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(54) **Liquid-fuel burner combustion head**

(57) A liquid-fuel burner combustion head (100) having, among other things, a cap (11) fixed to a cylindrical body (3) to divide a stream of primary air (A1) into at least three portions (A1r, A1sw, A1a). To do this, a number of equally spaced, calibrated, radial holes (12) are formed in a cylindrical surface (11bc) of the cap (11), and a number of equally spaced, inclined slots (13) are formed in an end surface (11bf) of the cap (11). An axial hole (14) is also formed in the end surface (11bf) of the cap (11), where the atomized liquid fuel comes out of a nozzle (2).

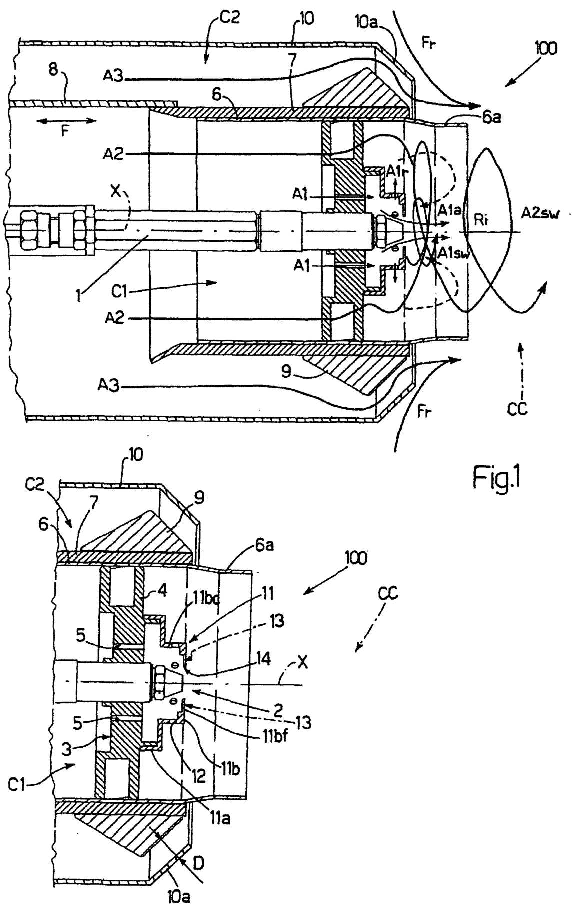

Fig.1

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Description

[0001] The present invention relates to a burner combustion head, particularly suitable for burning low NO_x emission liquid fuel.

[0002] As is known, in liquid-fuel burners, the combustion reaction between the fuel and combustion supporter is produced by a combustion head substantially comprising a tubular conduit, which conducts the combustion supporting fluid from a blower into the combustion chamber, and the combustion supporting fluid mixes with a liquid fuel atomized by one or more nozzles.

[0003] A known ignition device ignites the mixture to initiate combustion.

[0004] One of the main drawbacks of combustion heads, ecologically speaking, is the production, during combustion, of nitric oxides NO_x, which cause pollution.

[0005] Research into the production of nitric oxides NO_x has revealed they are mainly generated at high flame temperature.

[0006] For this reason, burners have been devised featuring combustion heads, in which the temperature of the flame is reduced by recirculating part of the combustion fumes inside the combustion head and the flame itself.

[0007] The fumes are recirculated inside the flame using the high outflow speed of the air from the burner head, which produces a so-called "entrainment" effect, by which the fumes in the combustion chamber are drawn into the flame and, since they play no part in the combustion reaction, absorb heat, thus cooling the flame and reducing nitric oxide NO_X emissions.

[0008] Known solutions indeed provide for reducing the nitric oxides in the fumes to permissible regulation values, but only give good results with small-size burners, in which the flame, having a fairly large surface with respect to its volume, is easily penetrated by the fumes.

[0009] Conversely, in the case of medium-large-size burners, in which the flame surface (and therefore the exchange surface) is fairly small with respect to the volume of the flame, flame penetration by the fumes poses problems.

[0010] It is a main object of the present invention to eliminate this drawback.

[0011] More specifically, one object of the invention is to provide a combustion head which, as compared with known combustion heads, provides for improved mixing of the combustion supporting air and the fumes present in the combustion chamber, to reduce the presence of nitric oxides NO_X.

[0012] Another object of the present invention is to provide a combustion head which recirculates the fumes present in the combustion chamber to premix them with the combustion supporting air upstream from the combustion region, so as to reduce the temperature of the flame.

[0013] Another object of the present invention is to provide a combustion head which mixes the recirculated fumes and the combustion supporting air more effectively as compared with known combustion heads.

[0014] Another drawback of known combustion heads is the formation of large carbon deposits on the front of the head, and which may interfere with the fuel spray from the nozzle, thus impairing combustion.

[0015] It is therefore a further object of the present invention to prevent the formation of such carbon deposits.

[0016] The combustion head according to the present invention is also easier to produce, as compared with known combustion heads.

[0017] According to the present invention, there is provided a liquid-fuel combustion head, as claimed in Claim 1.

[0018] A non-limiting embodiment of the present invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 (and relative detail) shows an overall longitudinal section of the combustion head which is the main object of the present invention;
Figure 2 shows a front view in perspective of the Figure 1 combustion head;
Figure 3 shows a front view of the Figure 1 and 2 combustion head;
Figure 4A shows a rear view of a first detail of the combustion head in Figures 1, 2, 3;
Figure 4B shows a side view of the Figure 4A detail;
Figure 4C shows a section A-A of the Figure 4A detail;
Figure 5A shows a front view of a second detail of the combustion head in Figures 1, 2, 3;
Figure 5B shows a section B-B of the Figure 5A detail;
Figure 5C shows a section C-C of the Figure 5A detail;
Figure 6 shows the Figure 1-3 combustion head with a tertiary-combustion region, a secondary-combustion region, and an internal-recirculation region in a combustion chamber with which the combustion head is combined;
Figure 7 shows the Figure 1-3 combustion head with primary-combustion regions in a combustion chamber with which the combustion head is combined.
Figure 1 shows a combustion head 100 in accordance with the present invention.

[0019] As shown in Figure 1, a liquid fuel (e.g. gas oil) is fed to a nozzle 2 by a central pipe 1 (having a longitudinal axis of symmetry X).

[0020] Nozzle 2 atomizes the liquid fuel in known manner inside a combustion chamber CC (see below).

[0021] Pipe 1 is fitted coaxially with a cylindrical body 3, the outer cylindrical surface of which has equally spaced grooves 4 sloping with respect to longitudinal axis of symmetry X (see also Figures 4A, 4B, 4C).

[0022] A number of equally spaced calibrated holes 5 are formed, parallel to axis X, in the inner portion of cylindrical body 3 (see also Figure 4A), and cylindrical body

3 also comprises a central through hole FC for insertion of central pipe 1.

[0023] An intermediate pipe 6, of the same inside diameter as cylindrical body 3, is fixed to the outer surface of cylindrical body 3 (coaxially with both pipe 1 and cylindrical body 3), and comprises a tapered portion 6a downstream from cylindrical body 3 for the reasons explained in detail below.

[0024] A first channel C1, for feeding combustion supporting fluid (e.g. air) to nozzle 2 and combustion chamber CC, is therefore defined between central pipe 1 and intermediate pipe 6.

[0025] Intermediate pipe 6 is fitted with a coaxial cylinder 7, which can be slid in either of the axial directions indicated by arrow F by an operator or an actuator (not shown) using a bracket 8 connected to coaxial cylinder 7.

[0026] Coaxial cylinder 7 is fitted (by known means) with a toroidal ring 9, which, in the Figure 1 embodiment, has a triangular cross section.

[0027] An outer pipe 10 is fitted coaxially with axis X, central pipe 1, cylindrical body 3, intermediate pipe 6, and coaxial cylinder 7, and terminates with a truncated-cone-shaped edge 10a at the free end facing combustion chamber CC.

[0028] A second channel C2, for feeding combustion supporting fluid (e.g. air) to combustion chamber CC, is therefore defined between intermediate pipe 6 and outer pipe 10.

[0029] As explained in more detail below, the amount of combustion supporting fluid fed into combustion chamber CC along second channel C2 is regulated by adjusting the distance D between toroidal ring 9 and truncated-cone-shaped edge 10a, which is obviously done by simply moving coaxial cylinder 7 in either of the directions indicated by arrow F.

[0030] Cylindrical body 3 is fitted, in inventive manner, with a cap 11.

[0031] In the preferred embodiment in Figure 1, cap 11 comprises two superimposed cylindrical portions 11a, 11b of different diameters. More specifically, portion 11a, which is the portion actually fixed to cylindrical body 3, is larger in diameter than portion 11b.

[0032] As shown in more detail in Figures 5A, 5B, 5C, a number of equally spaced, calibrated, radial holes 12 are formed in a cylindrical surface 11bc of portion 11b; and a number of equally spaced slots 13, sloping with respect to axis X (see Figures 2, 3, 5A in particular), are formed in an end surface 11bf of portion 11b.

[0033] In a preferred solution, slots 13 slope in the same direction as, but not necessarily at the same angle as, grooves 4.

[0034] In end surface 11bf of portion 11b of cap 11, an axial hole 14 (Figures 1, 2, 5A) is formed precisely where the atomized liquid fuel comes out of nozzle 2.

[0035] As shown in Figures 1, 6, 7, cap 11 is supplied with combustion supporting fluid through calibrated holes 5 in cylindrical body 3.

[0036] In actual use, a fan (not shown) supplies an adequate stream of combustion supporting fluid (e.g. air), which is conducted into outer pipe 10 enclosing the whole of combustion head 100.

[0037] By virtue of the geometry of combustion head 100 described above, the air stream is then divided into three partial streams referred to respectively as primary air A1, secondary air A2, and tertiary air A3 (Figures 1, 3, 6, 7).

[0038] More specifically, primary air A1 and secondary air A2 flow inside channel C1, while tertiary air A3 is fed along channel C2 (Figure 1).

[0039] The flow of primary air A1 is determined by the number and section of calibrated holes 5, and is subsequently further divided into radial primary air A1r (out of holes 12), swirled primary air A1sw (out of slots 13), and axial primary air A1a (out of central hole 14) (Figures 1, 3, 7).

[0040] The flow of secondary air A2 is determined by the number and section of grooves 4 in cylindrical body 3.

[0041] Downstream from cylindrical body 3, secondary air stream A2 - which, downstream from cylindrical body 3, will be referred to as A2sw, for the sake of simplicity - has a high swirl component, and its expansion is contained substantially inside tapered portion 6a.

[0042] The flow of tertiary air A3 is determined by distance D between toroidal ring 9 and truncated-cone-shaped edge 10a; which distance D is adjustable as described previously.

[0043] The high momentum of tertiary air stream A3 produces, immediately downstream from truncated-cone-shaped edge 10a, an entrainment effect on the surrounding fluid. During combustion, this fluid comprises combustion products, some of which (Fr - Figures 1, 3, 6) are entrained by and mix with stream A3 (see below).

[0044] The combustion mechanisms are as follows.

[0045] The fuel is atomized by nozzle 2 (Figure 6). Given the high kinetic energy of the fuel droplets, only a minimum number are affected by secondary air stream A2sw, while most reach tertiary air stream A3.

[0046] The small amount of fuel affected by secondary air stream A2sw is nevertheless sufficient to feed a secondary-combustion region (Figure 6) detached from and located further forward with respect to the end portion of combustion head 100. The secondary-combustion region is characterized by a strong swirl (and turbulence) component which ensures stable combustion, also by virtue of internally recirculating hydrocarbon fragments (see below).

[0047] The temperature of the secondary-combustion region is fairly low (i.e. below 900°K, which is the temperature above which the thermal NO_x formation process begins to have a noticeable effect) for substantially two reasons:

1 - the flow of secondary air A2 is much greater than the theoretical stoichiometric conditions of the secondary-combustion region; the surplus of secondary air A2 therefore assists in reducing the temperature

of the secondary-combustion region (in fact, the surplus air not involved in the combustion reaction is an inert which absorbs heat);

2 - the high degree of turbulence in the field of motion provides for effectively mixing the combustion supporter and fuel, and so preventing the formation of regions with close to stoichiometric local combustion supporter/fuel conditions; which regions, as is known, are those which produce the highest temperatures of all.

[0048] In conventional flames, on the other hand, secondary-combustion region temperatures are high because of the mixing conditions, which, in certain points, may be close to stoichiometric, thus resulting in the formation of considerable amounts of NO_x.

[0049] Most of the fuel, however, defined by the larger, faster droplets (with greater kinetic energy) in the spray produced by nozzle 2, reaches tertiary air stream A3, where it produces a tertiary-combustion region (Figure 6).

[0050] In the tertiary-combustion region, combustion takes place in, on average, close to stoichiometric conditions (to begin with, even with a shortage of air), but temperature is nevertheless still reduced by the presence of recirculated fumes Fr (Figures 1, 6).

[0051] The high velocity of tertiary air stream A3, in fact, has an entrainment effect on the combustion products inside combustion chamber CC. Recirculated fumes Fr also act as heat-absorbing inerts in direct proportion to the extent to which the combustion supporter and recirculated fumes are mixed.

[0052] In combustion head 100 according to the invention, recirculated fumes Fr are allowed to mix well with tertiary air A3 before this becomes involved in the combustion process.

[0053] That is, tapered portion 6a (Figure 1) (close to which the "Coanda effect" causes tertiary air A3 to flow) gives tertiary air A3 and recirculated fumes Fr enough time and space to mix effectively before reaching the tertiary-combustion region.

[0054] Moreover, the fact that the tertiary-combustion region, in which most of the fuel is burned, is located in the outer portion of the frame provides for improved heat exchange between the flame and the surrounding environment, thus further cooling the flame. The above phenomena combine to reduce the formation of thermal NO_x by reducing the temperature of the flame.

[0055] Moreover, primary air stream A1 and the way in which it is distributed in cap 11 establish primary-combustion regions (Figure 7) for mainly keeping combustion head 100 clean close to nozzle 2.

[0056] That is, the swirling motion of secondary air stream A2sw produces a helical motion inside the stream (Figure 1) in the opposite axial direction (towards combustion head 100). In other words, secondary air stream A2sw produces a central depression, which in turn produces internal recirculation R1 (Figures 6, 7) of hydrocarbon fragments, which, as is known, are fragments of partly burnt fuel.

[0057] The hydrocarbon fragments are highly reactive, and partly fuel the secondary-combustion region to assist in stabilizing the flame.

[0058] The hydrocarbon fragments with greater kinetic energy, however, manage to reach the portion of combustion head 100 surrounding nozzle 2. Since this portion of combustion head 100 is cooled by the airflow from behind, the hydrocarbon fragments, if there were no primary-combustion region, would settle on the cold surfaces, thus forming carbon deposits, which would eventually be thick enough to interfere with the fuel spray from nozzle 2, thus impairing the combustion process.

[0059] The presence, however, of a flame front clinging to the surface of cap 11 (Figure 7) allows the combustion reaction of the hydrocarbon fragments to be completed.

[0060] Given the small size of the primary-combustion region, the percentage of total NO_x production is negligible.

Claims

1. A burner combustion head (100) comprising:

    - a central pipe (1) supplied with a liquid fuel and fitted on one end with a nozzle (2) for atomizing said liquid fuel in a combustion chamber (CC);
    - an intermediate pipe (6) coaxial with and outside said central pipe (1), with which it defines a first conduit (C1) for feeding a first stream of combustion supporting fluid (A1) and a second stream of combustion supporting fluid (A2) to said combustion chamber (CC); a cylindrical body (3) being interposed between said central pipe (1) and said intermediate pipe (6), and having openings (4) for imparting a swirling motion to said second stream of combustion supporting fluid (A2); said cylindrical body (3) also feeding said first stream of combustion supporting fluid (A1) to said nozzle (2); and
    - an outer pipe (10) coaxial with said intermediate pipe (6), with which it defines a second conduit (C2) for feeding a third stream of combustion supporting fluid (A3) to said combustion chamber;

    the combustion head being **characterized by** also comprising a cap (11) fixed to said cylindrical body (3) to divide said first stream of combustion supporting fluid (A1) into at least three portions (A1r, A1sw, A1a).

2. A combustion head (100) as claimed in Claim 1, **characterized in that** said cap (11) is located inside a tapered portion (6a) of said intermediate pipe (6).

3. A combustion head (100) as claimed in any one of the foregoing Claims, **characterized in that** said cap (11) comprises two superimposed cylindrical portions (11a, 11b) of different diameters.

4. A combustion head (100) as claimed in Claim 3, **characterized in that** said portion (11a) is larger in diameter than said portion (11b); said portion (11b) being fixed to said cylindrical body (3).

5. A combustion head (100) as claimed in any one of the foregoing Claims, **characterized in that** a number of equally spaced, calibrated, radial holes (12) are formed in a cylindrical surface (11bc) of said cap (11), and a number of equally spaced, inclined slots (13) are formed in an end surface (11bf) of said cap (11).

6. A combustion head (100) as claimed in Claim 5, **characterized in that** an axial hole (14) is also formed in said end surface (11bf) of said cap (11), where the atomized liquid fuel comes out of said nozzle (2).

7. A combustion head (100) as claimed in any one of the foregoing Claims, **characterized in that** the outlet section of said second conduit (C2) is adjustable.

8. A combustion head (100) as claimed in Claim 7, **characterized in that** said second conduit (C2) is adjustable by displacement of a toroidal member (9).

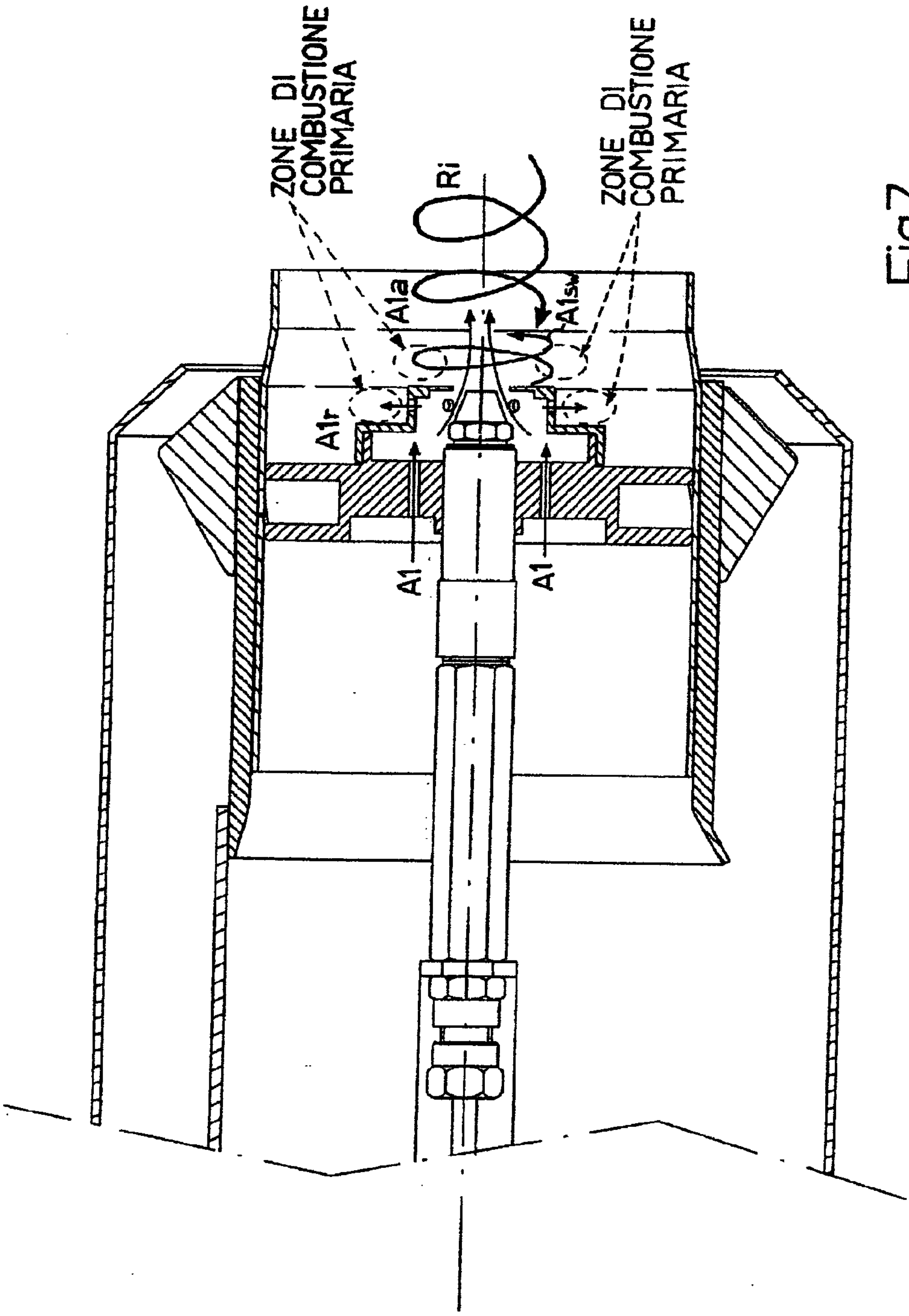

ZONE DI COMBUSTIONE PRIMARIA
ZONE DI COMBUSTIONE PRIMARIA
Ri
A1a
A1sw
A1r
A1
A1

Fig.7

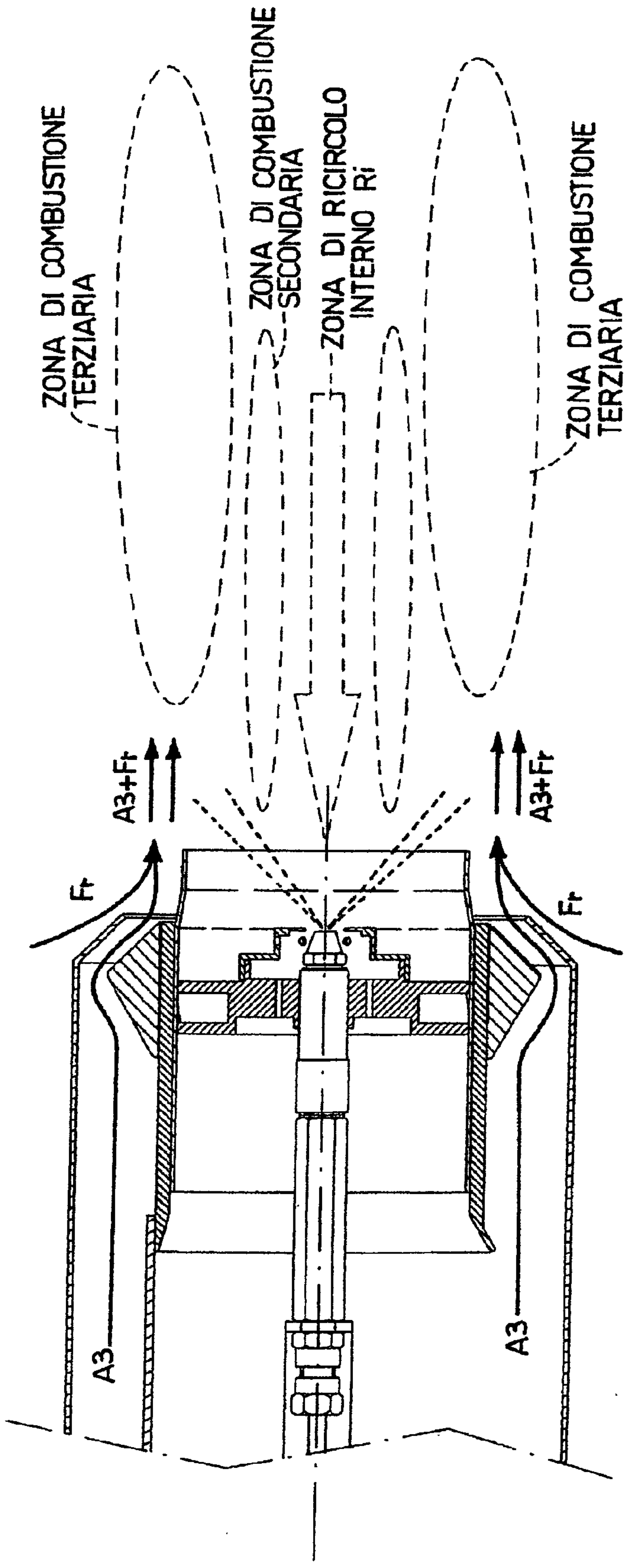

ZONA DI COMBUSTIONE TERZIARIA
ZONA DI COMBUSTIONE SECONDARIA
ZONA DI RICIRCOLO INTERNO Ri
ZONA DI COMBUSTIONE TERZIARIA
A3+Fr
A3+Fr
Fr
Fr
A3
A3

Fig.6

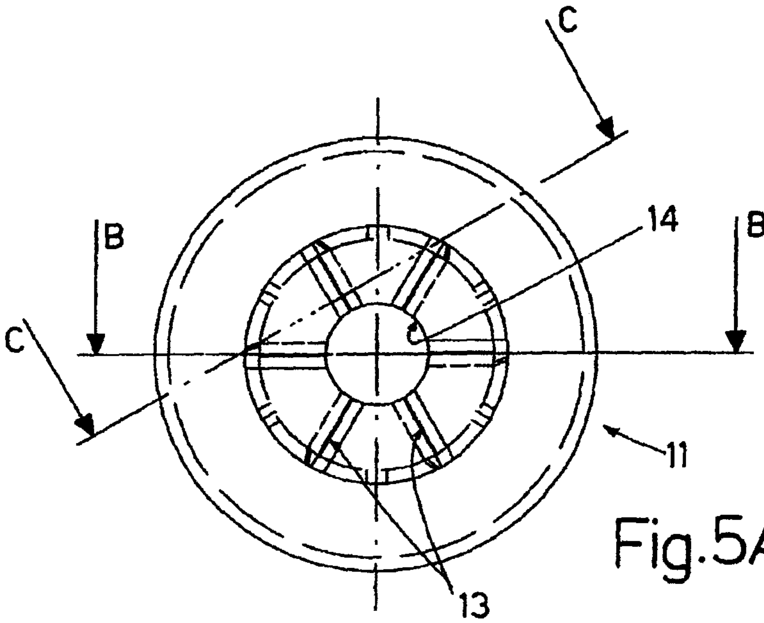


Fig.5A

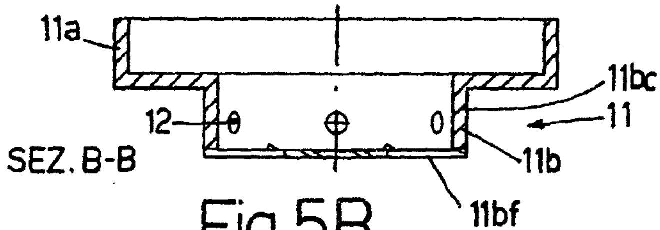


Fig.5B

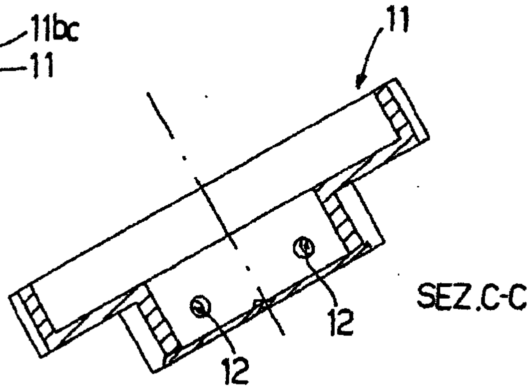


Fig.5C

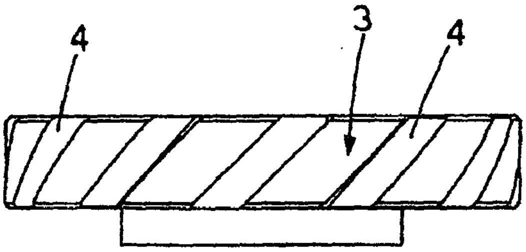
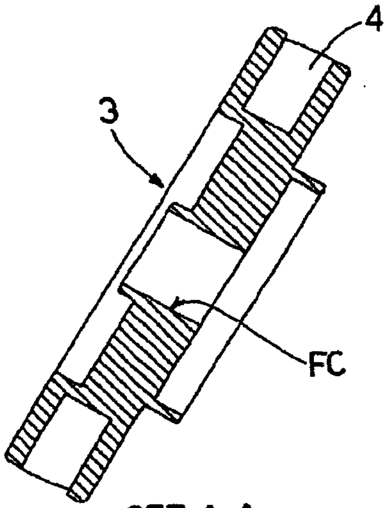


Fig.4B



SEZ.A-A

Fig.4C

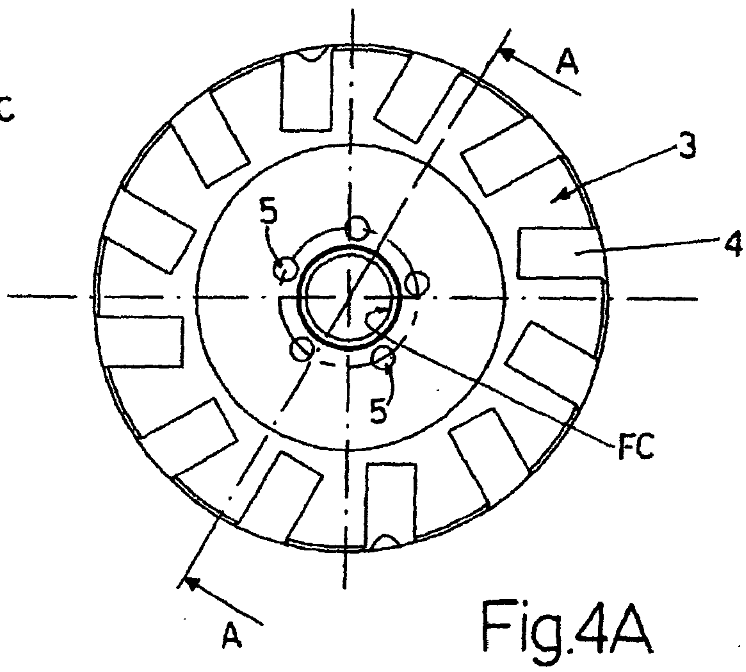


Fig.4A

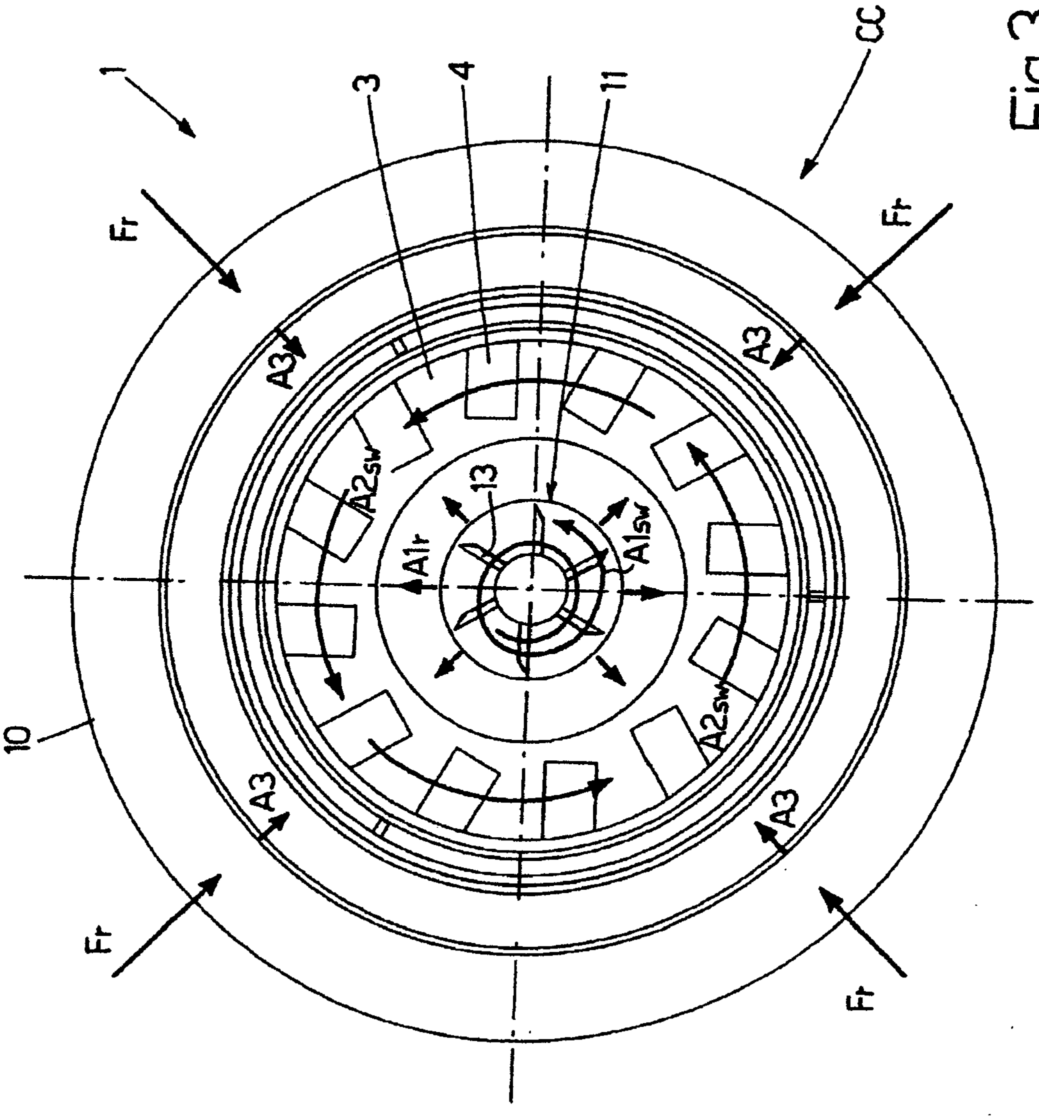


Fig.3

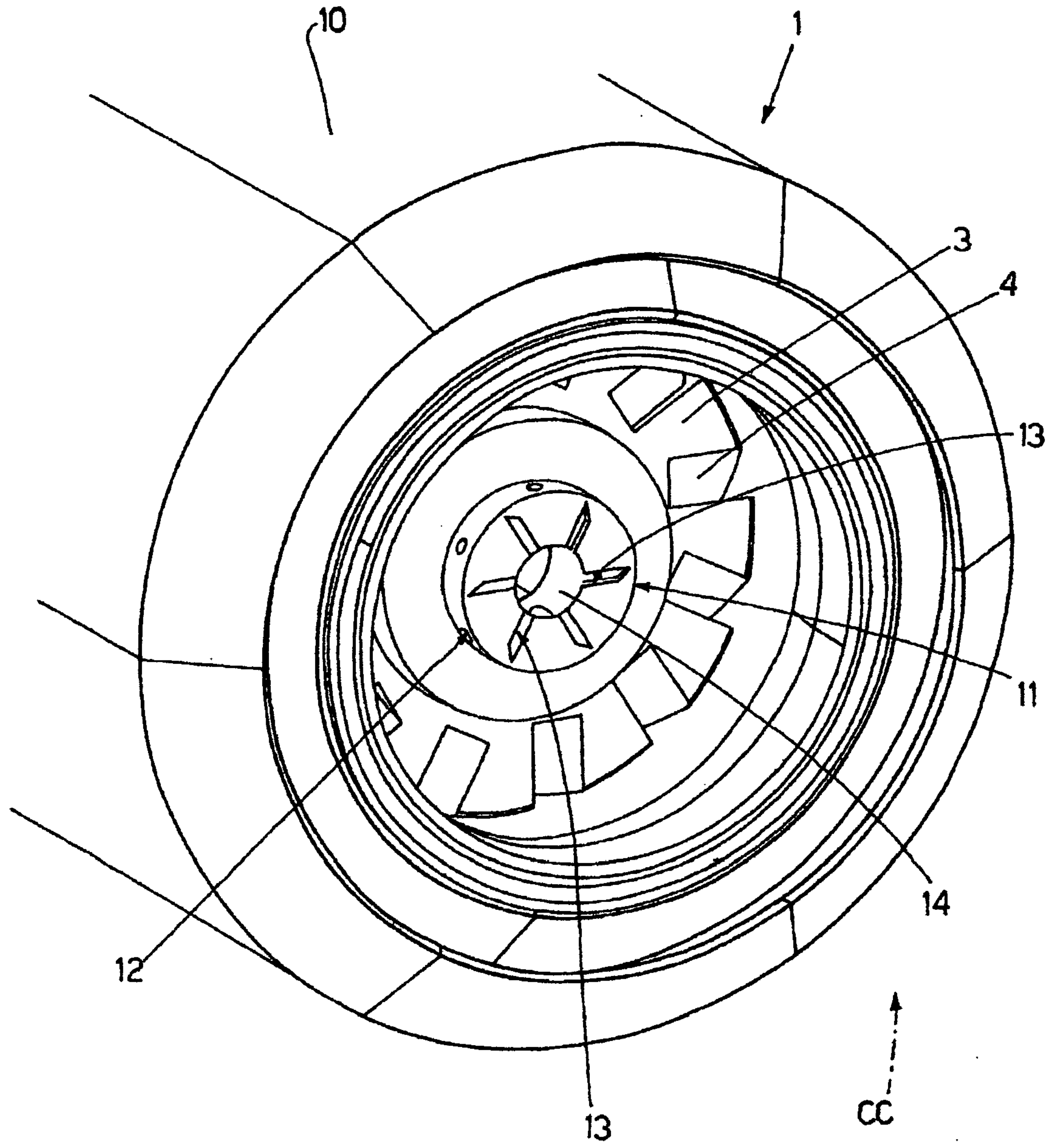
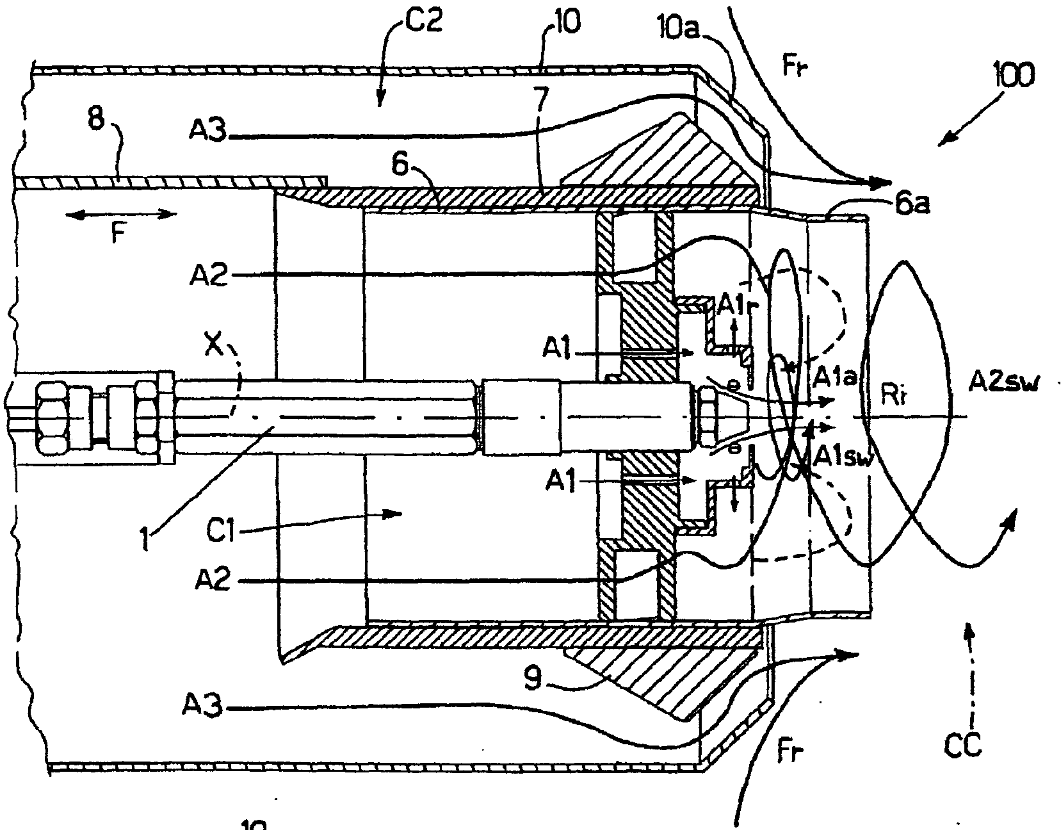


Fig.2


C2
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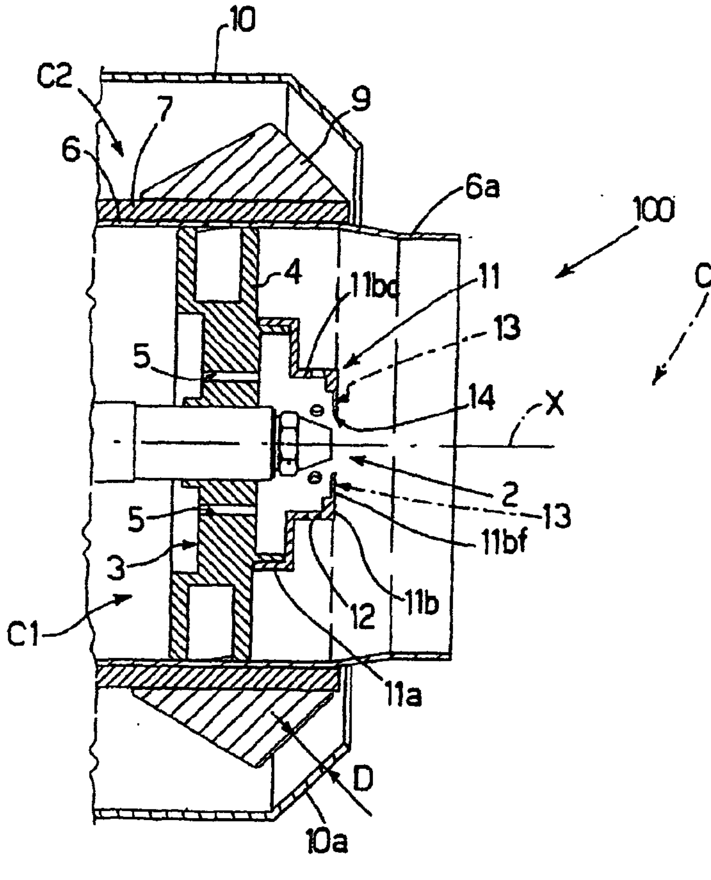
Fr
100
8
A3
7
6
6a
F
A2
A1r
X
A1
A1a
Ri
A2sw
A1sw
A1
1
C1
A2
9
A3
Fr
CC

Fig.1


10
C2
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7
6
6a
100
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13
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11bf
3
12
11b
C1
11a
D
10a

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EUROPEAN SEARCH REPORT

Application Number
EP 05 42 5122

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	24 October 2005	Gavriliu, C

CATEGORY OF CITED DOCUMENTS

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