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(54) **Combustion head for low-nox liquid fuel burner**

(57) A combustion head (1) for a burner provided with a nozzle (2) for atomizing a liquid fuel; the head (1) has a first body (4) adapted to receive a primary comburent flow (F1) and having a frontal wall (6) arranged to produce a swirl in the primary comburent flow (F1); and a second body (13) adapted to receive a secondary comburent flow (F2), to convey it towards a combustion chamber (CC) and to produce a swirl therein; a duct (25) and an intermediate body (20) which define a channel (C1), adapted to feed a tertiary comburent flow (F3) into the combustion chamber (CC) and having a tapered end profile which converges towards the first body (4) and the second body (13); and a frontal surface of the intermediate body (20) substantially lies on the plane defined by the frontal wall (6) of the first body (4).

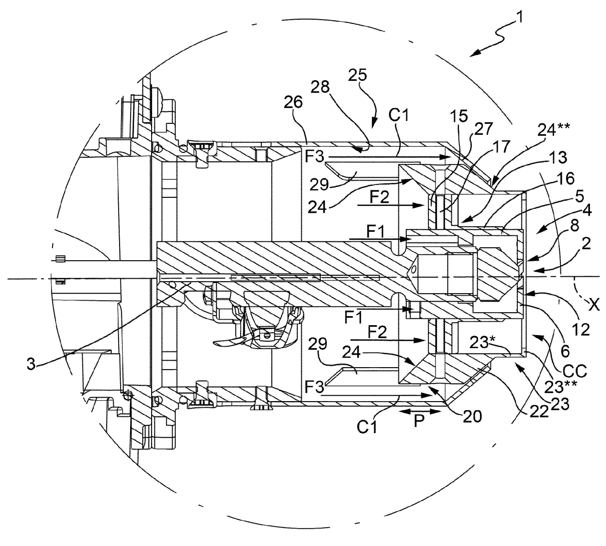

FIG.7

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Description

[0001] The present invention relates to a combustion head for a liquid fuel burner, and particularly suited for low NOx emission.

[0002] In liquid fuel burners, the combustion reaction between the liquid fuel and the comburent is known to occur by means of a combustion head. The comburent is conveyed through the combustion head into a combustion chamber, where it is mixed with the liquid fuel which is atomized by means of a nozzle. Within the combustion chamber, close to and downstream of the combustion head, an ignition device is arranged, adapted to trigger the mixture of liquid fuel and comburent so as to start the combustion process.

[0003] There is an increasing need to reduce the nitrogen oxides NOx which are generated during the combustion process and which cause pollution.

[0004] When designing combustion heads, a first solution considers that the related studies have shown that the nitrogen oxides NOx are especially generated when the flame temperature is high.

[0005] For this reason, burners have been fine-tuned, which are equipped with combustion heads in which the abatement of the flame temperature occurs by recirculating a part of the fumes generated by the combustion into the combustion head and at the flame itself. In order to recirculate the fumes inside the flame, the high outlet speed of the air from the burner head is exploited, which causes a phenomenon notoriously known in technical language as "recirculation". Due to this phenomenon, the fumes in the combustion chamber are recalled into the flame and as they do not participate in the combustion reaction, they absorb heat by cooling the flame itself, thus decreasing the nitrogen oxide NOx emissions.

[0006] Patent application EP-A1-1705424 describes a combustion head for liquid fuel burners, which comprises a central duct fed with a liquid fuel, has a longitudinal symmetry axis and is provided, at one end, with a nozzle for atomizing said liquid fuel into a combustion chamber. The combustion head comprises a first body with cylindrical extension and coaxial to the longitudinal symmetry axis, which is arranged to receive, at the inlet, a primary flow of comburent and has a frontal wall provided with a plurality of peripheral indentations for producing a swirl in said primary flow of comburent. The combustion head comprises a second body with cylindrical extension and coaxial to the longitudinal symmetry axis, which is fitted on the central duct and on which the first body with cylindrical extension is coaxially arranged, is adapted to receive, at the inlet, a secondary flow of comburent and has a plurality of openings which are adapted to produce a swirl in the secondary flow of comburent. The combustion head then comprises means for regulating the swirl produced both in the primary flow and in the secondary flow of comburent, which comprise a duct coaxial to the longitudinal symmetry axis and external to the second body with the interposition of an intermediate body, the latter being also coaxial to the longitudinal symmetry axis. Between the duct and the intermediate body a channel is defined, which is adapted to feed a tertiary flow of comburent into the combustion chamber.

[0007] The combustion process carried out through the combustion head described in EP-A1-1705424 generates the overall effect of curbing the formation of thermal NOx due to reduced flame temperatures. The reduction flame temperatures is obtained by means of a side leak of a portion of the comburent flow. In particular, such a portion of comburent leaks through a plurality of radial holes which are obtained in the first body with cylindrical extension. Thereby, the flame does not exclusively develop from the frontal surface of the nozzle, but it evenly spreads inside the combustion chamber.

[0008] However, it has been noted that zones of primary combustion are established close to the nozzle, which result in the formation of thermal NOx.

[0009] Moreover, the above-described combustion head for liquid fuel burners has no application in small boilers, in particular for household and residential use, as combustion flames with a high axial extension are generated, which are to be developed inside boilers of large volume.

[0010] Instead, document US-A-4798330 describes a combustion head for a burner which is fed with a fuel comprising a plurality of coaxial bodies fitted onto one another. The combustion head is provided so as to keep the frontal surface of the combustion head clean and to keep the combustion flame stable. However, the combustion head provided according to the dictates of US-A-4798330 does not curb the formation of thermal NOx.

[0011] Therefore, the object of the present invention is to provide a combustion head which allows the formation of NOx to be minimized during the combustion process, which may also be applied to small boilers, in particular for household and residential use, while being easy and cost-effective to be provided.

[0012] According to the present invention, a combustion head for a burner for liquid fuels is provided as claimed in claim 1 and, preferably, in any one of the subsequent claims, directly or indirectly depending on claim 1.

[0013] The present invention will now be described with reference to the accompanying drawings, which show a non-limiting embodiment thereof, in which:

- figure 1 shows a front perspective view of a first component of a combustion head provided in accordance with the present invention;
- figure 2 shows a front perspective view of a second component of the combustion head provided in accordance with the present invention, which is fitted onto the first component in figure 1;
- figure 3 shows a front perspective view of a third component of the combustion head provided in accordance with the present invention, arranged outside the second component in figure 2;

- figure 4 shows a front perspective view of a fourth component of the combustion head provided in accordance with the present invention, arranged outside the third component in figure 3;
- figures 5 and 6 show rear and front perspective views, respectively, of a combustion head assembly provided in accordance with the present invention, by assembling the components in figures from 1 to 4; and
- figure 7 is a sectional view of the combustion head assembly in figures 5 and 6.

[0014] In figures 1 to 6, numeral 1 indicates as a whole a combustion head where a liquid fuel, such as gas oil, is fed to a nozzle 2 (of known type) by means of a central duct 3 having a longitudinal symmetry axis X. Nozzle 2 is adapted to atomize the liquid fuel in a combustion chamber CC (of known type as well and not disclosed in detail).

[0015] The combustion head 1 is fitted onto the central duct 3 and comprises a plurality of components assembled with one another, which are coaxial to one another and to the longitudinal symmetry axis X.

[0016] Connected to the central duct 3 is a so-called primary swirl body 4, with cylindrical symmetry and which is hollow inside and coaxial to the longitudinal symmetry axis X. In particular, body 4 comprises an external, cylindrical lateral wall 5 which is coaxial to the longitudinal symmetry axis X, and a frontal wall 6 which is provided with a through hole 7 to allow the central duct 3 and nozzle 2 to be inserted. The frontal wall 6 of body 4 has a plurality of indentations 8 which are evenly spaced about the longitudinal symmetry axis X; each pair of reciprocally adjacent indentations 8 defines a partition 9 in which the frontal wall 6 is divided. In particular, according to the embodiment shown in figure 1, body 4 is divided into six partitions 9 defined by just as many indentations 8 which are evenly spaced about the longitudinal symmetry axis X. Each indentation 8 is defined by a portion 10 of base wall and by a pair of lateral walls 11, which face each other and are inclined by a first angle α with respect to the plane defined by a frontal flat surface 12 of the frontal wall 6.

[0017] According to a preferred variant, angle α is between 42°C and 48°C, and the angle is preferably equal to 45°C. Indentations 8 are in direct communication with the through hole 7.

[0018] Assembled on body 4 is a so-called secondary swirl body 13 (shown in figure 2), with cylindrical symmetry, which is hollow inside and coaxial to the longitudinal symmetry axis X. In particular, body 13 comprises an internal cylindrical surface 14 coaxial to the longitudinal symmetry axis X which defines a through opening within which the body 4 is accommodated. The diameter of the internal cylindrical surface 14 is substantially approximate to an external volume diameter of body 2. Body 13 is divided into a rear cylindrical portion 15 and a front cylindrical portion 16; the rear cylindrical portion 15 has an overall external volume diameter which is greater than the overall external volume diameter of the front cylindrical portion 16. The rear cylindrical portion 15 has a plurality of openings 17. In particular, according to the embodiment shown in figure 2, the rear cylindrical portion 15 has eight openings 17 which are evenly spaced about the longitudinal symmetry axis X.

[0019] Each opening 17 is defined by a base wall 18 and by a pair of lateral walls 19, which face each other and are inclined by an angles $\beta$with respect to the plane defined by a rear flat surface of the rear cylindrical portion 15. According to a preferred variant, angles β is between 42°C and 48°C, and angles β is preferably equal to 45°C. The openings 17 are not in direct communication with the through hole of body 13.

[0020] An intermediate body 20 is fixed in turn on body 13, which has cylindrical symmetry, is hollow inside and coaxial to the longitudinal symmetry axis X. In particular, the intermediate body 20 comprises an internal cylindrical surface 21 coaxial to the longitudinal symmetry axis X which defines a through opening within which body 13 is accommodated. The diameter of the internal cylindrical surface 21 is substantially approximate to an external volume diameter of the rear portion 13 of body 13.

[0021] The intermediate body 20 is also divided into a rear portion 22 and a front portion 23. The rear portion 22 has an external cylindrical surface, which has an overall external volume diameter which is greater than the overall external volume diameter of the front portion 23. Moreover, the rear portion 22 has a rear truncated cone-shaped surface 24 and a frontal truncated cone-shaped surface 24**, which are both coaxial to the longitudinal symmetry axis X. As shown in greater detail in figures 3 and 7, a plurality of calibrated through holes 24* are obtained on the rear portion 22, for the flame probe and the ignition electrodes to pass. Instead, the front portion 23 comprises a lateral cylindrical wall 23* coaxial to axis X and a ring-shaped portion 23** of frontal wall coaxial to axis X.

[0022] It is worth noting that the intermediate body 20 acts as a supporting element for primary swirl body 4, secondary swirl body 13 and central duct 3.

[0023] It is also worth noting that a frontal surface (defined in this case by the annular portion 23** of frontal wall) of the intermediate body 20 substantially lies on the plane defined by the frontal wall 6 of the primary swirl body 4. Nozzle 2 is placed directly facing the combustion chamber CC and, in use, the liquid fuel is directly atomized into the combustion chamber CC.

[0024] Duct 25 is fixed in turn to the intermediate body 20, which has a substantially cylindrical symmetry, is hollow inside and coaxial to the longitudinal symmetry axis X.

[0025] Duct 25 is divided into a rear cylindrical portion 26 and a front portion 27. The rear cylindrical portion 26 has an external cylindrical surface and an internal cylindrical surface 28, which are both coaxial to the longitudinal symmetry axis X. Instead, the front portion 27 has a truncated cone extension which is coaxial to the longitudinal symmetry axis X and is tapered towards the free end facing the combustion chamber CC. Furthermore, a plurality of indentations 27* are obtained on the front portion 27 for the flame probe and the ignition electrodes to pass.

[0026] Duct 25 then comprises a plurality of projections 29 which are connected to the internal cylindrical surface 28 of the rear portion 26 in a position close to the front portion 27 and extend inwards from duct 25. The projections 29 are evenly spaced about the longitudinal symmetry axis X, extend in the longitudinal direction over a section of the rear portion 26. According to a preferred variant, duct 25 comprises six projections 29 spaced 60°C apart from one another. Duct 27 is adapted to translate in one of the two longitudinal directions indicated by arrow P. In order to allow the translation of duct 25, a control (manually actuated or by means of an actuator of known type) is provided; the projections 29 rest with contact and, in use, slide on the external surface of the intermediate body 20 to allow the movement of duct 25.

[0027] It is worth noting that such a compact geometry of combustion head 1 allows the size of the combustion flame to be contained, as better described below.

[0028] In use, a blower (of known type and not shown) provides a flow F of comburent, such as air, which is conveyed into duct 25 which indeed encloses the whole combustion head 1, and from here it is then divided into a number of comburent flows.

[0029] In particular, as shown in detail in figure 7, the comburent flow at the inlet of combustion head 1 is divided into three partial flows indicated as primary comburent flow F1, secondary comburent flow F2 and tertiary comburent flow F3, respectively, due to the particular geometry of the combustion head 1 itself.

[0030] The primary comburent flow F1 flows into the primary swirl body 4 in the longitudinal direction. When the primary comburent flow F1 meets indentations 8, the flow lines F1 take n a helical and no longer longitudinal flow, and the speed at which flow F1 exits the primary swirl body 4 has a high tangential motion (swirl) component. The indentations 8 are hence arranged to produce a swirl in the primary comburent flow F1. The primary comburent flow F1 is then further exclusively divided into a primary swirled comburent flow which exits the indentations 8, and an axial primary comburent flow which exits the section left free from the nozzle into the through hole 7.

[0031] The secondary comburent flow F2 flows into the secondary swirl body 13 in the longitudinal direction. The flow rate of the secondary comburent flow F2 is determined by the number and section of the openings 17 made in the rear cylindrical portion 15, and is usually greater than the primary comburent flow F1. Also in this case, due to the passage of the secondary comburent flow F2 through the openings 17, the flow lines F2 take on a helical and no longer longitudinal flow, and the speed at which flow F2 exits the secondary swirl body 13 has a high tangential motion (swirl) component. The openings 17 are hence arranged to produce a swirl in the secondary comburent flow F2.

[0032] The truncated cone-shaped profile of the rear surface 24 of the intermediate body 20 allows both the average speed of flow F1 at the inlet of the primary swirl body 4 and the average speed of flow F2 at the inlet of the secondary swirl body 13 to be increased. The increase the aforesaid average speeds results in an increase of the tangential motion (swirl) components of both the speed at which flow F2 exits the secondary swirl body 13 and the speed at which flow F1 exits the primary swirl body 4.

[0033] On the other hand, the tertiary comburent flow F3 is transported through a channel C1 defined between duct 25 and intermediate body 20. It is apparent that the final flow rate of the tertiary comburent flow F3 is determined by the distance between the front, truncated cone-shaped portion 27 of duct 25 and the intermediate body 20, which can vary due to the translation motion of duct 25.

[0034] The tertiary comburent flow F3 flows in channel C1 along a direction parallel to the longitudinal axis X.

[0035] At an end section thereof, close to the combustion chamber CC, channel C1 has a tapered profile which converges towards the primary swirl body 4 and towards the secondary swirl body 13. In particular, the end section has a truncated cone-shaped profile defined by the front portion 27 of duct 25, being the same as that of the rear portion 22 of intermediate body 20.

[0036] The profile of channel C1 is obtained so as to accelerate the tertiary comburent flow F3 before being fed into the combustion chamber and so as to direct the tertiary comburent flow F3 directly towards the primary comburent flow F1 and towards the secondary comburent flow F2 to limit the spatial area downstream of the combustion head 1, there the combustion flame develops.

[0037] Duct 25 is movable between a maximal closure position, corresponding to a tertiary comburent flow F3 with minimum flow rate, preferably equal to zero, and a minimum closure position corresponding to a tertiary comburent flow F3 with maximum flow rate.

[0038] In the minimum closure position, the axial component of the tertiary comburent flow F3 directly directed towards the primary comburent flow F1 and towards the secondary comburent flow F2 opposes the swirl generated by primary swirl body 4 and secondary swirl body 13; moreover, in this case, the profile of the intermediate body 20 on which the tertiary comburent flow F3 runs adherent due to the "Coanda effect" allows the combustion flame to have a prevalently axial flow.

[0039] In the maximal closure position, the tertiary comburent flow F3 does not influence the swirl generated by primary swirl body 4 and secondary swirl body 13; in this case, the combustion flame has a significantly small axial development.

[0040] The combustion process sequentially includes the following steps:

- atomizing the liquid fuel through nozzle 2;
- mixing the atomized liquid fuel with the primary comburent flow F1; the atomized liquid fuel has a high kinetic energy and only a small portion is involved in the primary comburent flow F1;
- mixing the secondary comburent flow F2 with the remaining portion of liquid fuel not mixed with the primary comburent flow F1;
- spatially confining the combustion flame between the tertiary comburent flow F3 adapted to control the swirl effect.

[0041] It is known from literature that the intensity of the swirl obtainable with a combustion head 1 has relevant effects on the polluting emissions of a combustion process. Moreover, it has been verified that the intensity of the swirl is quantifiable through the number of swirls and a combustion process with low levels of NOx emissions can be obtained for a swirl number greater than 1.

[0042] In essence, the combustion head 1 described hereto comprises four bodies indicated with numerals 4, 13, 20 and 25, respectively, which are assembled together and may be fitted onto any duct 3 with axial symmetry.

[0043] It is also worth noting that duct 25 and intermediate body 20 which determine the tertiary comburent flow F3 also influence the primary comburent flow F1 and the secondary comburent flow F2 due to the dynamic characteristics (i.e. due to flow rate and speed range) of the tertiary comburent flow F3.

[0044] In greater detail:

- the primary comburent flow F1 is generated due to the primary swirl body 4. By reasoning, without the secondary F2 and tertiary F3 comburent flows, the radial and tangential components of the primary comburent flow F1 would excessively open the cone of the comburent speed range. Accordingly, the combustion flame would have an excessive opening and a weak intensity, such as not to ensure the complete combustion of the harmful residues generated in the first combustion step and conveyed into the zone involved by the combustion flame due to the recirculating mechanism by primary swirl body 4 and secondary swirl body 13.
- The secondary comburent flow F2 is generated by the secondary swirl body 13. As seen above, the secondary comburent flow F2 is adapted to determine a geometrical confinement of the primary comburent flow F1 in order to improve the efficiency of the combustion flame.
- The tertiary comburent flow F3 is developed in the geometrical domain delimited by duct 25 and intermediate body 20. The tertiary comburent flow F3 only has one axial component (since no element for deviating the tertiary flow F3 in the tangential direction is provided). The object of the tertiary flow F3 is to confine the secondary comburent flow F2 (and therefore the primary comburent flow F1) in a controllable manner by means of an axial translation of duct 25. By means of the movement generated in duct 25, the tertiary comburent flow F3 may increase in flow rate thus determining an extension of the flame in the axial direction and a decrease of the radial extension, and vice versa.

[0045] Thereby, the formation of thermal NOx can be curbed by means controlling the axial and tangential components of the comburent flows F1, F2 and F3.

[0046] It has been experimentally verified that the number of swirls obtainable by means of the combustion head 1 described hereto (with a primary swirl 4 and a secondary swirl 13) is substantially high, in the order of 5.45, and such as to ensure a low level of NOx emissions.

[0047] Moreover, the opportunity to control the intended swirl level allows a yellow-blue colouring of the flame to be kept, which is easily detected by an optical sensor with a light dependent resistor and which is more reliable and less costly than those with ultraviolet radiation usually used in applications of this kind.

Claims

1. A combustion head (1) for a burner, which comprises a central duct (3) fed with a liquid fuel, has a longitudinal symmetry axis (X), and is provided, at one end, with a nozzle (2) for the atomization of said liquid fuel into a combustion chamber (CC); the combustion head (1) comprises:

a first body (4) with cylindrical extension and coaxial to the longitudinal symmetry axis (X); the first body (4) is arranged to be fitted on the central duct (3), is suited to receive at the inlet a primary flow (F1) of comburent and to convey it towards the nozzle (2), and has a frontal wall (6) provided with a plurality of peripheral indentations (8) which are suited to produce a swirl in said primary flow (F1) of comburent; and

a second body (13) with cylindrical extension and coaxial to the longitudinal symmetry axis (X); the second body (13) is fitted on the first body (4), is suited to receive at the inlet a secondary flow (F2) of comburent and to convey it towards the combustion chamber (CC), and has a plurality of openings (17) which are suited to produce a swirl in said secondary flow (F2) of comburent;

means (20, 25) for the regulation of the swirl produced in said primary flow (F1) of comburent and in said secondary flow (F2) of comburent; the regulation means (20, 25) comprise a duct (25) coaxial to the longitudinal symmetry axis (X) and external to the second body (13) with

the interposition of an intermediate body (20), which is also coaxial to the longitudinal symmetry axis (X); a channel (C1) is defined between the duct (25) and the intermediate body (20), which is suited to feed a tertiary flow (F3) of comburent into the combustion chamber (CC);
the combustion head (1) is **characterized in that** a frontal surface of the intermediate body (20) substantially lies on the plane defined by the frontal wall (6) of the first body (4), so that the nozzle (2) is in a position directly facing the combustion chamber (CC); and, at an end section thereof close to the combustion chamber (CC), the channel (C1) has a tapered profile which converges towards the first body (4) and the second body (13).

2. A combustion head according to claim 1, wherein the end section of the channel (C1) is defined by a front portion (27) of the duct (25), which is shaped as a truncated cone, is coaxial to the longitudinal symmetry axis (X), and faces a truncated cone-shaped surface (24**) of the intermediate element (20), which is also coaxial to the longitudinal symmetry axis (X).

3. A combustion head according to claim 1 or 2, wherein the duct (25) is movable with respect to the intermediate body (20) between a position of maximal closure, corresponding to a tertiary flow (F3) of comburent with minimum flow rate, preferably equal to zero, and a position of minimum closure, corresponding to a tertiary flow (F3) of comburent with maximum flow rate, and vice versa.

4. A combustion head according to claim 3, wherein the duct (25) comprises a number of internal projections (29), which are distributed about the longitudinal symmetry axis (X); the projections (29) rest with contact and, when in use, slide on an external surface of the intermediate body (20), so as to allow a translation motion of the duct (25) with respect to the intermediate body (20) between the position of maximal closure and the position of minimum closure, and vice versa.

5. A combustion head according to one of the preceding claims, wherein the intermediate body (20) has a rear surface (24) which is shaped as a truncated cone, is coaxial to the longitudinal symmetry axis (X), and is tapered towards the first body (4); the rear surface (24) being suited to increase the average axial speed of the primary flow (F1) of comburent and of the secondary flow (F2) of comburent at the inlet of the first body (4) and of the second boy (13), respectively.

6. A combustion head according to one of the preceding claims, wherein the frontal wall (6) is provided with a through hole (7) coaxial to the longitudinal symmetry axis (X).

7. A combustion head according to claim 6, wherein no radial through holes are provided on a cylindrical lateral wall of said first body (4); the primary flow (F1) of comburent at the outlet of the first body (4) is only divided into a primary swirled comburent flow and a primary axial comburent flow.

8. A combustion head according to one of the preceding claims, wherein each indentation (8) has a pair of lateral walls (11), which face each other and are inclined by a first angle (α) with respect to the plane defined by a front flat surface (12) of the frontal wall (6).

9. A combustion head according to claim 8, wherein the first angle (α) is between 42° and 48°, and is preferably equal to 45°.

10. A combustion head according to one of the preceding claims, wherein each opening (17) is defined by a pair of lateral walls (19), which face each other and are inclined by a second angle (β) with respect to the plane defined by a rear flat surface of the second body (13).

11. A combustion head according to claim 8, wherein the second angle (β) is between 42° and 48°, and is preferably equal to 45°.

12. A combustion head according to claim 10 or 11, wherein the second body (13) comprises a front portion (16) and a rear portion (15); the two portions (15, 16) are both cylindrical and coaxial to the longitudinal symmetry axis (X), but have different diameters; the openings (17) being obtained in the rear portion (15).

13. A liquid fuel burner provided with a combustion head (1) provided according to one or more of the claims from 1 to 12.

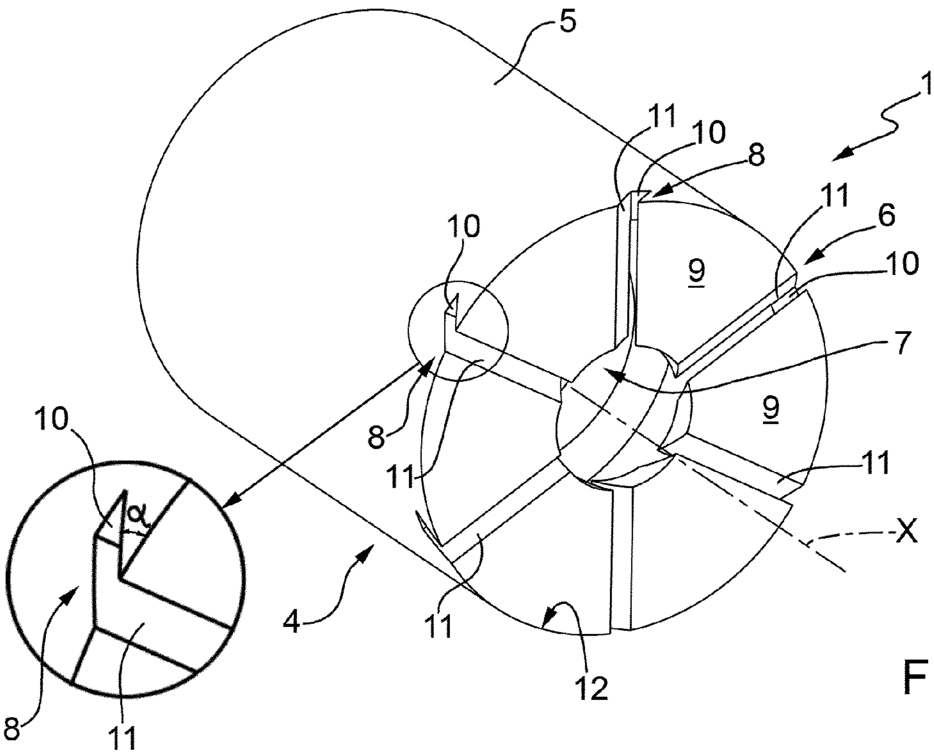
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FIG.1

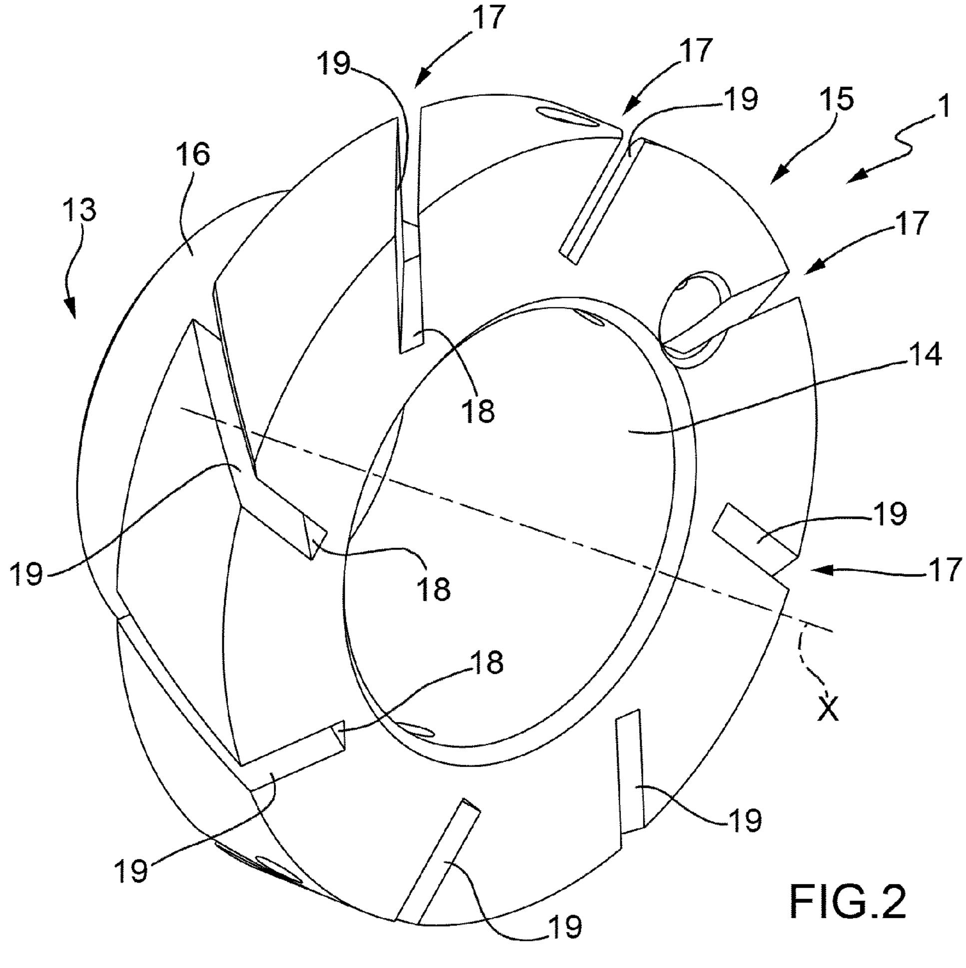
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FIG.2

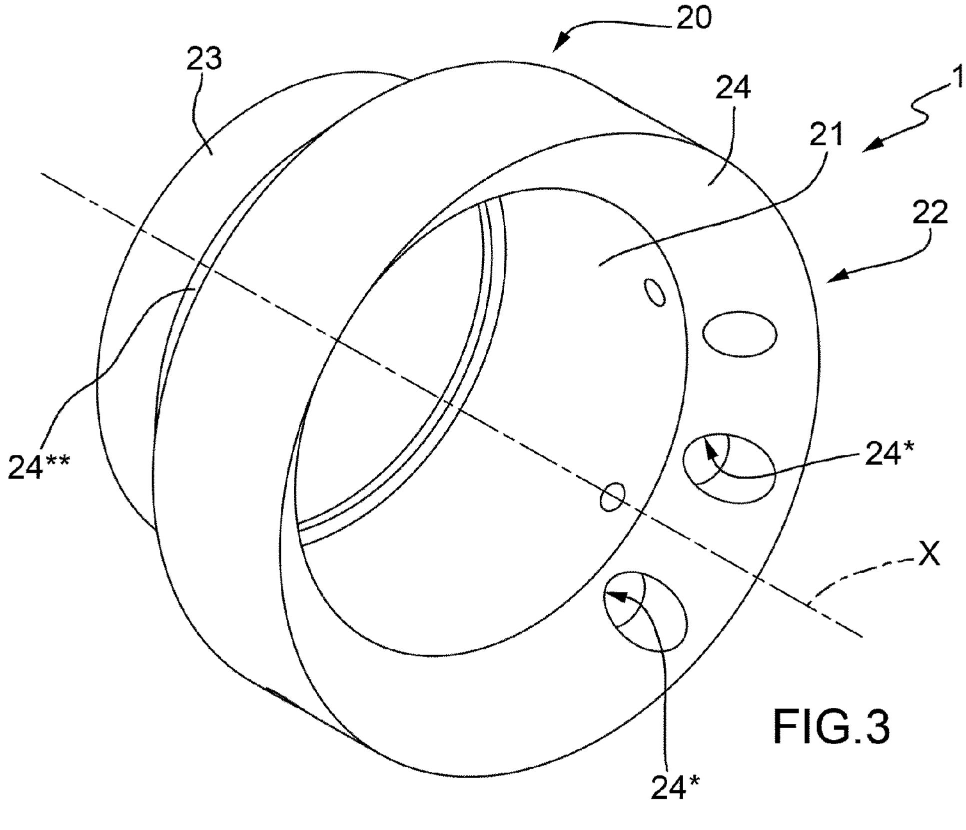

FIG.3

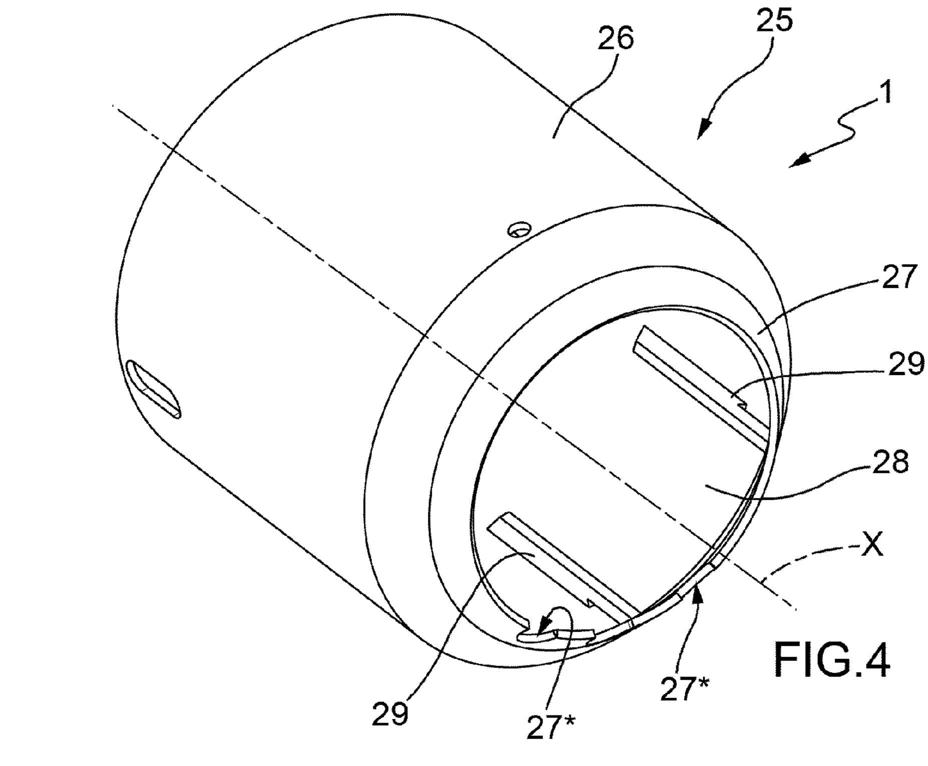

FIG.4

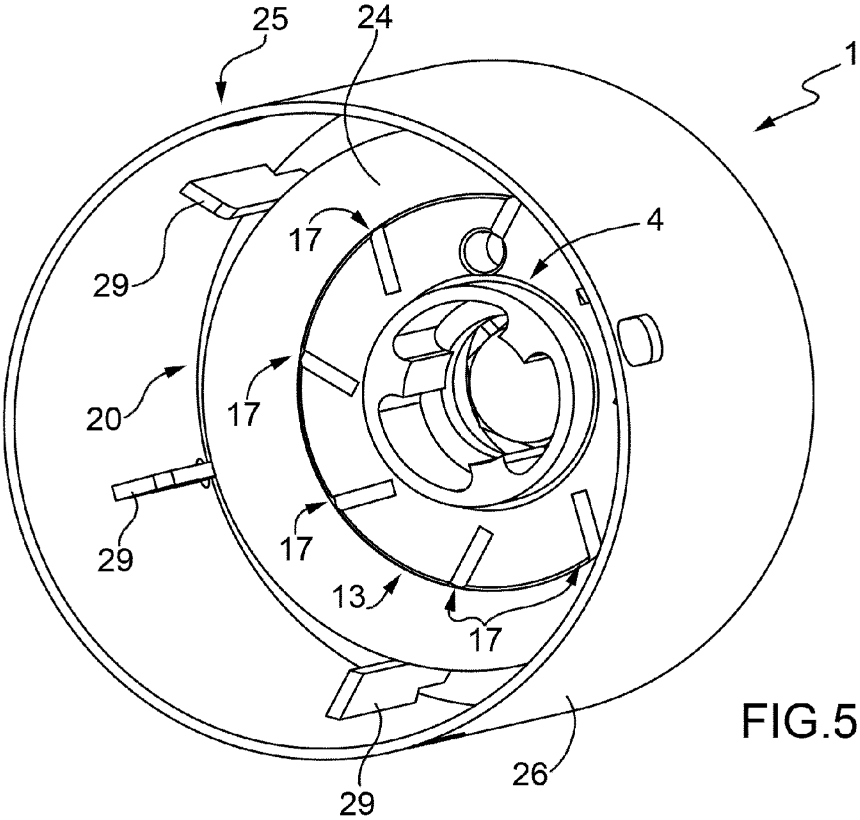
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FIG.5

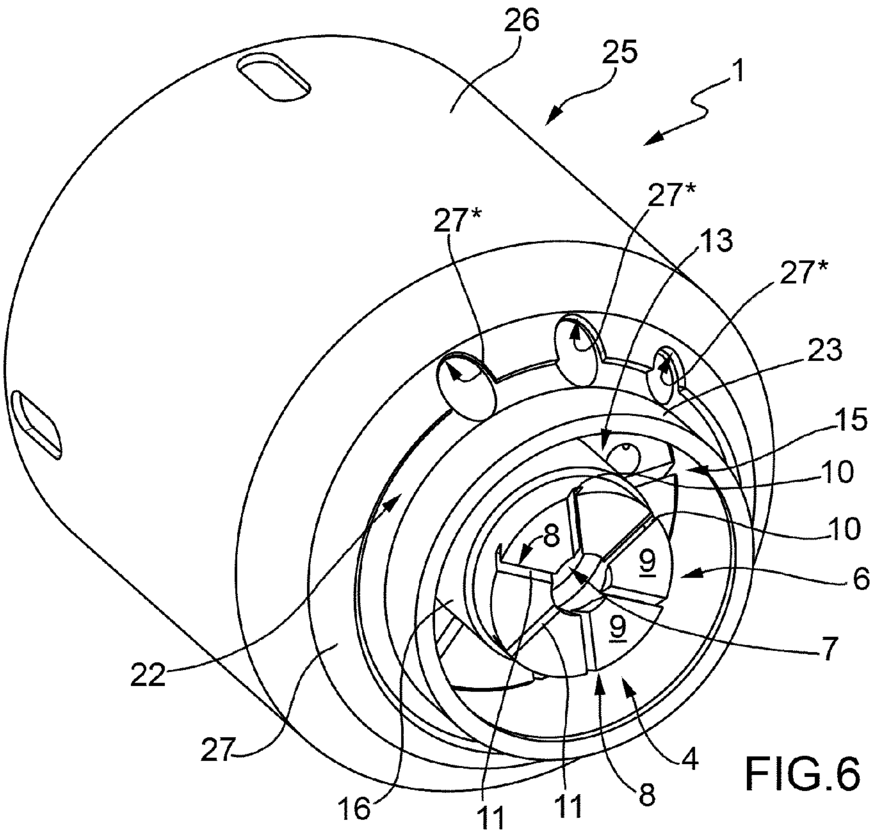
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FIG.6

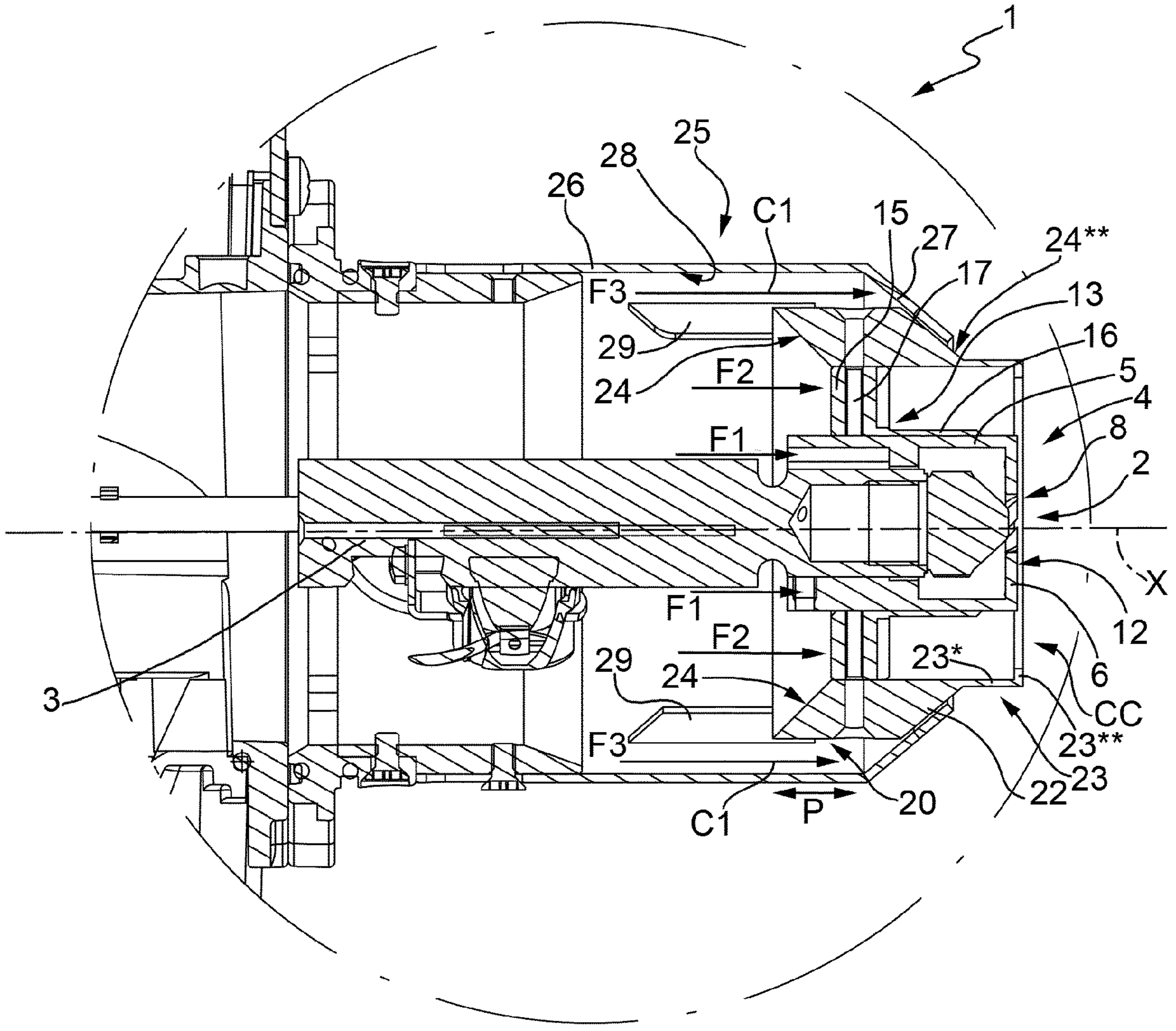
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FIG.7

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EUROPEAN SEARCH REPORT

Application Number
EP 11 19 2257

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y,D	EP 1 705 424 A1 (RIELLO SPA [IT]) 27 September 2006 (2006-09-27) * column 1, paragraph 5 - paragraph 7 * * column 2, paragraph 14 - paragraph 15 * * column 2, paragraph 19 - column 4, paragraph 42 * * figures 1-7 * -----	1-13	INV. F23C7/00 F23D11/24 F23D11/40
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