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(54) Gas burner assembly for a gas turbine

(57) A gas burner assembly for a gas turbine has a first, premix, burner (5), and a second burner (4) surrounded by the first burner (5); the second burner has a swirler (16) with vanes (21), a channel (40, 55) for feeding combustion air into the gaps (22) in the swirler (16), and at least a first gas feed line (52) for feeding a stream of fuel gas into the gaps (22); the first gas feed line (52) has an outlet (51) designed to generate a premix pilot flame, and the channel (40) has a number of calibrated-section choke holes (56) for setting combustion air flow to the swirler (16).

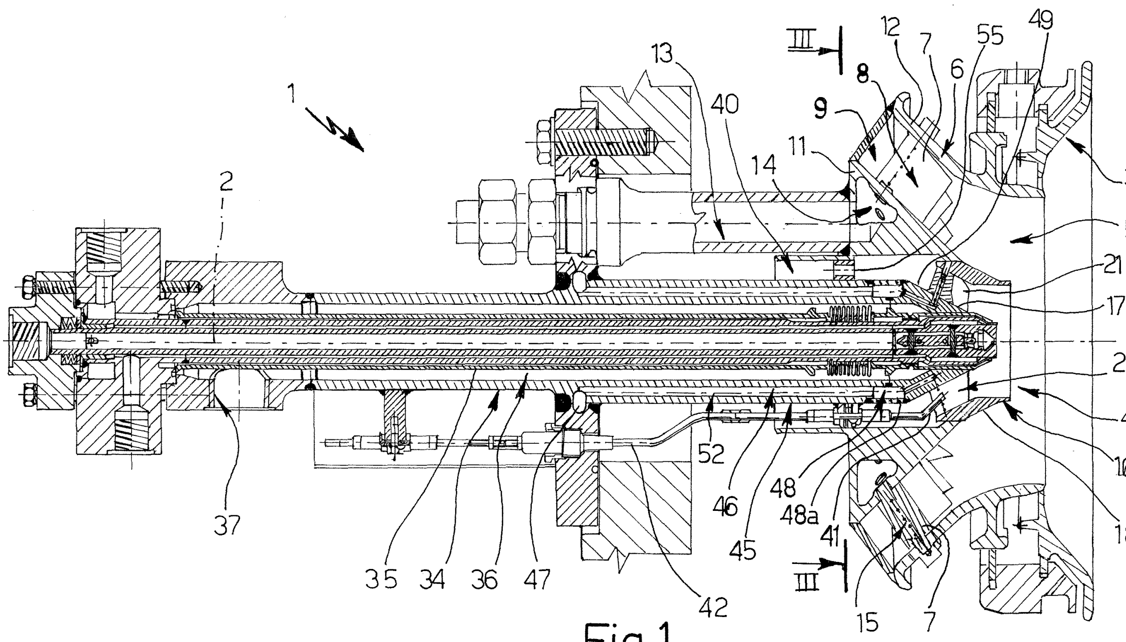

Fig.1

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Description

[0001] The present invention relates to a gas burner assembly for a gas turbine.

[0002] Gas turbine combustors are known comprising a combustion chamber, and a burner assembly (Figure 6) in turn comprising a peripheral burner (5) and a central burner (4). The peripheral burner has swirl or turbulence vanes (6), commonly known as a "diagonal swirler", at the outlet, and is a so-called "premix" burner, i.e. conducts a stream of fuel gas and an air stream, which are mixed, with a high surplus of air with respect to the stoichiometric ratio, at the "diagonal" swirler, upstream from the flame area.

[0003] The central burner has a substantially axial swirler (16a), conducts a stream of combustion air through the swirler, and comprises two separate gas feed lines. A first line (36a) generates a diffusion flame, i.e. injects a stream of fuel gas, in a practically stoichiometric ratio to the combustion air, by means of a number of nozzles (38a) on an inner cone (17a) of the axial swirler, so that combustion takes place inside the combustion chamber with substantially no premixing of the reactants.

[0004] The first feed line is mainly used for ignition and when starting or bringing the turbine up to speed. Once the turbine reaches an appropriate speed, and before it reaches nominal speed (3000 rpm), the peripheral premix burner is also activated : albeit for a short period of time, the turbine is therefore supplied simultaneously with gas burnt by the diffusion flame of the central burner and gas burnt by the premix flame of the peripheral burner ("mixed combustion").

[0005] A changeover is then made to "full-premix" mode, i.e. fuel gas is fed through the central burner from the second feed line (52a), and gas supply from the first line (36a) is cut off, so as to produce a pilot flame for ensuring stable combustion of the peripheral burner premix flame.

[0006] More specifically, the second gas feed line terminates with four pipes (60) located inside respective gaps between the vanes of the axial swirler (16a); and the fuel gas supplied by the pipes (about 10% of the gas flowing through the burner assembly as a whole) is injected parallel to the burner axis to produce a diffusion-type, and therefore highly stable, pilot flame.

[0007] A premix flame, however, burns at a lower temperature (1500°C as compared with 2000°C typical of a diffusion flame) and so produces fewer nitric oxide emissions.

[0008] A need is therefore felt for a gas burner with a premix- as opposed to diffusion-type pilot flame, but without impairing the stability of the pilot flame, and therefore of the peripheral premix burner combustion process.

[0009] It is an object of the present invention to provide a gas turbine gas burner designed to meet the above requirement in a straightforward, low-cost manner, and which, preferably, is of extremely simple design, can be produced by adapting standard burner assemblies, and allows the turbine to operate in any operating condition.

[0010] According to the present invention, there is provided a gas burner assembly for a gas turbine; the assembly having an axis and comprising:

- a first, premix, burner;
- a second burner surrounded by said first burner and comprising:

  a) a swirler comprising a number of vanes defining respective gaps;
  b) conducting means for feeding combustion air into said gaps;
  c) at least a first gas feed line for feeding a stream of fuel gas into said gaps;

and being characterized in that:

- said first gas feed line has an outlet designed to generate a premix pilot flame;
- said conducting means comprise calibrated-section choke means for setting combustion air flow to said swirler.

[0011] According to the present invention, there is also provided a method of adding a premix pilot flame to a burner, as defined in Claim 12.

[0012] A non-limiting embodiment of the invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 shows a cross section of a preferred embodiment of a gas turbine gas burner assembly in accordance with the present invention;
Figure 2 shows a larger-scale view, with parts removed for clarity, of a detail of the Figure 1 burner assembly;
Figure 3 shows a larger-scale section, with parts removed for clarity, along line III-III in Figure 1;
Figure 4 shows the same view as in Figure 3, of a variation of a component part in Figure 3;
Figure 5 shows the same view as in Figure 2, of a further preferred embodiment of a gas turbine gas burner assembly in accordance with the present invention;
Figure 6 is similar to Figure 1, and shows a larger-scale detail of a known gas burner that can be adapted to obtain the Figure 5 embodiment.

[0013] Number 1 in Figure 1 indicates a fuel gas burner assembly for a gas turbine (not shown).

[0014] Assembly 1 extends along an axis 2, generates, in use, combustion inside a chamber 3 (shown partly), and comprises a central burner 4, and a peripheral "premix" burner 5 coaxial with and surrounding burner 4.

[0015] Burner 5 has a swirl or turbulence generating device 6 known as a "swirler" and comprising a number of vanes 7 defining respective gaps 8. Gaps 8 conduct so-called "diagonally" into chamber 3 a stream of combustion air from an inlet 9 defined radially inwards by an externally conical, axially hollow body 11, and radially outwards by an annular, substantially conical wall 12. Burner 5 comprises a fuel gas feed line 13 which terminates with an annular header 14 formed in body 11 and communicating with gaps 8 via passages 15 formed in vanes 7. More specifically, the fuel gas and combustion air mixture formed in gaps 8, with more air than the theoretical stoichiometric ratio, is swirled sufficiently by device 6 to produce a premix flame.

[0016] Burner 4 has another swirl or turbulence generating device ("swirler") indicated 16 and comprising an inner cone 17, and an outer cone 18 which extends axially to form an extension of body 11 towards chamber 3.

[0017] With reference to Figure 2, cones 17, 18 have, respectively, an outer conical surface 19 and an inner conical surface 20, which are positioned facing each other to guide a stream of combustion air, and house between them ten vanes 21 defining respective gaps 22.

[0018] Vanes 21 have respective pressure faces; respective low-pressure faces; respective outer surfaces 23 resting on surface 20; and respective inner surfaces 24 resting on surface 19 and having respective fastening appendixes 26, which project along respective axes 27 converging at axis 2, and engage respective seats 28 formed in surface 19.

[0019] Seats 28 communicate with respective cavities 29, which are formed along axes 27 inside vanes 21 and through appendixes 26 up to surfaces 23, where they are plugged hermetically by respective screw fastening devices 30, each of which connects cone 18 in a fixed position to a relative vane 21. When devices 30 are all tightened down, vanes 21 are retained in a fixed position on cone 17, by preventing withdrawal of appendixes 26, and therefore of vanes 21, along respective axes 27, i.e. perpendicularly to surface 19.

[0020] With reference to Figure 1, burner 4 comprises an axial tubular body 34 which extends to form an axial extension of cone 17, is connected integrally to cone 17, and houses a gas oil or fuel oil burner 35 projecting axially from cone 17 towards chamber 3. Body 34 and burner 35 define radially, between them, an annular channel 36 for a first stream of fuel gas for producing a diffusion flame in chamber 3. Channel 36 has a lateral inlet 37 formed in body 34; and an outlet defined by a number of nozzles 38 (Figure 2) formed through cone 17 and debouching inside gaps 22 into which the combustion air also flows. The combustion air comes from an annular channel 40 which is located upstream from device 16, is coaxial with channel 36, and houses a known ignition electrode 41 for producing an ignition spark inside gaps 22, and which is powered by a known electric line 42 located alongside body 34 and not described in detail.

[0021] Channel 40 is defined radially outwards by body 11 and radially inwards by a cylindrical outer surface 45 of body 34.

[0022] Inside, body 34 has four passages 46 (Figure 3), parallel to axis 2, for a second stream of fuel gas for producing a pilot flame in chamber 3.

[0023] Passages 46 debouch, at one end, inside an annular inlet header 47 and, at the opposite end, inside an annular header 48 bounded axially by a rear portion 49 of cone 17 and separated radially from channel 40 by a cylindrical wall portion 48a, which is therefore swept externally by the combustion air stream flowing into device 16. More specifically, portion 49 is joined, e.g. welded, in fluidtight manner to the axial end of body 34 and to wall portion 48a, i.e. on opposite radial sides of header 48.

[0024] Header 48 communicates with gaps 22 via seats 28 and cavities 29. More specifically, with reference to Figure 2, seats 28 communicate with header 48 via respective holes 50 formed through portion 49 in directions substantially parallel to surface 19, and each cavity 29 communicates with gaps 22 via six relatively small-diameter holes 51, of which three are formed on the low-pressure face, and three on the pressure face.

[0025] Holes 51 define respective nozzles having axes substantially perpendicular to the air flow direction, and for producing a premix pilot flame with a large surplus of air with respect to the stoichiometric ratio. Nozzles 38, on the other hand, as stated, produce a diffusion flame with a practically stoichiometric fuel gas-combustion air ratio.

[0026] Device 16 simultaneously performs two functions : generating an appropriate amount of turbulence in the air stream; injecting the gaseous fuel by means of an appropriate number of holes (nozzles 51) in vanes 21. As such, the reactants are premixed completely before reaching the flame area. Best mixing is achieved by so contouring gaps 22 as to reduce losses caused by separation of the boundary layer.

[0027] For best performance of both the above functions, the air flow into device 16 is set, at the start of the working life of device 16, to achieve an optimum compromise between stable combustion and sufficiently low nitric oxide emissions.

[0028] The above setting is made by means of a constriction or choke with a calibrated or predetermined cross section, and which is defined by a ring or annular plate 55 (Figure 3) housed in fluidtight manner in channel 40, fixed, e.g. welded, to surface 45, and having a number of holes 56 spaced angularly about axis 2. The number and diameter of holes 56 are such as to achieve a satisfactory predetermined combustion air flow value, in terms of nitric oxide emissions and flame stability, over a wide operating range of the turbine.

[0029] At the turbine test and start-up stage, the air flow value is calibrated and improved as a function of the specific operating range of the turbine, and the emission range to be complied with, by further reducing and fine setting the flow section of holes 56, e.g. by inserting plugs or calibrated bushes (not shown), without impairing combustion stability.

[0030] Figure 4 shows a variation of ring 55 indicated

55a.

[0031] Ring 55a has two sets of calibrated circular holes 56a and 56b for the same function as holes 56 described above. Holes 56a, 56b alternate about axis 2, at least along part of the circumference of ring 55a, and are equally spaced 15° apart about axis 2. Holes 56b are twelve in number and of the same diameter; and holes 56a are twelve in number and of the same diameter larger than that of holes 56b.

[0032] Two diametrically opposite holes 57, forming part of holes 56a, may be used for the passage of a thermocouple; and two holes 58, also forming part of holes 56a, have a less than circular contour - more specifically, are U-shaped - for the passage of electrodes 41 and/or line 42.

[0033] At the turbine test and start-up stage, air flow through ring 55a can be fine set and improved as a function of the specific operating range of the turbine, and the emission range to be complied with, by reducing the air flow section, e.g. by inserting plugs 59 (Figure 4) or calibrated bushes (not shown) inside some of holes 56b equally spaced about axis 2, or inside all of holes 56b.

[0034] In actual use, the gas from nozzles 38 may be used for ignition and when starting or bringing the turbine up to speed. Once an appropriate turbine speed or load is reached, premix burner 5 is also activated, and a changeover is made to full-premix mode, i.e. fuel gas is fed through nozzles 51, and gas supply from nozzles 38 is cut off, so as to produce a premix pilot flame.

[0035] Device 16, however, is compact, and permits ignition of burner 4 directly by the gas from nozzles 51, with no need for a dedicated gas stream from nozzles 38, on account of electrode 41 producing a spark at nozzles 51. Burner 4 can therefore be ignited, and the turbine subsequently started or brought up to speed, directly by the premix gas feed line - i.e. the line (indicated 52 in Figure 1) comprising passages 46, header 48, holes 50, and cavities 29, and terminating with nozzles 51 - with no need for a diffusion flame, thus affording advantages in terms of reducing vibration. Obviously, in these operating conditions, after the turbine is started up and burner 5 is activated, gas flow from nozzles 51 is reduced to simply produce the pilot flame to keep the premix flame of burner 5 stable.

[0036] Again in the above operating conditions, the feed line terminating with channel 36 and with nozzles 38 need not be used, thus eliminating the need for gas control and feed devices, such as regulating valves, sensors, piping, etc..., and so reducing cost and making additional space available for other components; alternatively, nozzles 38 may be closed, and channel 36 also used to feed gas (in known manner not shown) to nozzles 51 in parallel with passages 46, to increase the maximum gas flow from nozzles 51, thus enhancing the operating range and versatility of assembly 1.

[0037] As will be clear from the foregoing description, assembly 1 has a single, completely premix type, pilot flame, thus reducing nitric oxide emissions, while still ensuring flame stability throughout the operating range.

[0038] Using device 16 and calibrating the combustion air flow or flow passage, nitric oxide emissions may be reduced to 30 mg/Nm3 (in low-load operating conditions) without compromising stability of the combustion process. In particular, nitric oxide emissions of below 9 ppm with 15% oxygen in the fumes are obtainable.

[0039] Device 16, with ring 55 or 55a, may be used to update a standard-production burner, or to adapt an already operating standard burner, to obtain a premix as opposed to diffusion pilot flame.

[0040] In fact, a known burner assembly (such as the one shown in Figure 6) can be converted to assembly 1 by substituting device 16 for the existing swirler and assembling ring 55, 55a inside channel 40.

[0041] As regards the gas feed line terminating with nozzles 38 and generating the diffusion flame, on the other hand, the premix pilot flame configuration involves no alterations to the standard burner, and tests show the reduction in air flow produced by ring 55 in no way affects stability of the diffusion flame.

[0042] Device 16 requires no shielding or particular or additional heat protection along the gas feed line to nozzles 51, on account of the combustion air flow into device 16 flowing directly over the outside of wall portion 48a of header 48.

[0043] Calibrating air flow by means of holes arranged about axis 2, and in particular by means of the specific hole solutions shown and described in connection with rings 55, 55a, provides for achieving optimum fluid-dynamic performance as regards effective premixing of the premix pilot flame combustion air.

[0044] Other advantages will be obvious from the construction characteristics described above.

[0045] Figure 5 shows a different swirl or turbulence generating device ("swirler") 16b, which is obtained by simply modifying, as opposed to replacing, a "swirler" 16a of a known assembly 1a (Figure 6) to obtain a premix flame.

[0046] In Figure 6, with the exception of swirler 16a and the absence of ring 55, 55a, the component parts of assembly 1a are indicated using the same reference numbers as for assembly 1 described above, while the component parts of swirler 16a are indicated using the same reference numbers as device 16 followed by the letter "a".

[0047] More specifically, the geometry and structure of the known swirler 16a differ from devices 16, 16b by being configured to generate:

- a diffusion flame by means of fuel gas from a feed line 36a defined by channel 36 and terminating with a number of holes 38a, which are formed in cone 17a as of an annular header 39 bounded by cone 17a and by burner 35, and debouch in all eight gaps 22a;
- a diffusion pilot flame by means of fuel gas from a line 52a defined by passage 46 and terminating with

four nozzles 60, known as a "pilot pipe", aligned with passage 46 and which debouch inside respective gaps 22a.

[0048] With reference to Figure 5, device 16b produces the premix pilot flame in burner 4 by means of gas from holes 51a formed through cone 17a in lieu of holes 38a.

[0049] The device 16b embodiment therefore has the advantage of dispensing with perforated vanes 21 to inject the fuel gas, and employing the same standard vanes 21a and cones 17a, 18a of swirler 16a, thus minimizing the alterations required to known assembly 1a to add a premix pilot flame to an existing diffusion pilot flame.

[0050] In the Figure 5 solution, the fuel gas generating the premix flame is supplied by line 36a, while line 52a remains unchanged and is again used to produce a diffusion pilot flame. In other words, to effectively premix the gas and air, the Figure 5 solution calls for altering the geometry of the gas outlet of line 36a.

[0051] With reference to Figure 6, the process by which to convert assembly 1a to the Figure 5 solution comprises the following steps:

- closing holes 38a : in particular, by welding with filler material;
- mechanically polishing surface 19a, on the portions of material closing holes 38a : in particular, to obtain a surface roughness of surface 19a preventing the formation of secondary swirl in gaps 22a;
- drilling cone 17a to form the new holes 51a (Figure 5);
  - o holes 51a are drilled at the four gaps 22a with no nozzles 60 (the four gaps 22a housing nozzles 60 and the four gaps 22a into which holes 51a debouch alternate);
  - o holes 51a have respective axes 62 perpendicular to axis 2;
  - o the axial position of holes 51a is close to the arc joining the rear ends 63 of inner surfaces 24a of adjacent vanes 21a : to determine an unequivocal starting position, axis 62 is located 12 millimetres (measured parallel to axis 2) from the rear edge 64 of cone 18a;
  - o for each of the four gaps 22a concerned, two holes 51a are drilled, are three millimetres in diameter, and are equally spaced about axis 2 along the arc joining the edges of the two adjacent vanes 21a;
- machining the inner surfaces of holes 51a to an appropriate inner surface roughness.

[0052] The number of holes 51a for each gap 22a and the diameter of the holes may differ from those indicated above, depending on the composition of the fuel gas. More specifically, the slope of axes 62 with respect to axis 2, the diameter and, hence, penetration of the gas jet, and the location of holes 51a are the parameters which define the degree of premixing with no risk of flashback, and may differ from those indicated above by way of example.

[0053] The above alterations to convert assembly 1a to the Figure 5 solution do not require assembly of ring 55, 55a to improve premixing, and calibration of the combustion air in channel 40 is the same as in the known assembly 1a.

[0054] In actual use, the gas from holes 51a is used for ignition, by virtue of electrode 41 generating a spark at one of the four gaps 22a in which holes 51a are formed.

[0055] Subsequently, as the gas turbine is being brought up to speed, in addition to line 36a, the line defined by passages 15 is also used in parallel to feed fuel gas to burner 5 until the turbine reaches a speed corresponding to a no-load operating condition.

[0056] At this point, line 52a is also activated, so that gas is supplied simultaneously along three lines, to commence powering the electric machine. Once line 52a is activated, gas flow from holes 51a is cut off, and the premix flame of burner 5 is stabilized solely by the diffusion pilot flame.

[0057] Upon exceeding a reference or so-called "technical minimum" load equal, for example, to 60% of the base load of the electric machine powered by the gas turbine, pilot combustion is switched from the diffusion flame to the premix flame, i.e. fuel gas supply is switched from line 52a to line 36a.

[0058] As in the Figure 1 solution, by virtue of the alterations to assembly 1a to obtain device 16b, operation is characterized by a lower level of pollution (marked reduction in exhaust emissions) as compared with known assembly 1a.

[0059] As compared with the Figure 1 solution, combustion and operation of the turbine are far more stable, and conversion of assembly 1a much cheaper, though the emission level is slightly higher (but still below the 30 mg/Nm3 target level).

[0060] The Figure 5 solution also provides for more flexible operation as compared with the Figure 1 solution. The Figure 1 solution, in fact, does not permit use of a diffusion pilot line, whereas the Figure 5 solution allows a choice between using as a pilot :

- line 36a only, throughout the operating range, to reduce emissions and minimize pollution : in the event this is mandatory, fuel gas supply may be reduced from three to two lines (eliminating supply by line 52a); or
- also line 52a, as described above, when greater operating stability is required (in particular transient conditions and with partial loads below the so-called "technical minimum").

[0061] Clearly, changes may be made to the solutions described and illustrated herein without, however, departing from the scope of the present invention, as defined in the accompanying Claims.

Claims

1. A gas burner assembly for a gas turbine; the assembly having an axis (2) and comprising:

   - a first, premix, burner (5);
   - a second burner (4) surrounded by said first burner (5) and comprising:

     a) a swirler (16) comprising a number of vanes (21) defining respective gaps (22);
     b) conducting means (40) for feeding combustion air into said gaps (22);
     c) at least a first gas feed line (52) for feeding a stream of fuel gas into said gaps (22);

   and being **characterized in that**:
   - said first gas feed line (52) has an outlet (51) designed to generate a premix pilot flame;
   - said conducting means (40) comprise calibrated-section choke means for setting combustion air flow to said swirler (16).

2. An assembly as claimed in Claim 1, **characterized in that** said second burner comprises an ignition device (41); said swirler (16) and said ignition device (41) being so positioned with respect to each other that a spark is produced in said gaps (22) at said outlet (51).

3. An assembly as claimed in Claim 2, **characterized by** comprising a second gas feed line (36) which feeds gas to said outlet (51) in parallel with said first gas feed line (52).

4. An assembly as claimed in any one of the foregoing Claims, **characterized in that** said gas feed line (52) comprises, for each said vane (21), a relative cavity (29) communicating with said gaps (22) through said outlet (51); said outlet (51) being defined by holes formed in said vanes (21) along axes substantially perpendicular to the direction of the combustion air stream.

5. An assembly as claimed in any one of the foregoing Claims, **characterized in that** said calibrated-section choke means (56) comprise a number of calibrated-section holes (56) spaced angularly about said axis.

6. An assembly as claimed in Claim 5, **characterized in that** said calibrated-section holes are circular and equally spaced about said axis, at least along part of the circumference.

7. An assembly as claimed in Claim 5 or 6, **characterized in that** said calibrated-section choke means (56) comprise a first number of calibrated-section holes (56a) and a second number of calibrated-section holes (56b) alternating about said axis, at least along part of the circumference, and differing in diameter.

8. An assembly as claimed in any one of Claims 5 to 7, **characterized in that** said calibrated-section holes (56) are formed in a plate (55) housed in fluidtight manner inside a combustion air channel (40).

9. An assembly as claimed in any one of Claims 5 to 8, **characterized by** comprising fine calibrating means (59) for reducing the flow section of said calibrated-section holes (56).

10. An assembly as claimed in any one of the foregoing Claims, **characterized in that** said gas feed line comprises an annular header (48) defined radially outwards by an annular wall (48a) forming part of said combustion air conducting means (40).

11. An assembly as claimed in Claim 10, **characterized in that** said annular header (48) is defined axially by a rear portion (49) of an inner cone (17) of said swirler (16).

12. A method of adding a premix pilot flame to a burner (4) having an axis (2) and comprising:

    - a swirler (16a) comprising an inner cone (17a), and a number of vanes (21a) defining respective gaps (22a);
    - conducting means (40) for feeding combustion air into said gaps (22a);
    - a first fuel gas feed line (52a) comprising outlet nozzles (60) located inside some of said gaps (22a) and designed to generate a diffusion pilot flame;
    - a second fuel gas feed line (36a) terminating with a number of diffusion holes (38a), which debouch, through said inner cone (17a), inside all of said gaps (22a= and are designed to generate a diffusion flame;

    the method being **characterized by** comprising the steps of:

    - closing said diffusion holes (38a);
    - forming, through said inner cone (17a) and at the gaps (22a) having no outlet nozzles (60) of said first fuel gas feed line (52a), new holes (51a) defining the outlet of said second fuel gas feed line (36a) and designed to produce a premix pilot flame.

13. A method as claimed in Claim 12, **characterized in that** said new holes (51a) are formed with respective axes (62) perpendicular to the axis (2) of the burner (4).

14. A method as claimed in Claim 12 or 13, **characterized in that** said new holes (51a) are formed close to the arc joining the rear ends (63) of the respective inner surfaces (24a) of adjacent vanes (21a).

15. A method as claimed in Claim 14, **characterized in that** said new holes (51a) are formed along respective axes (62) located twelve millimetres from the rear edge (64) of an outer cone (18a) of said swirler.

16. A method as claimed in Claim 14 or 15, **characterized in that**, for each said gap (22a) having no said outlet nozzle (60), two said new holes (51a) are formed of three millimetres in diameter and equally spaced about the axis (2) of said burner (4), along the arc joining the edges of the relative two adjacent vanes (21a).

17. A method as claimed in any one of Claims 12 to 16, **characterized in that** the step of closing said diffusion holes (38a) is performed by welding with filler material.

18. A method as claimed in any one of Claims 12 to 17, **characterized by** comprising the step of machining the inner surface of said new holes (51a) and the surfaces of said inner cone (17a) to reduce the degree of roughness.

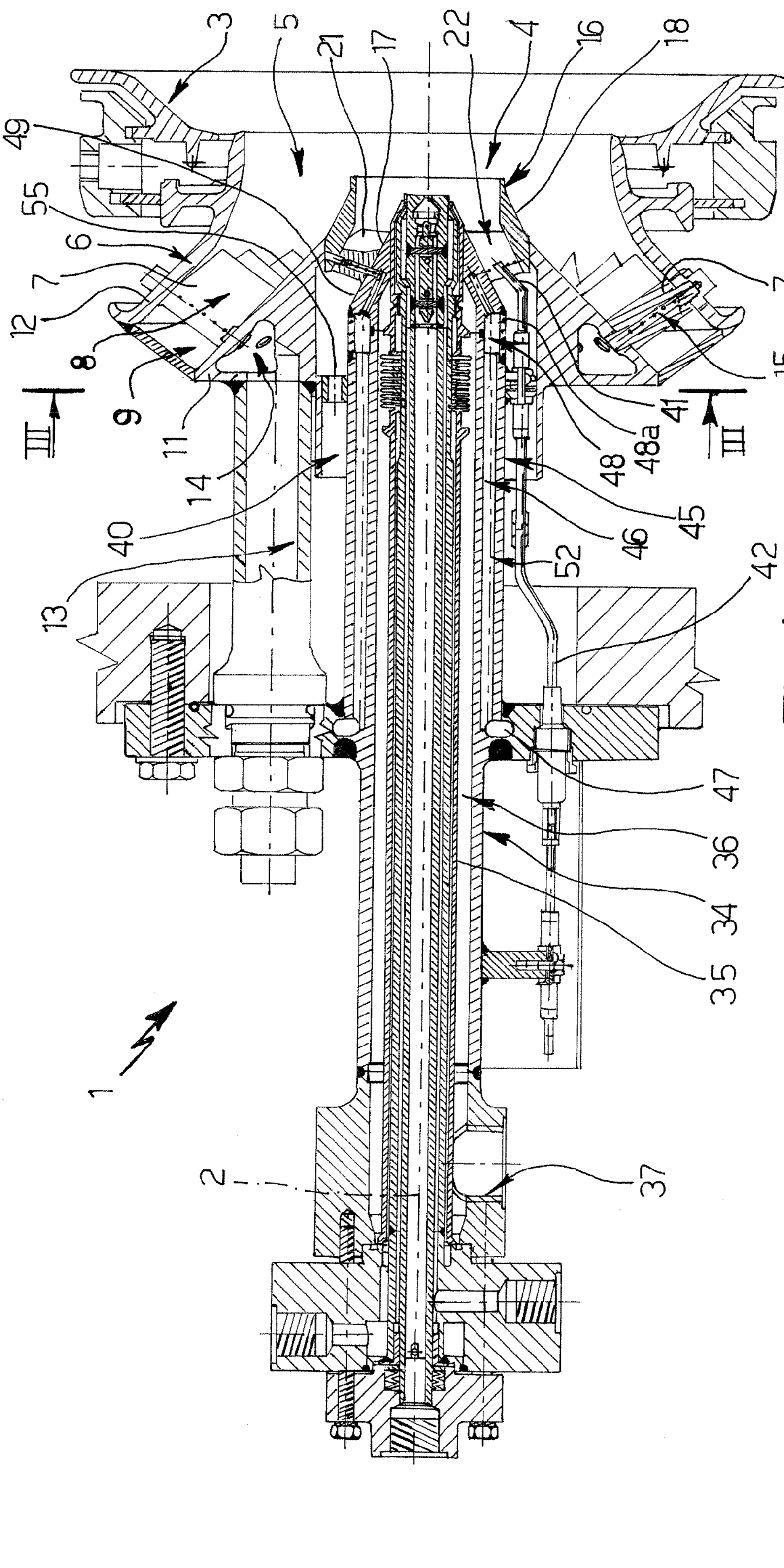
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Fig.1

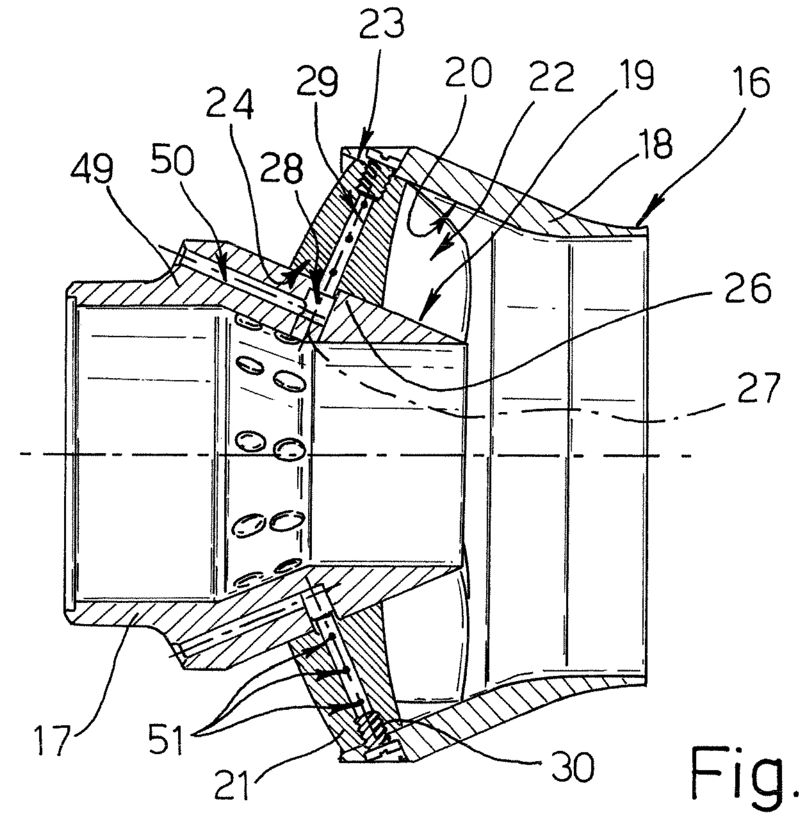
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Fig.2

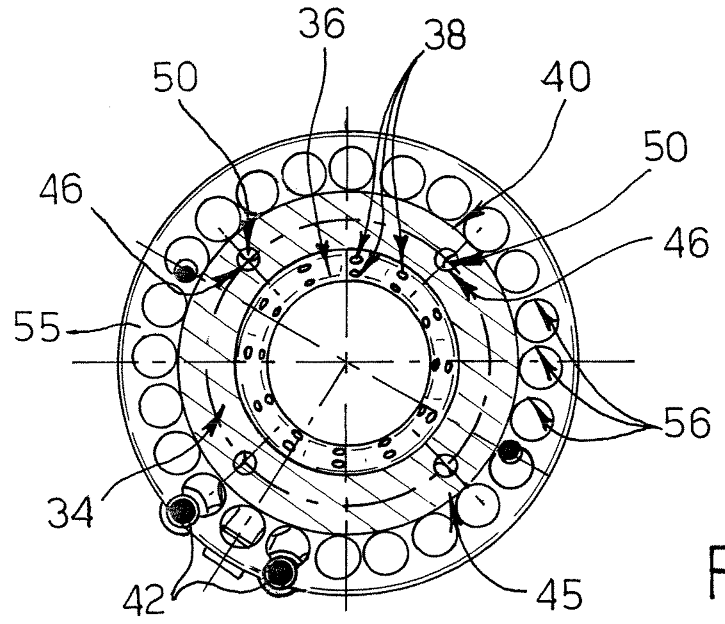
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Fig.3

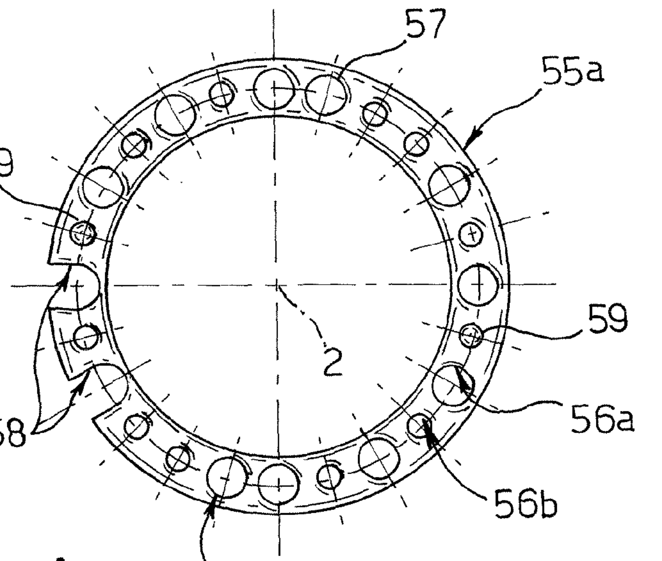
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Fig. 4

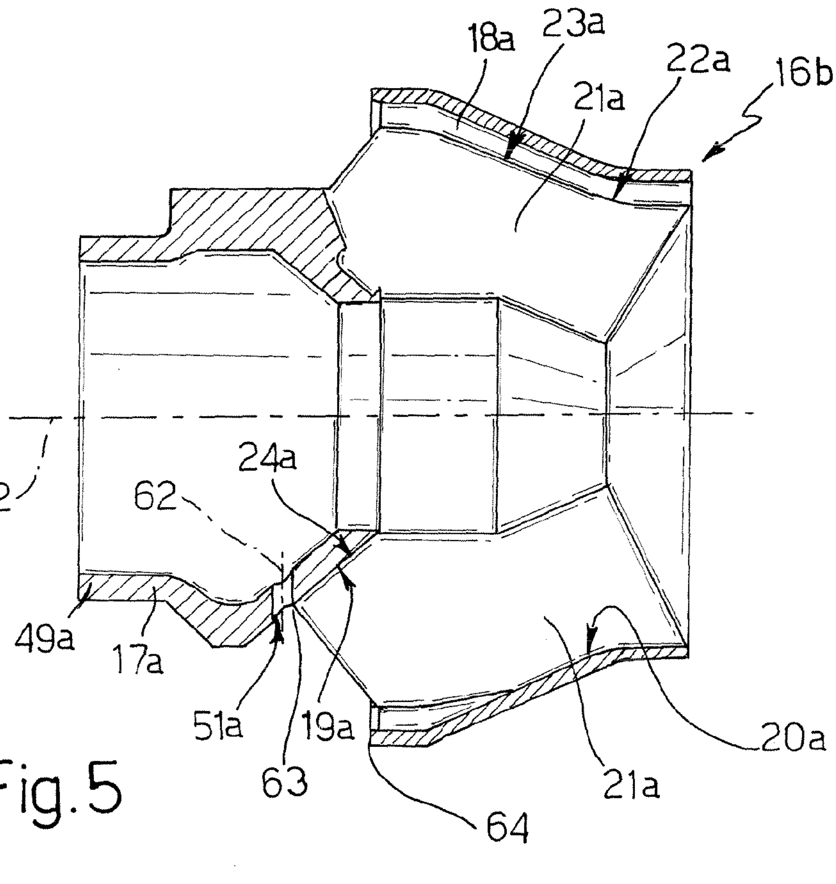
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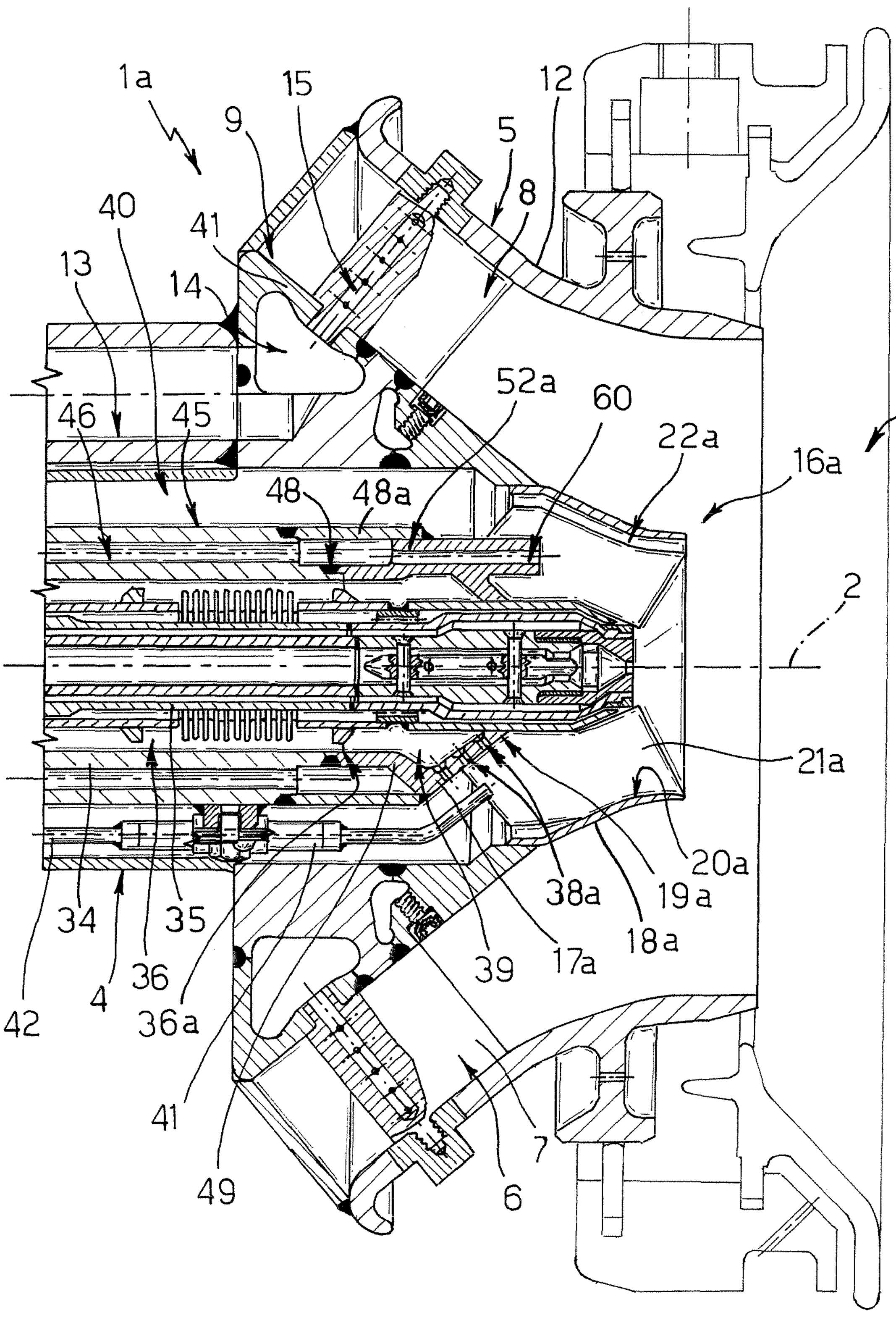
Fig. 5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4
41
7
49
6

Fig.6