least an injection head as defined above and an injection manifold coupled to the injection head.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0031]** The present invention will now be described with reference to the accompanying drawings, which show some non-limitative embodiment thereof, in which:

- figure 1 is a longitudinal cross section of a gas turbine assembly;
- figure 2 is a simplified longitudinal cross section of a can combustor of the gas turbine assembly of figure 1, including an injection head in accordance to an embodiment of the present invention;
- figure 3 is a perspective view of the injection head of figure 2;
- figure 4 is an perspective exploded view of the injection head of figure 2, cut along an axial longitudinal plane;
- figure 5 is a side view of a component of the injection head of figure 2;
- figure 6 is an enlarged side view of a first portion of the component of figure 5;
- figure 7 is a cross section of the component of figure 5, cut along plane VII-VII of figure 6;
- figure 8 is an enlarged side view of a second portion of the component of figure 5.

## DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

**[0032]** Figure 1 shows a simplified view of a gas turbine assembly, designated as whole with numeral 1. The gas turbine assembly 1 comprises a compressor section 2, a combustor assembly 3 and a turbine section 5. The compressor section 2 and the turbine section 5 extend along a main axis M. The combustor assembly 3 may be a single-stage combustor assembly or a sequential combustor assembly. In one embodiment, the combustor assembly 3 comprises a plurality of sequential can combustors 7, circumferentially arranged about the main axis M.

**[0033]** The compressor section 3 of the gas turbine assembly 1 provides a compressed airflow, which is added with fuel and burned in the can combustors 7. The airflow delivered by the compressor section 2 is supplied to the combustor assembly 3 and to the turbine section 5 for the purpose of cooling.

**[0034]** In the combustor assembly 3, the can combustors 7 are coupled to the turbine section 5 through respective transition ducts 8.

**[0035]** A portion of one of the can combustors 7 is illustrated in Figure 2. The can combustor 7 extends along a central axis A and comprises an shell 10, a liner 11 defining a flow path 12 for compressed air or hot gas and an injection unit 13 configured to deliver a controlled amount of fuel into air or hot gas in the flow path. The can combustor 7 may be run on different kinds of fuel, depending on conditions. for example, the can combustor 7 may use a gas fuel as a primary fuel and a liquid fuel

as a secondary fuel.

**[0036]** The injection unit 13 in turn comprises an injection manifold 14, coupled to fuel feed lines (here not shown) for receiving the primary fuel and the secondary fuel, and an injection head 15. The injection manifold 14 is coupled to the injection head 15 through a compensator 17, which is configured to allow relative movements of the injection manifold 14 and of the injection head 15 in an axial direction and/or in a radial direction. The compensator 17 allows to damp vibrations and accommodate thermal expansion and may be in the form of bellows and/or an axial slider.

**[0037]** The injection head 15, shown in figures 3 and 4, comprises a swirler 18 and a fuel insert 20 extending about the central axis A of the can combustor 7.

**[0038]** The swirler 18 comprises a plurality of streamlined hollow vanes 21, extending radially around the central axis A, and flow channels 22 defined between adjacent vanes 21. The vanes 21 are configured to impart a tangential component of velocity to a gas flowing through the channels 22, thereby favouring mixing of the gas flow and of fuel injected by the injection head 15 as explained later on. The vanes may have straight, curved segmented trailing edges, e.g. lobed or zig-zag trailing edges, in order to improve mixing in accordance with design preferences.

**[0039]** The swirler 18 comprises a first shell 18a and a second shell 18b, defining a leading portion and a trailing portion of the vanes 21, respectively. The first shell 18a and the second shell 18b are joined to one another at a junction surface S transverse to the central axis A. in one embodiment, the junction surface S may advantageously be a junction plane perpendicular to the central axis A. The first shell 18a and the second shell 18b have respective wall reinforcements 23a, 23b defined by locally increased thickness and extending in a radial direction along the junction surface S. Respective coupling members 25a, 25b, are provided at the junction surface S and may be defined by features mutually engaging in a sealing manner, such as a groove and a coupling rib.

**[0040]** The second shell 18b is fixed to the first shell 18a at the junction surface S, e.g. by outer fastening members 26 arranged around the first shell and the second shell and configured to retain the first shell 18a and the second shell 18b against one another. The fastening members 26 may include perforated plates extending radially outwards from the first shell 18a and the second shell 18b and screws engaging holes in the perforated plates. In one embodiment (not shown), the second shell 18b may be welded to the first shell 18a at the junction surface S.

**[0041]** Near wall cooling channels 27 may be provided in the walls of the first shell 18a and of the second shell 18b and extend along respective paths defined in accordance with design preferences.

**[0042]** The fuel insert 20 comprises a plenum assembly 30 extending about the central axis A and a plurality of injector fingers 31, 32, which extend radially outward

from the plenum assembly 30. Each injection finger 31, 32 is provided with one or more respective fuel nozzle 35 (two in the embodiment illustrated). Moreover, the injector fingers 31, 32 are at least in part enclosed within respective hollow vanes 21 of the swirler 18. Specifically, radially inner portions of the injection fingers 31, 32, in the vicinity of the plenum assembly 30, may lie outside the first shell 18a and second shell 18b of the swirler 18, whereas radially outer portions are encapsulated inside respective hollow vanes 21. The fuel nozzles 35 are arranged through the second shell 18b, i.e. through the trailing portion of the vanes 21, to feed primary and/or secondary fuel into gas flowing through the channels 22. Not all the vanes 21 need to accommodate a respective injector finger 31, 32 and some may have only an aerodynamic function. The number and configuration of the vanes 21 and the number and configuration of the injector fingers 31, 32 may be separately chosen in accordance with design preferences e.g. to optimize mixing action and turbine inlet temperature profile. In one embodiment, for example, injector fingers 31 may be arranged to inject fuel in every second vane 21. Other patterns are available, anyway.

**[0043]** A clamping bolt 36 is provided in an axial seat 37 along the central axis A through the first shell 18a and the fuel insert 20. The clamping bolt 36 comprises a screw 36a and a locking nut 36b that co-operate to clamp the first shell 18 and the fuel insert 20 together. The second shell 18b has an axial passage 39 and the screw 36a is selectively insertable and extractable through the axial passage 39. In one embodiment (not shown), the screw 36a is integral with one of the first shell 18 and the fuel insert 20 and passes through the other one. A streamlined nose 40 is provided on the leading side, i.e. the first shell 18a, to protect the clamping bolt 36. The streamlined nose 40 joins a radially inner wall of the channels 22 smoothly, without step transitions.

**[0044]** The plenum assembly 30 is annular in shape and the axial seat 37 for the clamping bolt is defined in a space inside the plenum assembly 30. Specifically, the plenum assembly 30 comprises a primary fuel plenum 41 and a secondary fuel plenum 42, both annular in shape. The primary fuel plenum 41 is delimited by an inner tubular wall 41a and an outer tubular wall 41b (figure 8). The secondary fuel plenum 42 is enclosed between the inner tubular wall 41a and the outer tubular wall 41b of the primary fuel plenum 41.

**[0045]** The fuel insert 20 furthermore comprises primary fuel lines 43, fluidly coupled to the primary fuel plenum 41 and delimited by walls of respective injector fingers 31, and secondary fuel lines 44, fluidly coupled to the secondary fuel plenum 42 and extending radially outward inside respective primary fuel lines 43.

**[0046]** One of the injector fingers, indicated as inlet injector finger 32, is configured for connection to a fuel feed manifold 45 (figure 2) and comprises a primary inlet line 47, fluidly coupled to the primary fuel plenum 41, and a secondary inlet line 48, fluidly coupled to the secondary

fuel plenum 42 and enclosed within the primary inlet line 47. The inlet injector finger 32 comprises respective one or more nozzles 35, fluidly coupled to the primary inlet line 47 and to the secondary inlet line 48. The nozzles 35 of the inlet injector finger 32 are arranged to inject fuel in a downstream direction in a manner similar to the nozzles 35 of the other injector fingers 31, i.e. through the second shell 18b forming the trailing portion of the vanes 21. A deflector 50 is arranged in the primary inlet line 47 upstream of the nozzle 35 of the inlet injector finger 32. The deflector 50 may be defined by a baffle extending transversely to the direction of primary fuel flowing through the primary inlet line 47. Specifically, the deflector 50 is configured to reduce velocity of the primary fuel within the primary inlet line 47 before the primary fuel reaches the nozzles 35 of the inlet injector finger 32. Reduction of velocity is obtained by creating a vortex upstream of the nozzles 35 of the inlet injector finger 32 and favours even pressure conditions at all the nozzles 35 of the injection head 15.

**[0047]** In one embodiment, reinforcing ribs 51 are provided inside the secondary inlet line 48. The reinforcing ribs 51 extend radially substantially over the entire length of the respective portion of the secondary inlet line 48 and connect opposite walls thereof, in one embodiment with X-shaped cross section. The reinforcing ribs 51 therefore prevent expansion of the secondary inlet line 48 in a circumferential direction, when fuel pressure in the secondary inlet line 48 exceeds pressure in the primary inlet line 47.

**[0048]** Further reinforcing ribs 51 extending radially may be provided for the same purpose inside the secondary fuel lines of injector fingers other than the inlet injector finger, the further radial reinforcing ribs 51 being configured to prevent expansion of the respective secondary fuel lines in a circumferential direction on account of pressure excess in the respective secondary fuel lines compared to the respective primary fuel lines.

**[0049]** Likewise, circumferential reinforcing ribs 52 extending circumferentially inside the secondary fuel plenum 42 are provided and connect opposite walls of the secondary inlet line 48. The circumferential reinforcing ribs 52 therefore are configured to prevent expansion of the secondary fuel plenum 42 in a radial direction on account of pressure excess in the secondary fuel plenum 42 compared to the primary fuel plenum 41.

**[0050]** Finally, it is evident that the described combustor may be subject to modifications and variations, without departing from the scope of the present invention, as defined in the appended claims.

## Claims

1. An injection head for a gas turbine combustor, the injection head comprising a swirler (18) and a fuel insert (20) extending about a central axis (A); wherein the swirler (18) comprises a plurality of

- streamlined hollow vanes (21), extending radially around the central axis (A), and flow channels (22) defined between adjacent vanes (21); wherein the swirler (18) comprises a first shell (18a), defining a leading portion of the vanes (21) and a second shell (18b), defining a trailing portion of the vanes (21), the first shell (18a) and the second shell (18b) being joined to one another at a junction surface (S) transverse to the central axis (A); wherein the fuel insert (20) comprises a plenum assembly (30) extending about the central axis (A) and a plurality of injector fingers (31, 32) extending radially outward from the plenum assembly (30) and provided each with at least a respective fuel nozzle (35); and wherein the injector fingers (31, 32) are at least in part enclosed within respective hollow vanes (21) and the fuel nozzles (35) are arranged through the second shell (18b).
2. The injection head according to claim 1, comprising a clamping bolt (36), extending along the central axis (A) and clamping the first shell (18a) and the fuel insert (20) together.
  3. The injection head according to claim 2, wherein the second shell (18b) is fixed to the first shell (18a) at the junction surface (S), preferably by outer fastening members (26) arranged around the first shell (18a) and the second shell (18b) and configured to retain the first shell (18a) and the second shell (18b) against one another or by welding.
  4. The injection head according to claim 2 or 3, wherein the first shell (18a) and the second shell (18b) have respective wall reinforcements (23a, 23b) extending in a radial direction at the junction surface (S) and respective coupling members (25a, 35b) mutually engaging in a sealing manner.
  5. The injection head according to any one of claims 2 to 4, wherein the second shell (18b) has an axial passage and the clamping bolt (36) is selectively insertable and extractable through the axial passage.
  6. The injection head according to any one of claims 2 to 5, wherein the plenum assembly (30) is annular in shape and wherein an axial seat (37) for the clamping bolt (36) is defined in a space inside the plenum assembly (30).
  7. The injection head according to any one of the preceding claims, wherein the fuel insert (20) comprises a primary fuel plenum (41), annular in shape and delimited by an inner tubular wall (41) and an outer tubular wall (42), and a secondary fuel plenum (42), annular in shape and enclosed between the inner tubular wall (41a) and the outer tubular wall (41zb) of the primary fuel plenum (41).
  8. The injection head according to claim 7, wherein the fuel insert (20) comprises primary fuel lines (43), fluidly coupled to the primary fuel plenum (41) and delimited by walls of respective injector fingers (31, 32), and secondary fuel lines (44), fluidly coupled to the secondary fuel plenum (42) and extending radially outward inside respective primary fuel lines (43).
  9. The injection head according to any one of the preceding claims, wherein the injector fingers (31, 32) include an inlet injector finger (31, 32), configured for connection to a fuel feed manifold (14) and comprising a primary inlet line (47), fluidly coupled to the primary fuel plenum (41), and a secondary inlet line (48), fluidly coupled to the secondary fuel plenum (42) and enclosed within the primary inlet line (47).
  10. The injection head according to claim 9, wherein the inlet injector finger (31, 32) comprises at least one respective nozzle (35), fluidly coupled to the primary inlet line (47) and to the secondary inlet line (48), and a deflector (50), arranged in the primary inlet line (47) upstream of the nozzle (35) of the inlet injector finger (31, 32) and configured to reduce velocity of a primary fuel within the primary inlet line (47) before the primary fuel reaches the at least one nozzle (35) of the inlet injector finger (31, 32), the deflector (50) being preferably configured to create a vortex upstream of the at least one nozzle (35) of the inlet injector finger (31, 32).
  11. The injection head according to claim 9 or 10, comprising radial reinforcing ribs (51) extending radially inside the secondary inlet line (48).
  12. The injection head according to claim 11, wherein the radial reinforcing ribs connect opposite walls of the secondary inlet line (48) and are configured to prevent expansion of the secondary inlet line (48) in a circumferential direction on account of pressure excess in the secondary inlet line (48) with respect to the primary inlet line (47).
  13. The injection head according to claim 11 or 12, comprising further radial reinforcing ribs extending radially inside the secondary fuel lines (44) of injector fingers (31, 32) other than the inlet injector finger (31, 32), the further radial reinforcing ribs being configured to prevent expansion of the respective secondary fuel lines (44) in a circumferential direction on account of pressure excess in the respective secondary fuel lines (44) compared to the respective primary fuel lines (43).
  14. The injection head according to any one of the preceding claims, comprising circumferential reinforcing ribs (52) extending circumferentially inside the secondary fuel plenum (42), wherein the circumfer-

ential reinforcing ribs (52) connect opposite walls of the secondary inlet line (48) and are configured to prevent expansion of the secondary fuel plenum (42) in a radial direction on account of pressure excess in the secondary fuel plenum (42) compared to the primary fuel plenum (41). 5

15. A gas turbine combustor, comprising at least an injection head (15) according to any one of the preceding claims and an injection manifold coupled to the injection head. 10

15

20

25

30

35

40

45

50

55

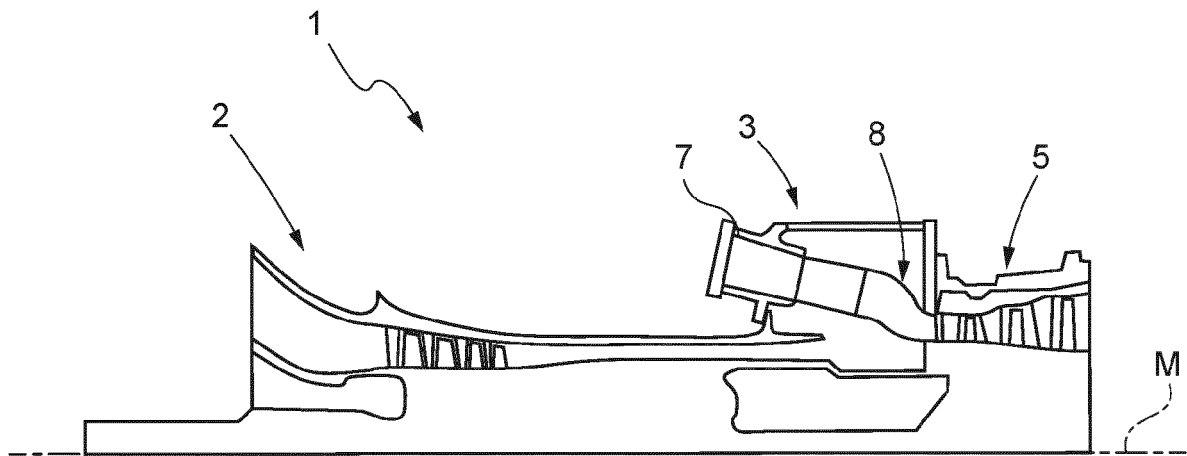


FIG. 1

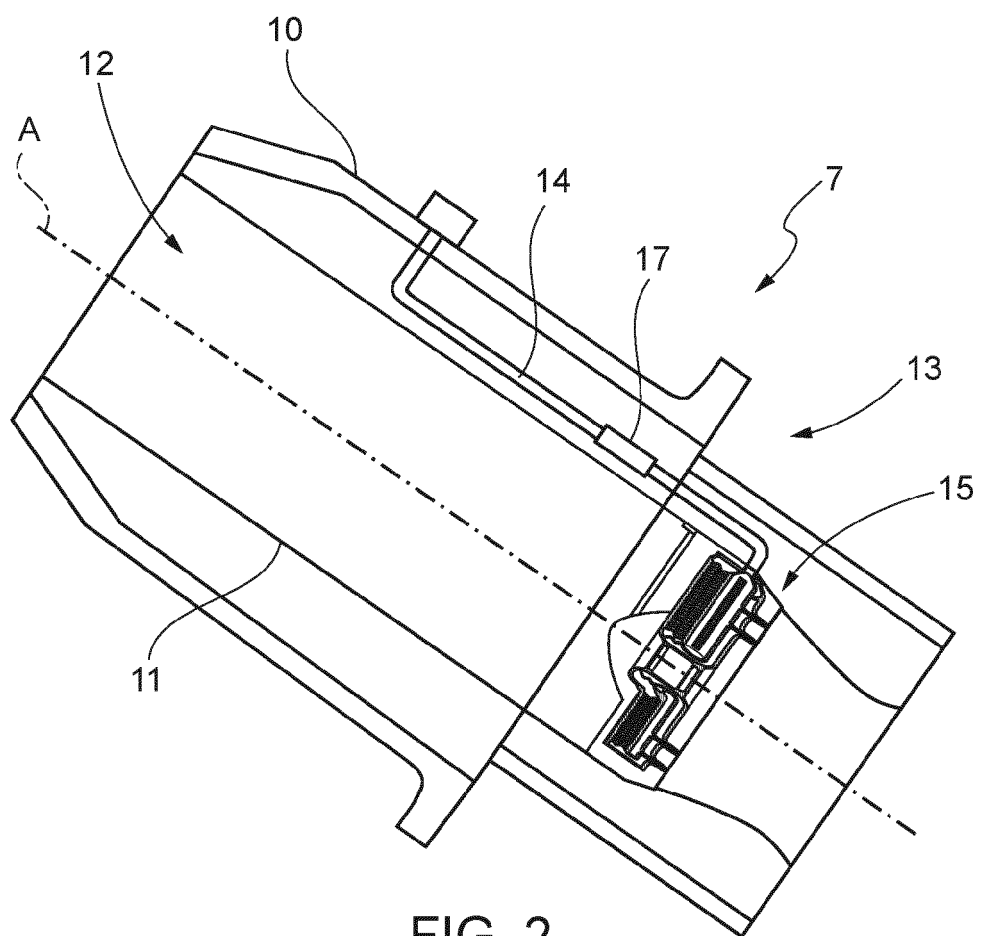


FIG. 2

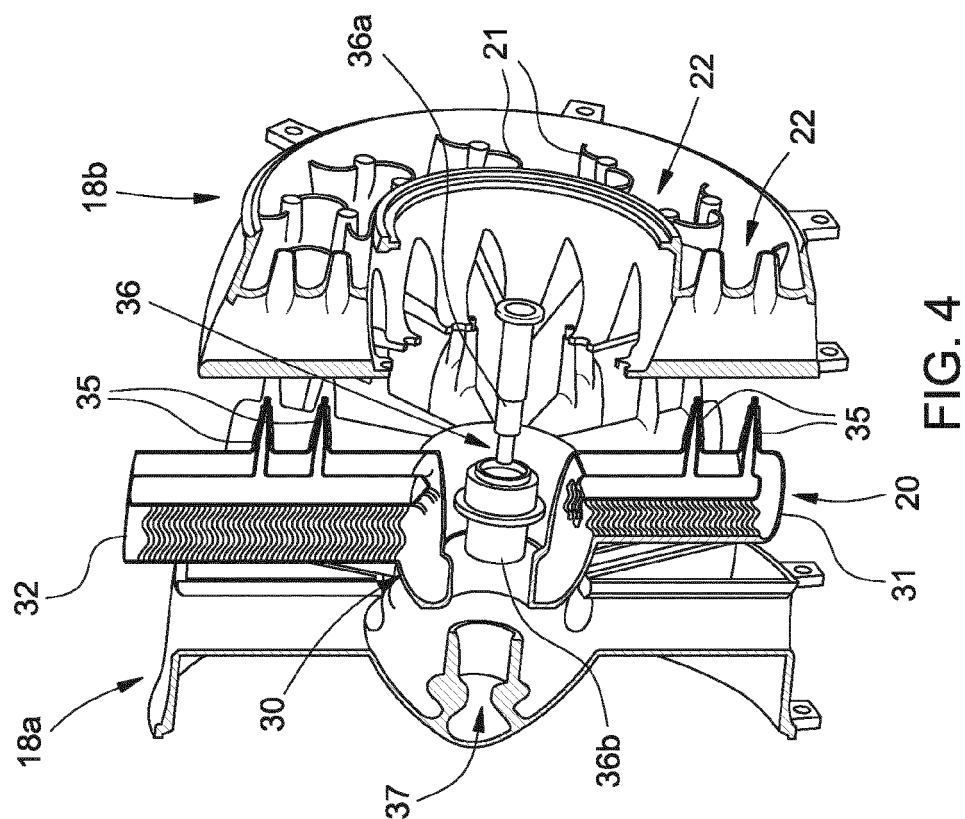


FIG. 4

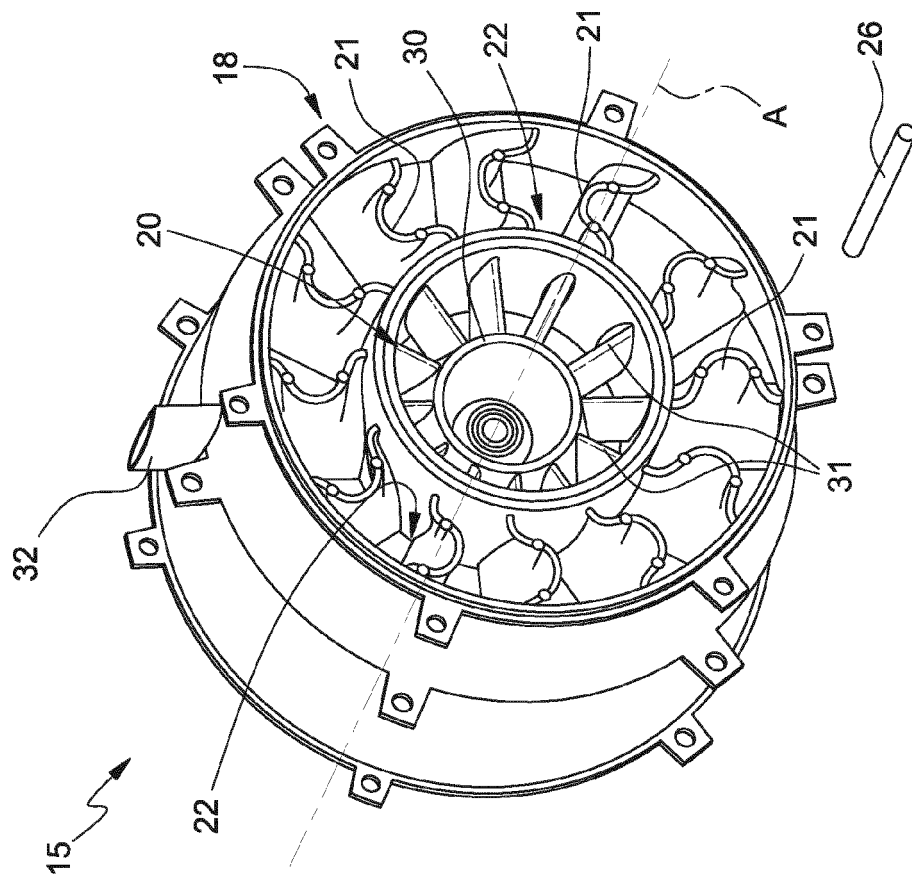
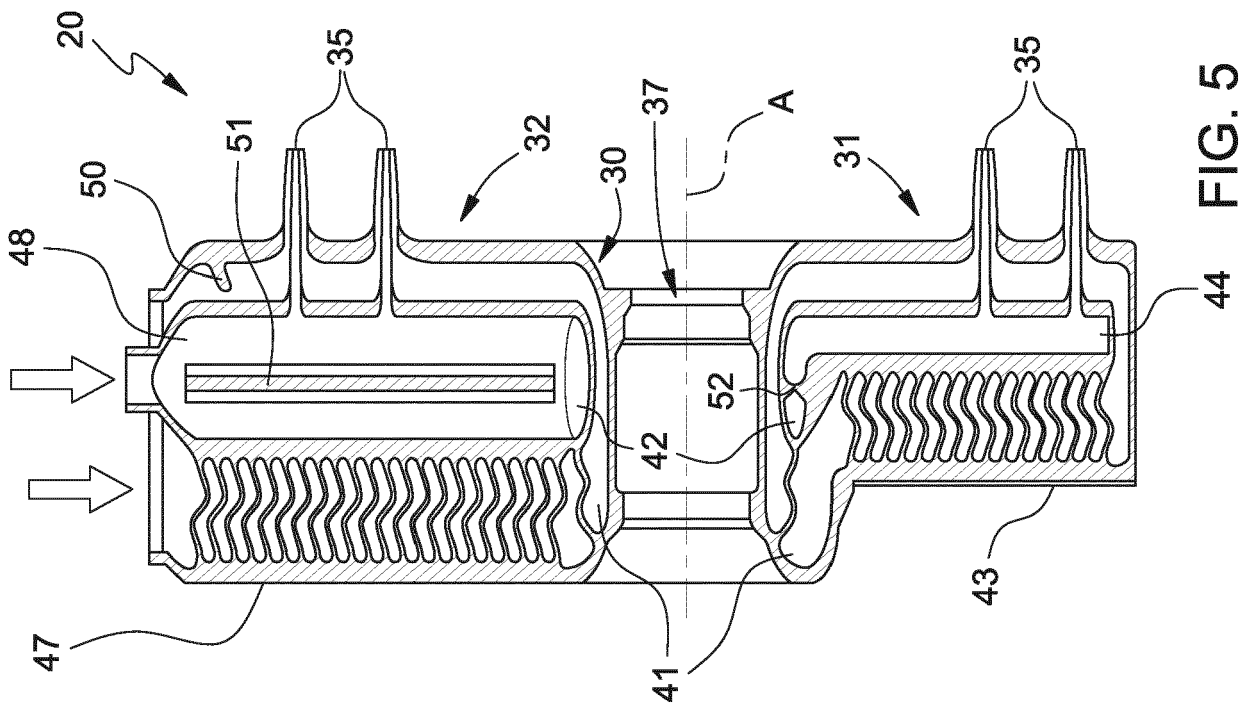
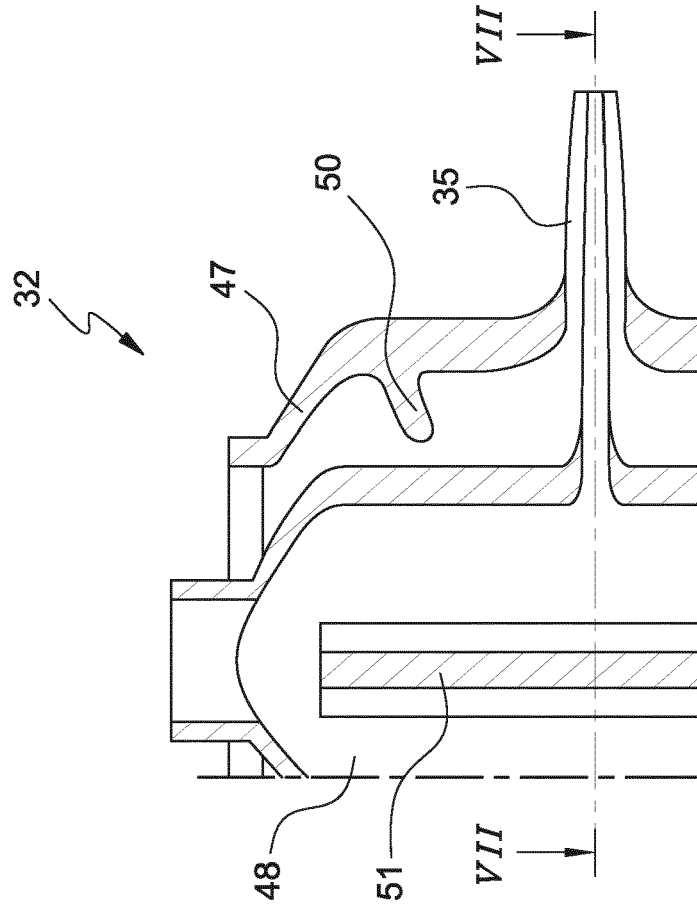


FIG. 3



56



6.  
G.  
F.

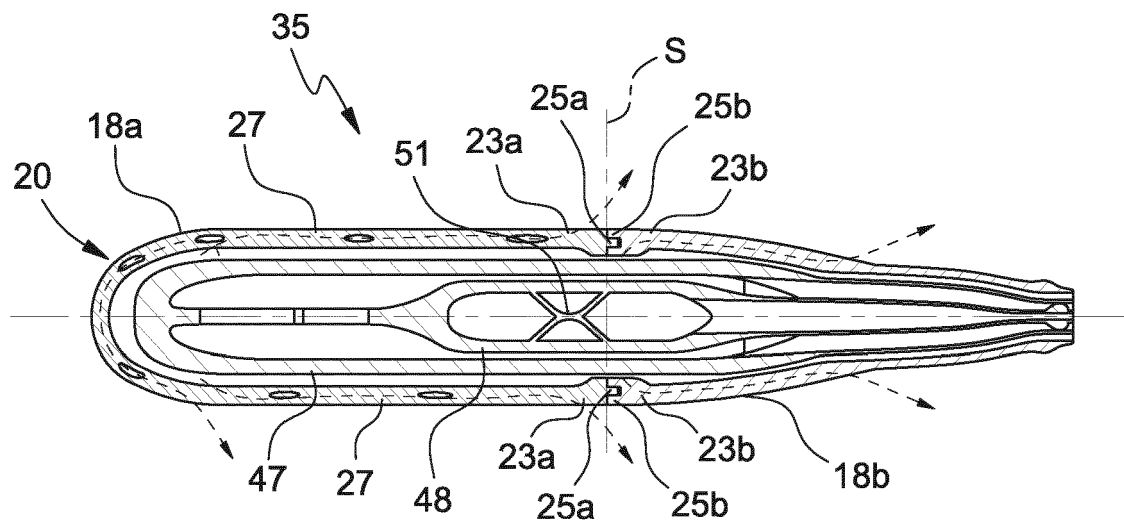


FIG. 7

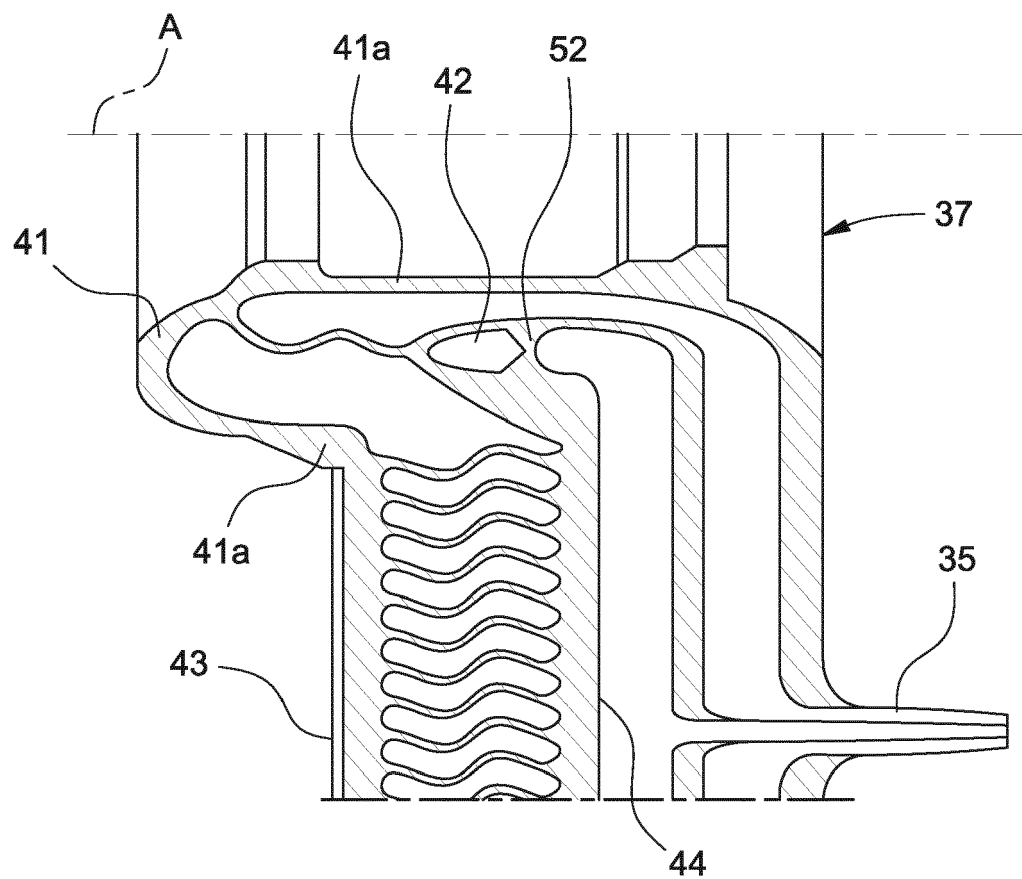


FIG. 8



## EUROPEAN SEARCH REPORT

Application Number  
EP 19 21 9657

5

10

15

20

25

30

35

40

45

50

55

2

EPO FORM 1503 03.02 (P04C01)

| 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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | US 5 680 766 A (JOSHI NARENDRA D [US] ET AL) 28 October 1997 (1997-10-28)<br>* column 4, line 12 - line 54; figure 3 *<br>----- | 1-15                                                     | INV.<br>F23R3/28<br>F23R3/14            |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | US 2014/230448 A1 (HUTH MICHAEL [DE])<br>21 August 2014 (2014-08-21)<br>* paragraph [0032] - paragraph [0036];<br>figures 3-5 * | 1-15                                                     |                                         |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | US 2009/056336 A1 (CHILA RONALD JAMES [US] ET AL) 5 March 2009 (2009-03-05)<br>* paragraphs [0018], [0019]; figures 3-5 *       | 1-15                                                     |                                         |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | US 2016/290238 A1 (LOEFFEL KASPAR [CH] ET AL) 6 October 2016 (2016-10-06)<br>* abstract; figures *<br>-----                     | 1-15                                                     |                                         |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                 |                                                          | TECHNICAL FIELDS SEARCHED (IPC)         |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                 |                                                          | F23R<br>F23C                            |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                 |                                                          |                                         |
| Place of search<br><b>The Hague</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                 | Date of completion of the search<br><b>17 March 2020</b> | Examiner<br><b>Mootz, Frank</b>         |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                                                                                                                 |                                                          |                                         |

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 19 21 9657

5

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.

17-03-2020

10

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
|-------------------------------------------|---------------------|----------------------------|---------------------|
| US 5680766 A                              | 28-10-1997          | NONE                       |                     |
| US 2014230448 A1                          | 21-08-2014          | CA 2697200 A1              | 23-09-2010          |
|                                           |                     | CN 101846320 A             | 29-09-2010          |
|                                           |                     | EP 2233836 A1              | 29-09-2010          |
|                                           |                     | JP 5615008 B2              | 29-10-2014          |
|                                           |                     | JP 2010223577 A            | 07-10-2010          |
|                                           |                     | RU 2010110965 A            | 27-09-2011          |
|                                           |                     | US 2010236252 A1           | 23-09-2010          |
|                                           |                     | US 2014230448 A1           | 21-08-2014          |
| US 2009056336 A1                          | 05-03-2009          | CH 697862 A2               | 13-03-2009          |
|                                           |                     | CN 101377305 A             | 04-03-2009          |
|                                           |                     | DE 102008044448 A1         | 05-03-2009          |
|                                           |                     | JP 2009052877 A            | 12-03-2009          |
|                                           |                     | US 2009056336 A1           | 05-03-2009          |
| US 2016290238 A1                          | 06-10-2016          | CN 106016360 A             | 12-10-2016          |
|                                           |                     | EP 3076084 A1              | 05-10-2016          |
|                                           |                     | JP 2016191545 A            | 10-11-2016          |
|                                           |                     | KR 20160117278 A           | 10-10-2016          |
|                                           |                     | US 2016290238 A1           | 06-10-2016          |

15

20

25

30

35

40

45

50

55

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**

*This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.*

**Patent documents cited in the description**

- RU 2018146133 [0001]