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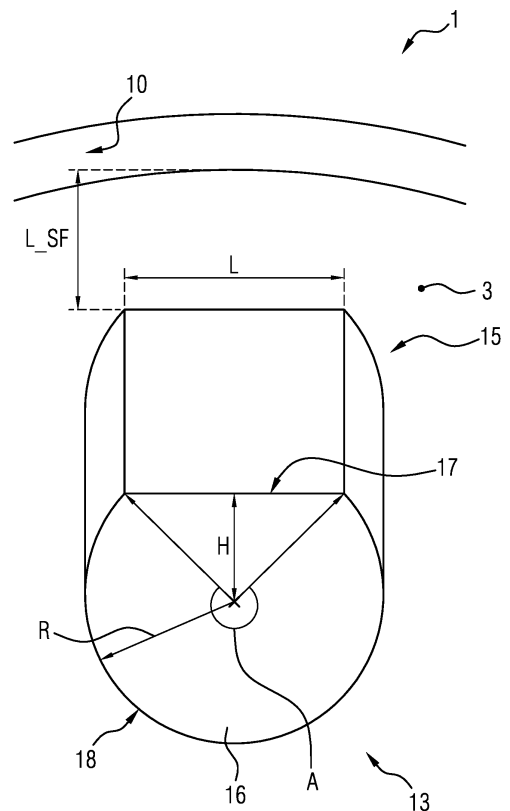
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(54) **NOZZLE BODY FOR A FLUID INJECTOR AND FLUID INJECTOR**

(57) A nozzle body (1) for a fluid injector (13) comprises a nozzle wall (3) which limits a penetrating opening (5) of the nozzle body (1) along a longitudinal axis (LA) from a fluid inlet end (21) to a fluid outlet end (22). The nozzle body (1) further comprises a sac volume portion (9) of the nozzle wall (3) formed in the region of the fluid outlet end (22) such as to limit a sac volume (11). Further, a needle seat (7) is formed as a portion of the nozzle wall 3 between the fluid inlet end (21) and the sac volume portion (9) of the nozzle body (1) to interact with a needle (32) to prevent a fluid flow through a flow hole (13) in a closed position and otherwise to enable it. The flow hole (13) comprises a hole axis (HA) and penetrates the nozzle wall (3) in the region of the fluid outlet end (22) from the opening (5) to outside of the nozzle body (1). The flow hole (13) comprises a shape of a circular segment with respect to a cross-section perpendicular to the hole axis (HA).

FIG 3



Description

[0001] The invention relates to a nozzle body for a fluid injector and a fluid injector.

[0002] Injectors are in widespread use, in particular for internal combustion engines where they may be arranged in order to dose a fluid into an intake manifold of the internal combustion engine or directly into a combustion chamber of a cylinder of the internal combustion engine.

[0003] In order to enable a beneficial combustion process, it is necessary to provide good spray quality and fluid penetration of a fluid into the combustion chamber, amongst others. In this context generating a low particulate number of pollutant emissions is an ongoing task. To achieve this there is a possibility to influence on the flow and spray behaviour of fluid escaping the fluid injector.

[0004] One object of the invention is to create a nozzle body for a fluid injector and a corresponding fluid injector which facilitate a reliable dosing of fluid with enhanced spray quality and characteristics.

[0005] The object is achieved by the features of the independent claims. Advantageous embodiments of the invention are given in the sub claims.

[0006] According to a first aspect of the invention a nozzle body for a fluid injector comprises a nozzle wall which limits a penetrating opening of the nozzle body along a longitudinal axis from a fluid inlet end to a fluid outlet end of the nozzle body. The nozzle body further comprises a sac volume portion of the nozzle wall formed in the region of the fluid outlet end such as to limit a sac volume. The nozzle body further comprises a needle seat formed as a portion of the nozzle wall between the fluid inlet end and the sac volume portion of the nozzle body to interact with a needle to prevent a fluid flow through a flow hole in a closed position and otherwise to enable it. The flow hole comprises a hole axis and penetrates the nozzle wall in the region of the fluid outlet end from the opening to outside of the nozzle body wherein the flow hole comprises a shape of a circular segment with respect to a cross-section perpendicular to the hole axis.

[0007] Such a configuration of a nozzle body for a fluid injector enables beneficial streaming conditions for a streaming fluid and contributes to enhanced spray quality of the fluid and a profitable combustion process. Due to the particular shape of the one or more flow holes the spray characteristics of the respective flow hole can be influenced specifically including spray penetration and atomization of the fluid escaping out of the nozzle body.

[0008] Spray penetration and its atomization are important parameters of a nozzle body and a corresponding fluid injector that affect the particulate number and the combustion process of a combustion engine particularly. By modifying the geometry of the nozzle body, for example geometrical data of the flow holes (e.g. their length to diameter ratio, spray or plume angle, their positioning through the wall of the nozzle body), it is possible to con-

trol the internal flow behaviour and influence spray characteristics to a certain extent.

[0009] But it is a knowledge of the invention that these parameters are subject to design and application requirements and just allow for slight control of the spray characteristics. For example, the length of the respective flow hole is driven by the blank design which is predetermined. A hole diameter of a flow hole is given by a target static mass flow rate which represents the amount of fluid per period of time and depends on customer and application requirements. Furthermore, a B-spray or plume angle of a corresponding flow hole depends on spray requirements requested by a customer. Hence, only few hole-drilling parameters of the respective flow holes are available for spray optimization and it is strictly limited to obtain best spray quality for each application.

[0010] Therefore, the described nozzle body with one or more specifically shaped flow holes presents a possibility to significantly influence the spray characteristics of the respective flow hole and the nozzle body as well as a corresponding fluid injector. In detail, by adapting the shape of the flow hole to a circular segment it is possible to control the intensity and extension of a cavitation zone occurring inside the flow hole. Such a cavitation zone is an area of phase change inside the respective flow hole wherein liquid fluid turns to vapour and cavitation bubbles occurs. Inside the flow hole acceleration of the fluid flow occurs as well as reduction of pressure. This leads to a cavitation zone which is typically located closer to the inlet of the respective flow hole than to the outlet. The cavitation zone is strictly linked to spray breakup primary and as a consequence to spray plume penetration secondary.

[0011] The particular shape of the one or more flow holes has influence on the cavitation zone and beneficially affects streaming conditions and spray behaviour of the fluid. The nozzle body enables in a simple manner to improve spray characteristics such as enhanced controllability of the fluid spray and advantageously affects the atomization of the fluid spray out of the nozzle body. Therefore, the nozzle body contributes to desirable spray penetration into a combustion chamber with respect to given application requirements, for instances.

[0012] According to one embodiment of the nozzle body, the shape of the circular segment of the flow hole comprises a linear portion with predetermined length and a circular portion with predetermined radius with respect to the hole axis.

[0013] According to a further embodiment of the nozzle body, the flow hole comprises a predetermined height which represents a given distance of the hole axis to the linear portion.

[0014] By creating a circular segment shape of the flow hole it is possible to influence on flow separation and, as a consequence, to drive the intensity and extension of the cavitation inside the flow holes. With respect to a cross section area perpendicular to the hole axis the shape of the flow hole is comparable to the shape of the

letter "D". Hence, the flow hole as a whole is formed with a cut cylindrical shape which beneficially influences streaming conditions and spray behaviour of the fluid.

[0015] Such a configuration of the nozzle body and the flow holes contributes to increase turbulence intensity at an outlet of the respective flow hole and causes shifting of the cavitation zone. The cavitation zone is moved closer to the flow hole's outlet, for example, such that collapsing cavitation bubbles are enhancing the spray breakup of the fluid. Therefore, using an embodiment of the described nozzle body it is possible to completely change the flow behaviour of the fluid while keeping the seat blank, the B- or plume angle and/or the static mass flow rate of the streaming fluid substantially unmodified.

[0016] According to a further embodiment of the nozzle body geometrical data of the flow hole are predetermined by a D-factor which represents the ratio of the predetermined height of the flow hole and the predetermined radius of the circular portion.

[0017] Such a D-factor simply sums up the geometrical data of the respective flow hole and represents the geometrical size of the linear and circular portion. The dimension of the D-factor has to be big enough to generate a desired extension of the cavitation area and is advantageously optimized based on spray targeting and specific application requirements.

[0018] According to a further embodiment of the nozzle body the sac volume portion comprises a sac volume step and the flow hole comprises a hole inlet which is formed at a predetermined distance from the sac volume step with respect to the longitudinal axis.

[0019] This embodiment of the nozzle body indicates a further important parameter to significantly affect the streaming condition for the streaming fluid. The sac volume step is extending perpendicular to the longitudinal axis of the nozzle body, for example, and comprises the predetermined distance to the respective flow hole inlet. Therefore, this distance defines the positioning of the flow holes inside the nozzle wall and is usually given.

[0020] According to a second aspect of the invention a fluid injector comprises a nozzle body in accordance with one of the embodiments described above and a needle which is arranged axially movable in the opening of the nozzle body with respect to the longitudinal axis to prevent a fluid flow through the flow hole in a closed position and otherwise to enable it.

[0021] Such a fluid injector enables enhanced performance especially concerning improved streaming conditions of a streaming fluid with beneficial spray stability and controllability as well as penetration characteristics into a combustion chamber, for instance. Because the fluid injector comprises one embodiment of the nozzle body all characteristics and features corresponding to the nozzle body as described above also relate to the fluid injector and vice versa.

[0022] Exemplary embodiments of the invention are explained in the following with the aid of schematic drawings and reference numbers. Identical reference num-

bers designate elements or components with identical functions. The Figures show:

Figure 1	an exemplary embodiment of a fluid injector;
Figure 2	an exemplary embodiment of a nozzle body for a fluid injector;
Figure 3	exemplary geometrical data of a flow hole of the nozzle body;
Figures 4A - 4C	exemplary embodiments of a flow hole for a nozzle body;
Figures 5A - 5C	exemplary shear stress conditions inside different flow holes; and
Figures 6A - 6C	exemplary streaming conditions of a fluid inside different flow holes.

[0023] Figure 1 illustrates a cross-section of an exemplary embodiment of a fluid injector 30 which comprises a nozzle body 1 and a needle 32. The needle 32 is arranged axially movable inside an opening 5 of the nozzle body 1 with respect to a longitudinal axis LA to prevent a fluid flow through a flow hole 13 in a closed position and otherwise to enable it.

[0024] The nozzle body 1 comprises a nozzle wall 3 (in figure 1 just illustrated as a line) which limits the penetrating opening 5 of the nozzle body 1. The nozzle wall 3 comprises a needle seat 7 and a sac volume portion 9 adjacent to the needle seat 7 with respect to the longitudinal axis LA. The needle seat 7 and the sac volume portion 9 are formed at a fluid outlet end 22 of the nozzle body 1 whereas a fluid inlet end 21 is located at an opposite side of the nozzle body 1 with respect to the longitudinal axis LA. The nozzle body 1 is configured rotationally symmetric with respect to the longitudinal axis LA, for example.

[0025] The flow hole 13 penetrates the nozzle wall 3 in the region of the fluid outlet end 22 from the opening 5 to outside of the nozzle body 1 for dosing fluid into a combustion chamber, for example. The nozzle body 1 may comprise one or more flow holes 13 for dosing a given amount of fluid. On basis of the following figures it is apparent that the flow hole 13 comprises a particular shape which enables advantageous streaming conditions of a streaming fluid with beneficial spray stability and controllability as well as penetration characteristics into a combustion chamber, for example.

[0026] Figure 2 shows an enlarged view of the sac volume portion 9 of the nozzle body 1 at the fluid outlet end 22 which realizes a nozzle tip of the nozzle body 1. From this figure 2 it is apparent that the sac volume portion 9 is directly adjacent to the needle seat 7 and formed as one part of the nozzle wall 3 such that it limits a sac volume 11. The sac volume portion 9 comprises a sac

volume step 10 which is configured substantially parallel to the longitudinal axis LA.

[0027] The flow hole 13 is arranged between the nozzle tip of the nozzle body 1 and the needle seat 7 with a predetermined distance L_{SF} from the sac volume step 10 with respect to a direction perpendicular to the longitudinal axis LA. The flow hole 13 comprises a hole inlet 15 and a hole outlet 16 in terms of a streaming direction of a streaming fluid. The flow hole 13 further comprises a hole axis HA. The hole axis HA comprises a predetermined tilt with respect to the longitudinal axis LA and therefore defines spray or plume angle of the fluid which exits the flow hole 13 through the hole outlet 16 during an operation of the nozzle body 1. Further parameters to influence spray characteristics are a length of the flow hole 13 and its shape as mentioned above.

[0028] Figure 3 illustrates exemplary geometrical data of the flow hole 13 in a perspective view from outside of the nozzle body 1. Hence, the illustrated Figure 3 represents the inner contour of the nozzle wall 3 which is in contact with the streaming fluid during an operation of the nozzle body 1 and the corresponding fluid injector 30 and corresponds to a side view substantially perpendicular to the one illustrated in Figure 2. From this illustration it is apparent that the flow hole 13 comprises a specific shape of a circular segment comprising a linear portion 17 and a circular portion 18 with respect to a cross section perpendicular to the hole axis HA. The linear portion 17 comprises a predetermined length L and the circular portion 18 is defined by a given radius R.

[0029] The cross section shape of the flow hole 13 may be compared with the shape of the letter "D". Hence, the flow hole 13 as a whole is formed with a cut cylindrical shape which strongly influences streaming conditions and spray behaviour of the fluid. Furthermore, the linear portion 17 faces the sac volume step 10 whereas the circular portion 18 faces the nozzle tip. Hence, the linear portion 17 of the flow hole 13 and the sac volume step 10 define the predetermined distance L_{SF} . The flow hole 13 further comprises a given height H which represents a distance between the linear portion 17 and the hole axis HA.

[0030] The circular segment shape of the flow hole 13 is further characterized by an angle A which beneficially comprises a value between 180° included and 360° excluded. If angle A would have a value of 360° the length L of the linear portion 17 would be equal to zero and the corresponding flow hole would comprise an entire cylindrical shape without a linear portion 17 as described above. In such a case, the height H of the flow hole would be equal to the radius R of the circular portion 18. Such a configuration would represent a typical flow hole of a corresponding nozzle body with no particular shape.

[0031] If the angle A has a value of 180° the corresponding flow hole 13 comprises a shape of a half cylinder. In such a case the height H is equal to zero and the length L of the linear portion 17 is two times the radius R of the circular portion 18 and hence representing a

diameter of the circular segment shaped flow hole 13.

[0032] The geometrical data of the respective flow hole 13 can also be represented by a D-factor which gives the ratio of the predetermined height H of the flow hole 13 and the predetermined radius R of the circular portion 18. Thus, the D-factor characterizes the geometrical size of the linear and circular portion 17 and 18 of the respective flow hole 13. Regarding the examples discussed above the D-factor would be equal to 1 if the angle A would have a value of 360° and the D-factor is zero if the angle A has a value of 180° .

[0033] Such a configuration of the nozzle body 1 and the fluid injector 30 with at least one particularly shaped flow hole 13 enables beneficial streaming and spray characteristics of the fluid such that spray penetration and its atomization can advantageously be affected. This further contributes to a low particulate number of pollutant emissions and a profitable combustion process of a combustion engine in particular.

[0034] If other parameters of the nozzle body 1 and/or the flow holes 13 (e.g. length, position, tilt) are subject to design and application requirements and just allow for limited control of the spray characteristics the described specific shape of the respective flow hole 13 can be applied alternatively or additionally to significantly influence streaming and spray behaviour of the fluid.

[0035] Therefore, the one or more particularly shaped flow holes 13 enables to control the intensity and extension of a cavitation zone occurring inside the respective flow hole 13. Such a cavitation zone is an area of phase change inside the respective flow hole 13 wherein liquid fluid turns to vapour and cavitation bubbles occurs. Inside the flow hole 13 acceleration of the fluid flow occurs as well as reduction of fluid pressure. This leads to a cavitation zone which is typically located closer to the hole inlet 15 of the respective flow hole 13 than to the outlet 16. The cavitation zone is strictly linked to spray breakup and hence strongly influences the spray penetration of the fluid out of the nozzle body 1.

[0036] The particular shape of the flow hole 13 has influence on the cavitation zone and affects its position inside the respective flow hole 13. Thus, the nozzle body 1 enables improvement of spray characteristics such as enhanced controllability of the fluid spray. The turbulence intensity of the fluid at the hole outlet 16 is then increased and causes shifting of the cavitation zone. The cavitation zone is moved closer to the hole outlet 16 of the flow hole 13 and collapsing cavitation bubbles advantageously enhances the fluid spray breakup at the fluid outlet end 22. Figures 4A to 4C illustrate three exemplary embodiments of flow holes with different D-factors (while keeping the distance L_{SF} , the B- or plume angle and a static mass flow rate of fluid invariant). Figure 4A represents a typical flow hole design with a completely cylindrical shape and therefore comprises a D-factor equal to 1. In contrast, figures 4B and 4C represent flow holes 13 with respective circular segment shapes wherein the flow hole 13 of figure 4B comprises a D-factor of 0.8 and the flow hole 13

of figure 4C comprises a D-factor of 0.5.

[0037] The dimension of the D-factor has to be big enough to generate a desired extension of the cavitation area and is advantageously optimized and adapted to given spray targeting and application requirements. The nozzle body 1 may comprise two or more flow holes with at least on flow hole 13 comprising a circular segment shape with respect to a cross section perpendicular to the hole axis HA depending on customer and application requirements, for example. It might be beneficial if all flow holes 13 of the nozzle body 1 comprise a cut cylindrical shape as described above with equal or different D-factors.

[0038] Figures 5A to 5C illustrate shear stress on the nozzle wall 3 inside the respective flow holes corresponding to the figures 4A to 4C (figure 5A with a D-factor of 1, figure 5B with a D-factor of 0.8 and figure 5C with a D-factor of 0.5; the bold black line or arrow is of no importance). From these illustrations it is apparent that the streaming conditions inside the respective flow hole 13 and the resulting shear stress on the nozzle wall 3 completely differs from each other by changing the geometrical data of the flow hole 13. Dark areas indicate regions of low shear stress wherein the streaming fluid has no significant influence on the nozzle wall 3 inside the flow hole 13.

[0039] By changing the design of the flow hole 13 to a cut cylindrical shape, the streaming conditions are completely changed, dark areas are less marked and the fluid gets beneficially guided inside the respective flow holes 13. In this context, a shear stress value of zero is associated to a flow separation/cavitation area. By decreasing the D-factor of the flow hole 13 the extension of the cavitation area is reducing.

[0040] Figures 6A to 6C show illustrations of streaming conditions inside respective flow holes 13 with different D-factors analogous to figures 4A to 4C and figures 5A to 5C (figure 6A with a D-factor of 1, figure 6B with a D-factor of 0.8 and figure 6C with a D-factor of 0.5). In this context, iso-surfaces are illustrated with a predetermined quantity of liquid fluid to vapour of 50%. Hence, the figures 6A to 6C represents equal volume fractions of liquid and vapour fluid with respect to the pictured iso-surfaces. Further parameters are maintained substantially constant such as the static mass flow rate through the flow hole 13 which represents the amount of fluid per period of time and depends on customer and application requirements, for example.

[0041] By decreasing the D-factor and forming a cut cylindrical shape of the flow hole 13 two vapour cores are generated which enables reduction of the spray penetration and therefore beneficially affects the spray characteristics of the nozzle body 1.

Reference signs

[0042]

1	nozzle body
3	nozzle wall
5	penetrating opening
7	needle seat
9	sac volume portion
10	sac volume step
11	sac volume
13	flow hole
15	hole inlet
16	hole outlet
17	linear portion of the flow hole
18	circular portion of the flow hole
21	fluid inlet end of the nozzle body
22	fluid outlet end of the nozzle body
30	fluid injector
32	needle
A	angle of the circular segment
H	height of the flow hole / distance of the hole axis and the linear portion of the flow hole
HA	hole axis of the flow hole
L	length of the linear portion of the flow hole
LA	longitudinal axis of the nozzle body
L_SF	distance of the sac volume step and the flow hole inlet
R	radius of the circular portion of the flow hole

Claims

1. Nozzle body (1) for a fluid injector (30), comprising
 - a nozzle wall (3) limiting a penetrating opening (5) of the nozzle body (1) along a longitudinal axis (LA) from a fluid inlet end (21) to a fluid outlet end (22) of the nozzle body (1),
 - a sac volume portion (9) of the nozzle wall (3) formed in the region of the fluid outlet end (22) such as to limit a sac volume (11), and
 - a needle seat (7) formed as a portion of the nozzle wall (3) between the fluid inlet end (21) and the sac volume portion (9) of the nozzle body (1) to interact with a needle (32) to prevent a fluid flow through a flow hole (13) in a closed position and otherwise to enable it, wherein the flow hole (13) comprises a hole axis (HA) and penetrates the nozzle wall (3) in the region of the fluid outlet end (22) from the opening (5) to outside of the nozzle body (1) and wherein the flow hole (13) comprises a shape of a circular segment with respect to a cross section perpendicular to the hole axis (HA).
2. Nozzle body (1) in accordance with claim 1, wherein the shape of the circular segment of the flow hole (13) comprises a linear portion (17) with predetermined length (L) and a circular portion (18) with predetermined radius (R) with respect to the hole axis

(HA).

3. Nozzle body (1) in accordance with claim 1 or 2, wherein the flow hole (13) comprises a predetermined height (H) which represents a given distance of the hole axis (HA) to the linear portion (17). 5
4. Nozzle body (1) in accordance with claim 2 and 3, wherein geometrical data of the flow hole (13) are predetermined by a D-factor which represents the ratio of the predetermined height (H) of the flow hole (13) and the predetermined radius (R) of the circular portion (18). 10
5. Nozzle body (1) in accordance with one of the claims 1 to 3, wherein the sac volume portion (9) comprises a sac volume step (10) and the flow hole (13) comprises a hole inlet (15), which is formed at a predetermined distance (L_SF) from the sac volume step (10) with respect to the longitudinal axis (A). 15 20
6. Fluid injector (30), comprising
 - a nozzle body (1) in accordance with one of the claims 1 to 5, and 25
 - a needle (32) which is arranged axially movable in the opening (5) of the nozzle body (1) with respect to the longitudinal axis (LA) to prevent a fluid flow through the flow hole (13) in a closed position and otherwise to enable it. 30

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FIG 1

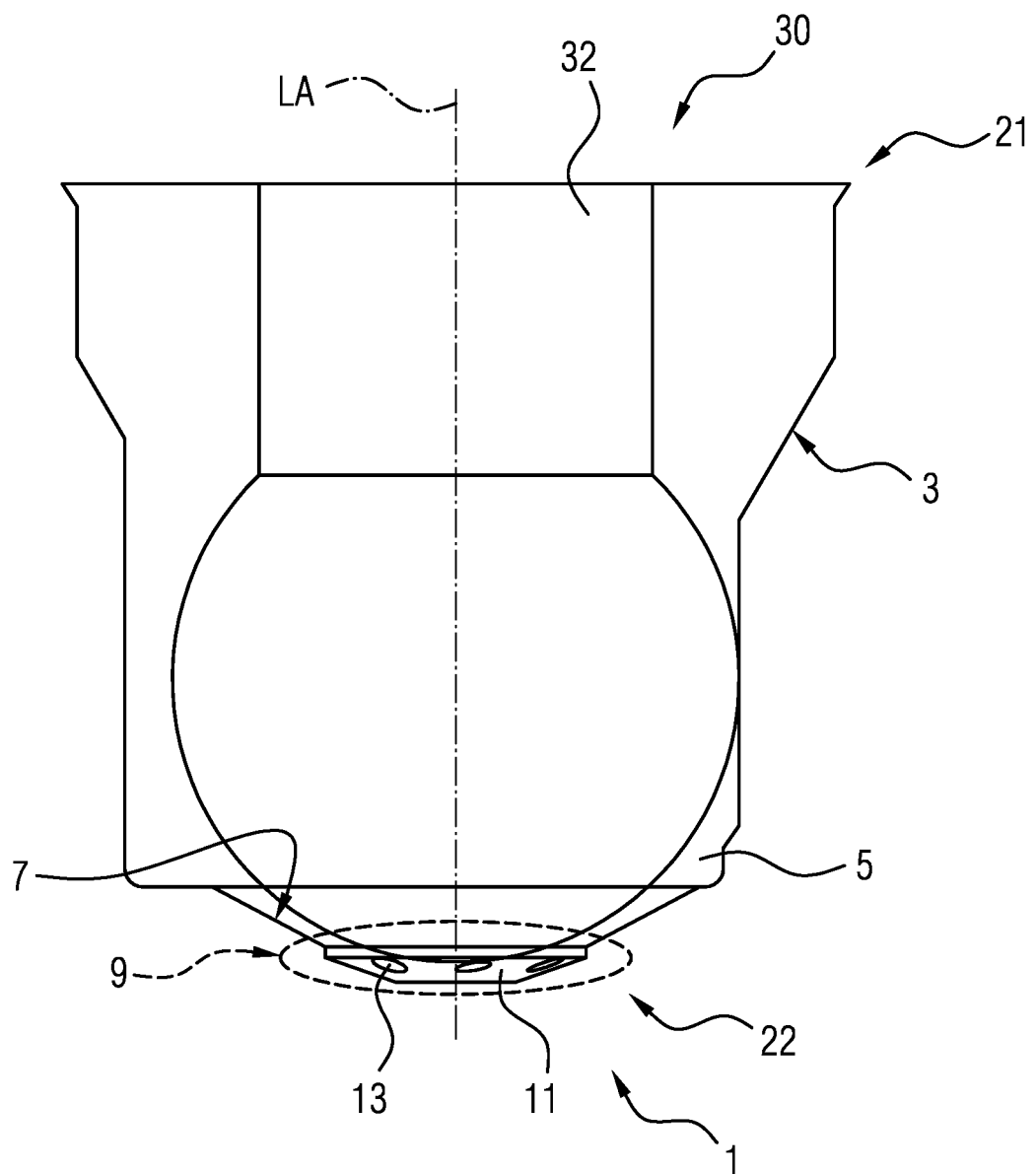


FIG 2

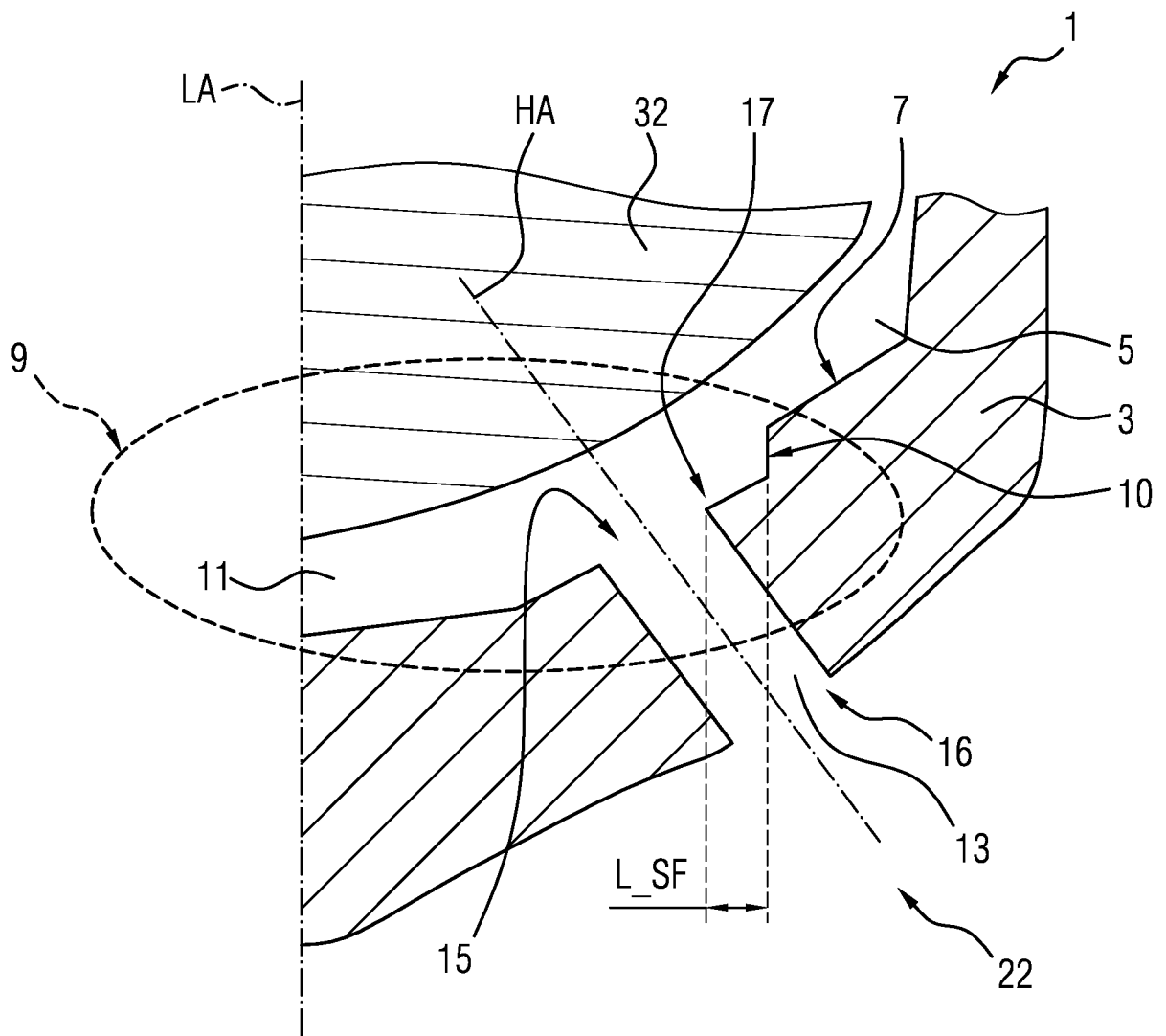


FIG 3

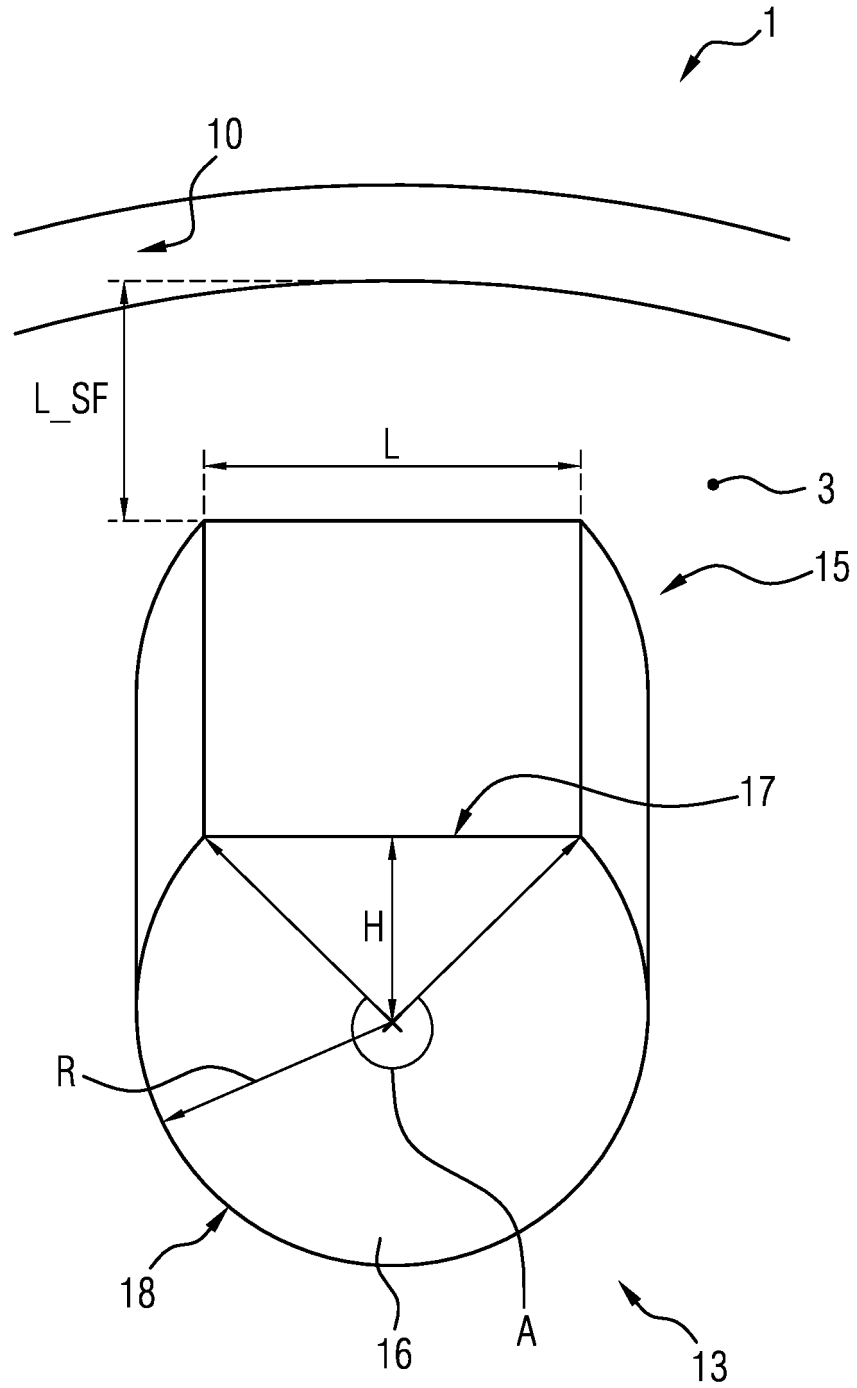


FIG 4A

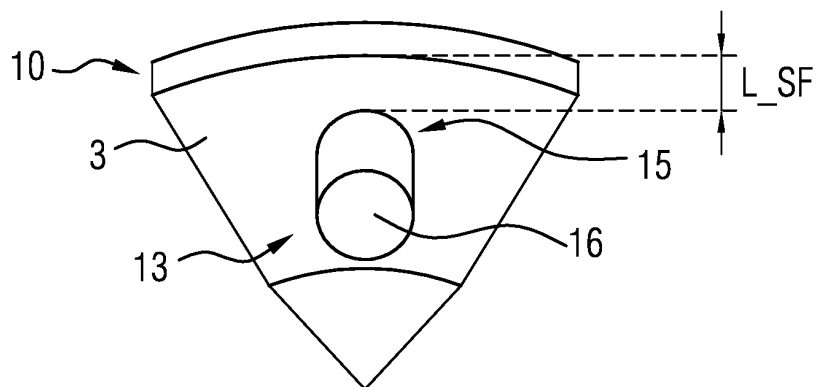


FIG 4B

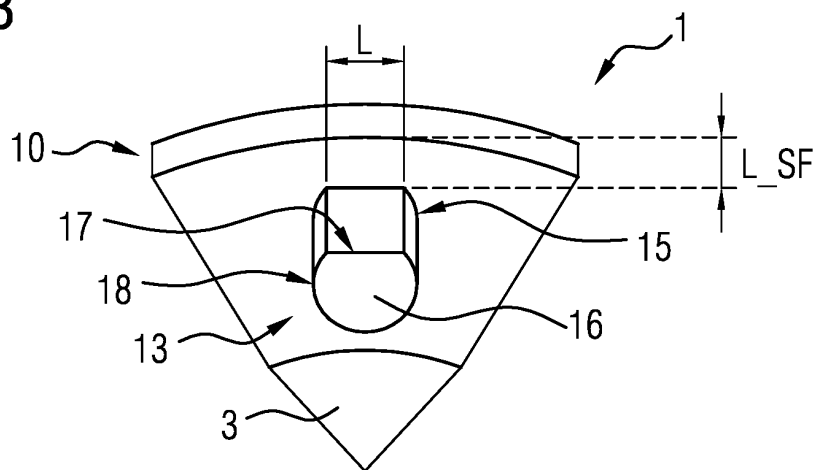


FIG 4C

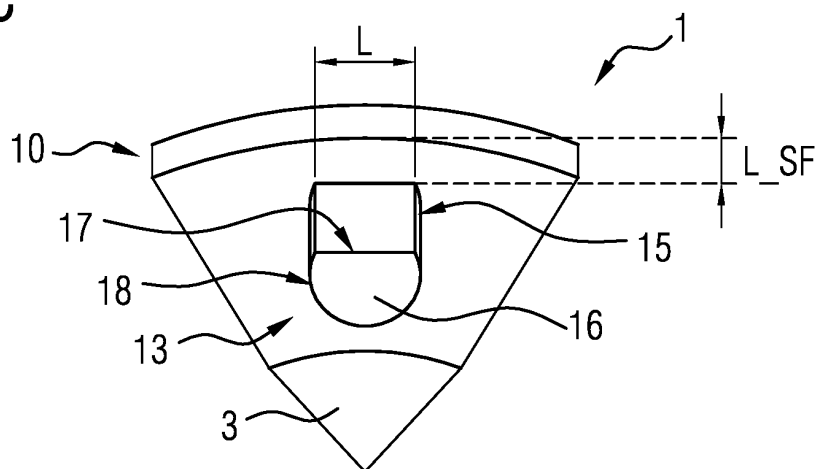


FIG 5A

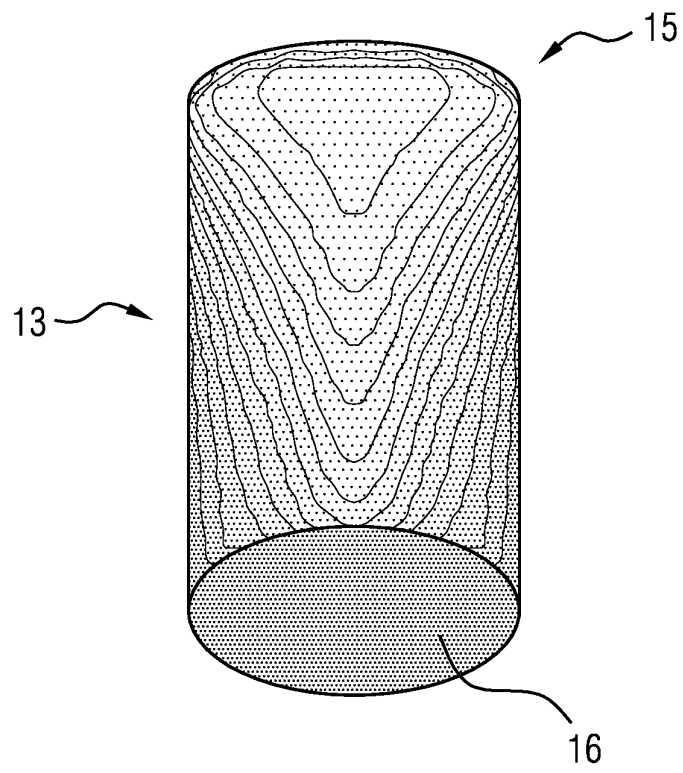


FIG 5B

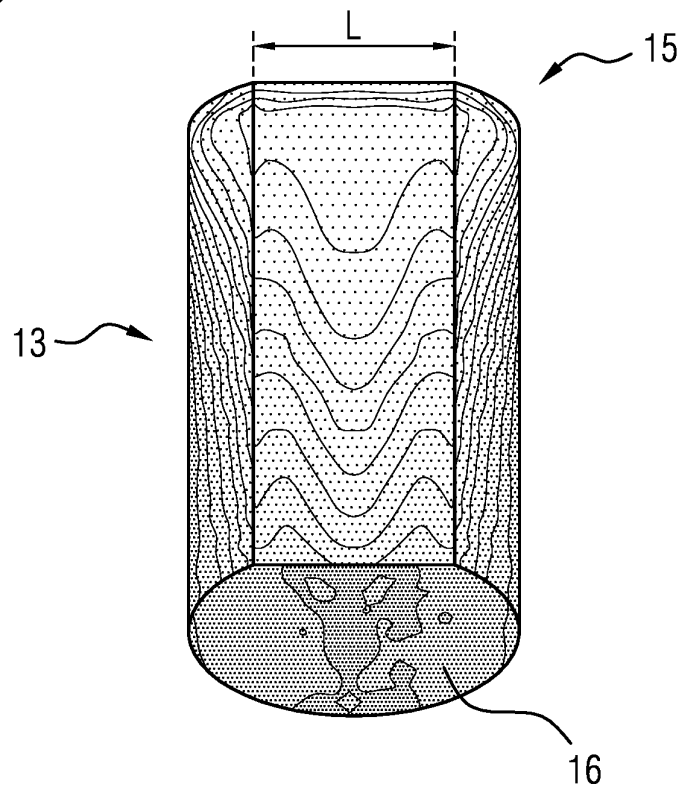


FIG 5C

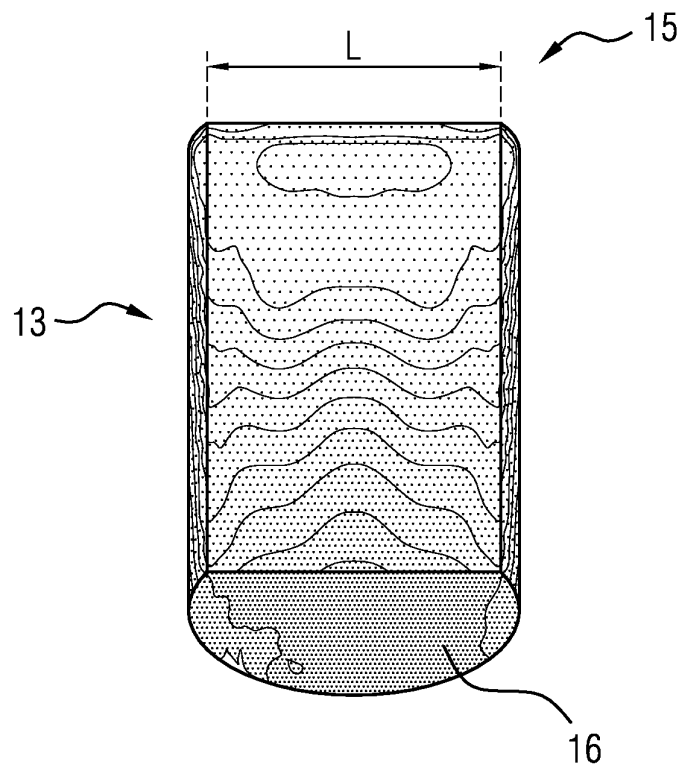


FIG 6A

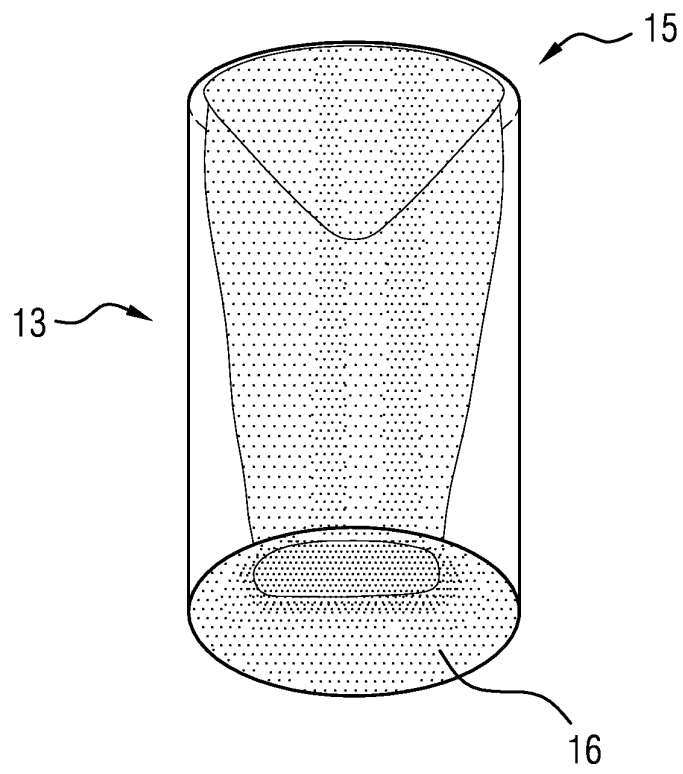


FIG 6B

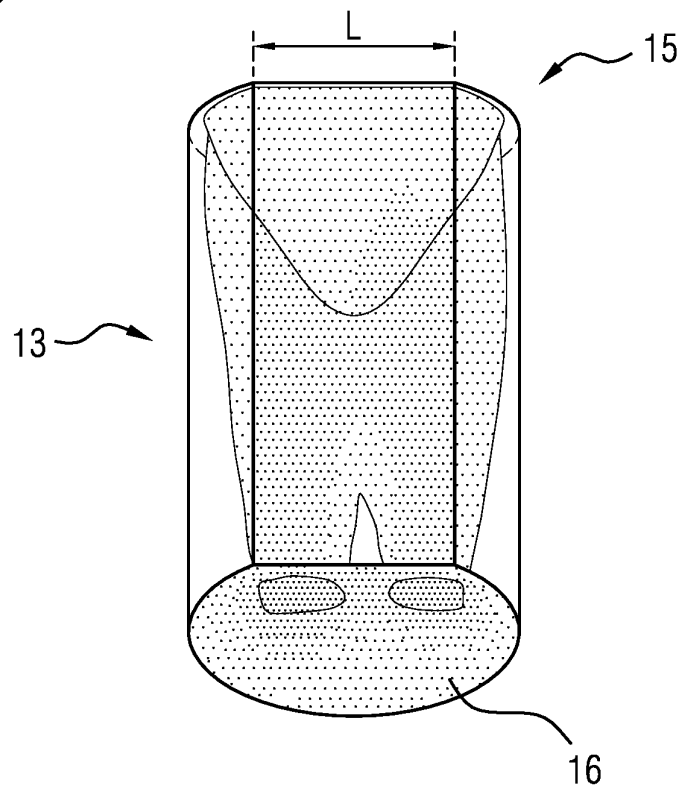
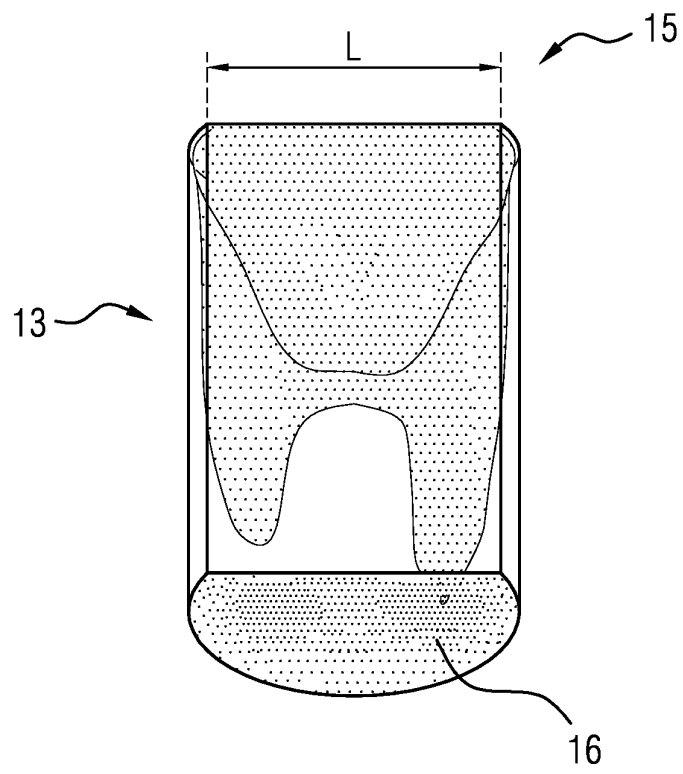


FIG 6C





EUROPEAN SEARCH REPORT

 Application Number
 EP 15 20 1845

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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