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(54) SILENCER AND METHOD FOR PRODUCING A SILENCER

(57) The present invention describes a silencer (1) comprising a main body (2) which defines a longitudinal axis (L) and which contains a channel (3), extending along the longitudinal axis (L) between an inlet opening (31) and an outlet opening (32), and a multiplicity of expansion chambers (4) located one after another along the longitudinal axis (L). The expansion chambers (4) each have an opening (5) next to the longitudinal axis (L). The sound absorber (1) also comprises at least one closure device (10) which is connected to the main body (2), is located on an outer wall (21) of the main body (2) and is designed to reversibly close at least one region of the main body (2). Also described are the use of the silencer (1) and a method for producing the silencer (1).

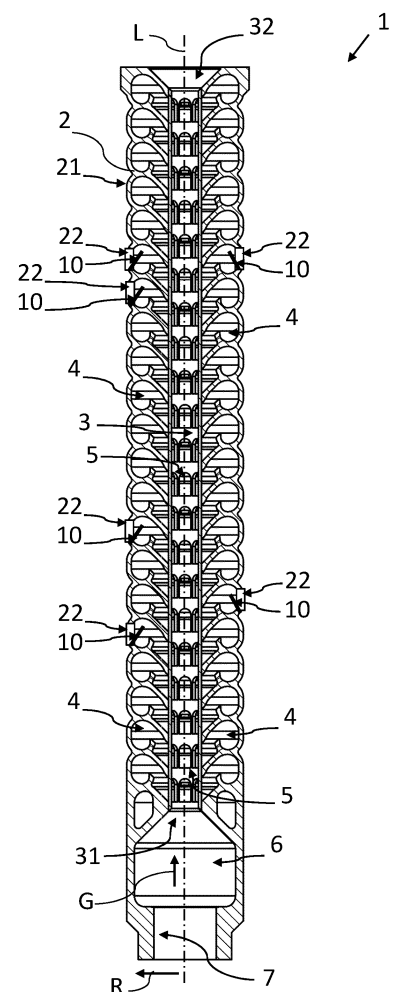


Fig. 1

Description

[0001] The present invention relates to a silencer for a firearm and to a method for producing such a silencer.

[0002] When gases are expelled from muzzles into the environment at high speed, it typically causes the gases to expand uncontrolledly, and this results in noise being generated. The generation of noise is additionally heightened if the gas flows at supersonic speed. Such situations can arise, for example, at exhaust gas outlets of piston engines or turbines or in the muzzle region of firearms.

[0003] In order to reduce the generation of noise, silencers are frequently employed. A silencer for a firearm comprising a monolithic main body which extends along a longitudinal axis and has multiple expansion chambers located one behind another along the longitudinal axis is described, for example, in US 2014/0262605 A1. DE 10 2018 221 095 A1 also describes a further silencer for a firearm.

[0004] Known silencers do not operate efficiently in water environments, since the silencer geometry can fill with water during operation, and this is not desirable in any event. The outer walls of known silencers are solid because their main aim is to stem the flow of combustion gases generated by a bullet being fired and thus reduce the noise. This means that the water cannot be drained except through the bore of the barrel.

[0005] An object of the present invention is to provide a silencer which has a good damping effect, preferably combined with a low weight, and can be used reliably in a maritime environment.

[0006] This object is achieved by the subject matter of the independent claims.

[0007] According to a first aspect of the invention, a muzzle signature reducer, i.e. silencer, for a firearm is provided. The silencer comprises a main body which defines a longitudinal axis and which contains a channel, extending along the longitudinal axis between an inlet opening and an outlet opening, and a multiplicity of expansion chambers located one after another along the longitudinal axis. The expansion chambers each have an opening next to the longitudinal axis. The silencer also comprises at least one closure device which is connected to the main body. The at least one closure device is located on an outer wall of the main body and is designed to reversibly close at least one region of the main body.

[0008] According to a second aspect of the invention, a method for producing a silencer according to a first aspect of the invention is provided, the main body being built up in layers by an additive production method, i.e. a 3D printing method.

[0009] An idea on which the invention is based is that the water can continuously drain out of the silencer. This very quickly empties the through-bore, i.e. the channel. As soon as a shot is fired, the outer walls are closed and significant noise cancellation occurs, the bullet advantageously not being influenced by the water in the channel.

[0010] One of the advantages of the silencer according to the invention is that, as a result of the at least one closure device on the outer wall of the main body, the silencer is ready for operation within a few seconds after leaving a water environment, for example at the end of a diving operation or if the silencer is wet for any other reason. The silencer is ready for operation in particular when the channel and optionally the expansion chambers are only filled with air. Furthermore, a user does not need to perform any manual movements to empty the water out of the silencer, because the water can drain automatically.

[0011] The silencer according to the invention can also suppress, i.e. damp, the sound automatically when a shot is fired by the at least one closure device deforming, and the user does not need to take any manual action. A further advantage is the straightforward design of the silencer, since no special moving parts or mechanisms or double-walled structures are required.

[0012] The idea of the method according to the second aspect of the invention is to produce the main body by an additive or generative manufacturing method, i.e. a 3D printing method. 3D printing methods within the scope of the present disclosure include all generative, i.e. additive, manufacturing methods in which geometric models are taken as a basis to produce objects of a predefined form from formless materials, such as liquids and powders, or form-neutral semifinished products, such as material in the form of a strip or wire, by chemical and/or physical processes in a special generative manufacturing system. 3D printing methods within the scope of the present application use additive processes in which the starting material is sequentially built up in layers in predefined forms. In this way, an outstanding freedom of design is ensured, with the result that in particular the at least one closure device can be adapted in terms of geometry to many different designs of known silencers. In particular, in the present case the main body and the at least one closure device can be made particularly easily and/or with especially complex geometries, for example from a metal material. This makes it possible to increase the performance of the silencer.

[0013] Advantageous configurations and developments will emerge from the dependent claims that refer back to the independent claims, in combination with the description.

[0014] According to one embodiment of the present invention, the outer wall has a lateral surface with at least one cutout, the at least one cutout being reversibly closable by means of the at least one closure device. For example, each expansion chamber may be assigned at least one cutout or a single cutout. Furthermore, each expansion chamber may be assigned at least one closure device or a single closure device.

[0015] According to a further embodiment of the present invention, the at least one closure device changes between an open position and a closed position depending on a pressure ratio between an internal pressure in

the expansion chamber and an ambient pressure. This allows the at least one closure device, i.e. the closing mechanism, to open up the at least one cutout in the open position so that a fluid, in particular water, can drain out of the expansion chamber through the cutout. For example, the at least one closure device can project into the expansion chamber in the open position. Similarly, the at least one closure device can close the at least one cutout in the closed position, with the result that an exchange of fluid between the expansion chamber and the surrounding area is greatly reduced or completely prevented. Consequently, the at least one closure device can be in the open position or the closure device can open when the ambient pressure is higher than or approximately the same as the pressure inside the expansion chamber. When the pressure inside the expansion chamber is higher than the ambient pressure, the at least one closure device can close or be in the closed position. In the closed position, the outflow of combustion gases from the expansion chamber is considerably reduced or prevented.

[0016] According to a further embodiment of the present invention, the at least one closure device has an arcuate, i.e. curved, starting form in the open position, so that the expansion chambers are open at ambient pressure. The curved starting form allows the fluid to flow out of the expansion chambers even more easily. As soon as the pressure in the expansion chamber is considerably higher than the ambient pressure, the high pressure causes the closure device to elastically deform into the closed position, i.e. the closed state.

[0017] According to a further embodiment of the present invention, in the closed position, a predetermined leakiness in a region of contact of the at least one closure device with the at least one cutout is set by means of a porosity of the contact region or an increased surface roughness in the contact region, or both. In this way, the predetermined leakiness allows a moderate outflow of the combustion gas from the silencer, in particular a slow reduction in an excess pressure in the expansion chamber with respect to the ambient pressure, before the next shot. The silencer can therefore also provide very good damping performance along with a low weight. Consequently, as a result of the predetermined leakiness, the silencer can be designed for lower pressures than conventional silencers for the same intended use. This means that, in the closed position, it is possible to set, i.e. provide, a predetermined leakiness of the at least one closure device in interaction with the cutout, for example by means of a specific roughness of the contact surfaces of the contact region.

[0018] The porosity of the contact region can be formed, for example, by outflow holes located in the contact region, whether in the closure device or the main body or both. With preference, the at least one closure device stays closed for a long time, for example several seconds, and has the effect that a fluid, in particular a combustion gas, can escape slowly into the surrounding area owing to the straightforward, predetermined leaki-

ness. In some use scenarios, such as in the case of single shots fired quickly one after another, however, a compromise between a damping performance of the silencer and an ever-increasing pressure loading is expedient.

[0019] According to a further embodiment of the present invention, the at least one closure device is integral with the main body and elastically deformable. Therefore, because of its elastic deformability, the at least one closure device can change reversibly between the open position and the closed position. It is possible, for example, for the at least one closure device, i.e. the at least one closing mechanism, to have a blade-like structure connected to the main body, i.e. the main structure, via a bar. A surface of the blade-like structure can be designed such that a certain minimum pressure inside the expansion chamber is sufficient to elastically deform the closure device into the closed position. Furthermore, the bar can be designed such that it affords the deformation necessary for shooting and withstands a minimum number of shooting loads. This means that a service life and robustness of the at least one closure device can be set via the bar. A fatigue strength can be taken into account in the design of the at least one closure device, in order to ensure that the minimum number of shooting loads can be achieved without structural failure.

[0020] As an alternative or in addition, the at least one closure device, i.e. the at least one closing mechanism, may have a board-like form. The board-like structure advantageously makes it possible to arrange a very high number of closure devices on the outer wall, in particular on the lateral surface of the outer wall. This makes it possible to increase an outflow rate of the fluid by maximizing the number of cutouts, a form of each cutout corresponding to a form of the closure device. In particular, the very high number of closure devices may be aligned and oriented along the longitudinal axis.

[0021] As an alternative or in addition, the at least one closure device, i.e. the at least one closing mechanism, may have a concertina-like structure. The concertina-like structure can be located, i.e. formed, in particular on a transition region from the main structure to the closure device, in order to make it easier for the closure device to close in combination with a large cutout. Furthermore, the concertina-like structure can positively influence an elastic deformability.

[0022] Optionally, the at least one closure device may for example have an iris-like structure or be in the form of an iris diaphragm. The iris diaphragm comprises, by way of example, multiple leaves which can be conjointly rotated inwards or outwards via a mechanism. Each leaf can be mounted on a pin, the leaves being connected to a ring via a respective further pin, in order that they move conjointly. As an alternative, the at least one closure device may have a flower-like form, the flower-like closure device being able to close like a flower. For example, the at least one closure device may change between an open position and a closed position depending on a pressure ratio between a pressure in the channel and

an ambient pressure.

[0023] In order for the closure device to close a relatively large cutout, a relatively large elastic deformation of the closure device is needed.

[0024] According to a further embodiment of the present invention, the at least one closure device has a respective free end oriented in the direction of the outlet opening. If there is a multiplicity of closure devices, they may be conjointly oriented in the direction of the outlet opening. The cutout may substantially correspond for example in its form to the closure device, which is to say have a similar form to the closing closure device.

[0025] According to a further embodiment of the present invention, the at least one closure device is polygonal, quadrangular, round or elliptical. In this way, the outflow rate of the fluid, e.g. water, can be controlled. For example, as viewed in a cross section, the closure device may engage in the cutout of the main structure like a wedge, so that a resulting contact surface between the closure device and the cutout in the closed position optimizes a sealing effect. This means that the closure device can engage in a frame of the cutout in the manner of a wedge, in order to achieve as high a sealing effect as possible. The at least one closure device may be designed in such a way that substantially a surface-area contact, and not just a linear contact, between the closure device and the cutout occurs. The closure device and the cutout interacting with the closure device can thus form a window design.

[0026] A thickness of the at least one closure device may be selected such that the at least one closure device can withstand conventional pressures in the silencer for a firearm. Dimensions of the at least one closure device may be provided for example depending on a respective height, which is to say a respective spacing between two leaves, of the multiplicity of expansion chambers. The respective height is, however, not limited to the spacing between two leaves, but rather can extend over two or more expansion chambers, with a leaf that crosses the closure device having, in the region of the outer wall, a gap so that the water can be released from the two or more expansion chambers through the closure device.

[0027] According to a further embodiment of the present invention, the at least one closure device is mounted in articulated fashion in each case, so that the at least one closure device can be pivoted relative to the outer wall. The at least one closure device may have, for example, a hinge joint and a rigid, for example flat, portion.

[0028] The at least one closure device may also have a spring device, the spring device being designed and arranged with respect to the at least one closure device such that the at least one closure device is kept in the open position without pressure loading.

[0029] According to a further embodiment of the present invention, a form or a size or both of the at least one closure device varies along the longitudinal axis. In this way, the at least one closure device can act more efficiently depending on its location in the silencer.

[0030] Typically, in a silencer the greatest pressures act at a barrel end of the firearm. These pressures become smaller towards the outlet opening, i.e. towards the silencer outlet. In particular, the form, for instance the thickness, and/or the size of the at least one closure device may get smaller along the longitudinal axis. This makes it possible for the at least one closure device to be more robust, for example heavier and/or larger, close to the highest loading in the region of the inlet opening. The more robust closure device can withstand higher pressures, it being possible for the closure device to become less robust and more lightweight towards the outlet opening. In this way, the closing function can be provided in every expansion chamber as efficiently as possible in weight terms.

[0031] Optionally, the main body may additionally form a plenum from which the inlet opening of the channel emerges, the plenum having a feed opening situated opposite the inlet opening of the channel. The plenum can thus be located upstream of the inlet opening of the channel with respect to the longitudinal axis and has a larger inside diameter than the channel with respect to the radial direction. A gas entering the plenum through the feed opening thus expands already in the plenum before it is fed to the channel and from there to the individual expansion chambers.

[0032] According to a further embodiment, in the region of the inlet opening of the channel, optionally in the region of the plenum, the main body has a connecting portion for connecting the main body to a tube, in particular to a barrel of a firearm. The connecting portion or the connecting structure may be formed, for example, by a thread.

[0033] According to a further embodiment of the present invention, the main body and the at least one closure device are made of a metal alloy. The metal alloy used may be for example an aluminium alloy, e.g. an aluminium-magnesium-scandium alloy marketed under the trade name "Scalmalloy", a titanium alloy, e.g. Ti6Al4V, a steel alloy, in particular 316L stainless steel, or a nickel-based alloy marketed under the trade name "Inconel".

[0034] According to a further embodiment of the present invention, the main body and the at least one closure device are made of a plastics material. In particular, the main body may be made of a fibre-reinforced plastics material such as printed CFRP material.

[0035] Optionally, the silencer may be formed in one piece, i.e. monolithically, or in multiple parts. If the silencer is formed in multiple parts, it is possible for example for the main body to be generatively manufactured and other components, for example the plenum and/or the connecting portion, to be machined. The silencer formed in multiple parts makes it possible e.g. to reduce costs, since only the relatively complex main body with the at least one closure device is additively produced and the other components are reworked by machining. This also makes it easier to clean the main body, in particular because the inside of the silencer is more readily acces-

sible. Furthermore, if the main body is damaged, it is possible to cost-efficiently replace only the main body. In addition, the main body can be combined with an already existing special connecting piece or connecting portion. In particular, the main body and the at least one closure device can be formed in one piece.

[0036] According to one embodiment of the method, the main body is built up in layers along the longitudinal axis, e.g. starting with the region of the inlet opening.

[0037] According to a further embodiment of the method, the additive production method comprises a selective laser melting method, an electron beam melting method or a deposition welding method. Selective laser melting methods are referred to for example as SLM methods. In SLM methods, a laser beam is used to melt a usually powdered starting material, in order to form the desired structure. Electron beam melting methods can also be referred to as EBM methods. In this case, an electron beam is used to melt a generally powdered starting material, in order to form the desired structure. In the case of deposition welding, a solid starting material is melted and deposited in layers in the molten state, in order to form the structure.

[0038] In other words, the present invention can be described as follows. The present invention provides small cutouts in the outer walls or the outer wall of the silencer which are provided with flexible structures, such as covers. These covers are open as standard, so that water can flow out when the silencer is in any position. When a shot is fired, the internal pressure generated by the shot causes the cover to elastically deform. This deformation seals off the outer wall of the silencer and prevents the gas from escaping, as a result of which the sounds of shots are reduced. The form of the at least one closure device, in particular its thickness and/or its length, and the number of closure devices and also the choice of material are important parameters for an effectiveness and/or a service life of the silencer. A fine-tuning of the thickness or form of the closure device may consist in finding a balance between the static pressure and a fatigue stress caused by a sequence of shots and making it elastically deform as far as possible in order to conduct the fluid that is to be discharged from the silencer. The larger the cutouts are or the more cutouts there are or the better adapted the form of the cutouts is to generate a lower resistance for the fluid flow, the higher the drainage rate, i.e. outflow rate, of the fluid, in particular the water, is.

[0039] Within the context of the present disclosure, components with a "one-piece", "single-piece" or "integral" form or components formed "in one piece" in general are understood as meaning that these components exist as a single part that forms a material unit and in particular are produced as such, e.g. by a 3D printing method, where one of the other components cannot be detached from the others without breaking up the material cohesion.

[0040] As regards directional indications and axes, in particular directional indications and axes relating to the

progression of physical structures, a progression of an axis, a direction or a structure "along" another axis, direction or structure is understood herein to mean that they, in particular the tangents found at a respective point of the structures, extend in each case at an angle of less than 45 degrees, preferably less than 30 degrees and particularly preferably parallel to one another.

[0041] As regards directional indications and axes, in particular directional indications and axes relating to the progression of physical structures, a progression of an axis, a direction or a structure "transversely" to another axis, direction or structure is understood herein to mean that they, in particular the tangents found at a respective point of the structures, extend in each case at an angle of greater than or equal to 45 degrees, preferably greater than or equal to 60 degrees and particularly preferably perpendicularly in relation to one another.

[0042] The invention will be explained below with reference to the figures of the drawings. In the figures:

Figure 1 shows a schematic sectional view of a silencer for a firearm according to an exemplary embodiment of the present invention;

Figure 2 shows an enlarged, broken-away sectional view of the silencer illustrated in Figure 1 in the region of expansion chambers of the silencer;

Figure 3 shows a schematic sectional view of a silencer for a firearm according to a further exemplary embodiment of the present invention;

Figure 4 shows a schematic perspective view of a silencer for a firearm according to a further exemplary embodiment of the present invention;

Figure 5 shows an enlarged sectional view of an outlet opening of a silencer, the outlet opening being closeable by a closure device;

Figures 6A, 6B show results of a linear static simulation of deformations of the closure device when a single shot is fired from a firearm;

Figure 7 shows schematic front views of five different alternative configurations of a closure device of a silencer according to further exemplary embodiments of the present invention;

Figure 8 shows schematic side views of the five different alternative configura-

- tions of the closure device from Figure 7;
- Figure 9 shows schematic plan views of the five different alternative configurations of the closure device from Figures 7 and 8;
- Figure 10 shows schematic plan views of the five different alternative configurations of the closure device in cross section from Figures 7, 8 and 9;
- Figure 11 shows a schematic view of a firearm comprising a silencer according to a further exemplary embodiment of the present invention; and
- Figure 12 shows a schematic illustration of one step of a method for producing a silencer according to a further exemplary embodiment of the present invention.

[0043] In the figures, the same reference signs denote components that are the same or have the same function, unless indicated otherwise.

[0044] Figure 1 schematically shows, by way of example, a sectional view of a silencer 1. The silencer 1 has a main body 2. As illustrated by way of example in Figure 1, the main body 2 is realized as an elongate, in particular one-piece, i.e. monolithic, body defining a longitudinal axis L. The main body 2 may in particular have a for instance cylindrical shape, as schematically illustrated in Figure 1. The main body 2 may be made in particular of a metal material, e.g. a titanium alloy, a steel alloy or a nickel-based alloy.

[0045] As Figure 1 shows, the main body 2 has a channel 3, a multiplicity of expansion chambers 4, an optional plenum 6 and an optional connecting portion 7, or the main body 2 forms these structures. The plenum 6 may in particular be in the form of a cylindrical cavity enclosing the longitudinal axis L, as illustrated by way of example in Figure 1. The plenum 6 is formed in the region of the inlet opening 31 of the channel 3, the inlet opening 31 of the channel 3 emerging from the plenum 6. As Figure 1 also illustrates, the plenum 6 has a feed opening which is situated opposite the inlet opening 31 of the channel 3 and is spaced apart from the inlet opening 31 of the channel 3 along the longitudinal axis L. The feed opening serves for feeding in gas.

[0046] Figure 1 also symbolically illustrates that, in the region of the inlet opening 31 of the channel 3, the main body 2 has or forms a connecting portion 7 for connecting the main body 2 to a tube or a duct. The connecting portion 7 may for example be in the form of a thread. Figure 1 illustrates purely by way of example that the connecting portion 7 is in the form of an internal thread of

the feed opening of the plenum 6.

[0047] As illustrated in Figure 1, the channel 3 extends along, preferably coaxially with, the longitudinal axis L. The channel 3 may for example have a cylindrical cross section. The channel 3 extends between an inlet opening 31 intended for the feed of a gas flow into the channel 3, and an outlet opening 32 which is situated opposite the inlet opening 31 with respect to the longitudinal axis L and is intended for discharge of the gas flow from the channel 3 into the surrounding area. In Figures 1 and 2, an intended flow direction G of a gas flow from the inlet opening to the outlet opening 31, 32 of the channel 3 is symbolically illustrated by an arrow.

[0048] As Figure 1 also illustrates, the main body 2 has a multiplicity of expansion chambers 4. As Figure 1 illustrates by way of example, the expansion chambers 4 are located one after another, i.e. one behind another, along the longitudinal axis L and extend around, i.e. enclose, the longitudinal axis L. With respect to a radial direction R extending perpendicularly in relation to the longitudinal axis L, the expansion chambers 4 adjoin the channel 3. Optionally, the expansion chambers 4 are rotationally symmetrical with respect to the longitudinal axis L. The expansion chambers 4 also optionally extend coaxially with the longitudinal axis L. The expansion chambers 4 each have an opening 5 next to the longitudinal axis L.

[0049] The exemplary sound absorber 1 also comprises at least one closure device 10 which is connected to the main body 2, is located on an outer wall 21 of the main body 2 and is designed to reversibly close at least one region of the main body 2.

[0050] Figure 2 shows an enlarged, broken-away sectional view of the silencer 1 illustrated in Figure 1 in the region of expansion chambers 4 of the silencer 1. As Figure 2 schematically illustrates, each expansion chamber 4 has an opening 5, an inlet portion and a damping portion. The inlet portion and the damping portion are each formed by walls of the main body 2.

[0051] For example, the at least one closure device 10 may change between an open position and a closed position depending on a pressure ratio between a pressure inside the expansion chamber 4 and an ambient pressure. This allows the at least one closure device 10, i.e. the closing mechanism, to open up the at least one cutout 22 in the open position so that water can drain out of the expansion chamber 4 through the cutout 22.

[0052] As illustrated in Figure 2 by way of example, the at least one closure device 10 may project into the expansion chamber 4 in the open position. Similarly, the at least one closure device 10 can close the at least one cutout 22 in the closed position, with the result that an exchange of fluid between the expansion chamber 4 and the surrounding area is greatly reduced or completely prevented. Consequently, the at least one closure device 10 can be in the open position or the closure device 10 can open when the ambient pressure is higher than or approximately the same as the pressure inside the ex-

pansion chamber 4. When the pressure inside the expansion chamber 4 is higher than the ambient pressure, the at least one closure device 10 can close or be in the closed position. In the closed position, the outflow of combustion gases from the expansion chamber 4 is considerably reduced or prevented.

[0053] Furthermore, in the closed position, a predetermined leakiness in a region of contact of the at least one closure device 10 with the at least one cutout 22 may be set by means of a porosity of the contact region and/or an increased surface roughness in the contact region. In this way, the predetermined leakiness allows a moderate outflow of the combustion gas from the silencer 1, in particular a slow reduction in an excess pressure in the expansion chamber 4 with respect to the ambient pressure, before the next shot. This means that, in the closed position, it is possible to set, i.e. provide, a predetermined leakiness of the at least one closure device 10 in interaction with the cutout 22, for example by means of a specific roughness of the contact surfaces of the contact region. The porosity of the contact region can be formed, for example, by outflow holes located in the contact region, whether in the closure device 10 or the main body 2 or both. With preference, the at least one closure device 10 stays closed for a long time, for example several seconds, and has the effect that a fluid, in particular a combustion gas, can escape slowly into the surrounding area owing to the straightforward, predetermined leakiness.

[0054] As Figure 2 schematically illustrates, the inlet portion may be produced in particular as a cross-sectionally flat structure inclined by an angle α relative to the longitudinal axis L. As Figure 2 schematically illustrates, the inlet portion has a first surface next to the inlet opening 31 of the channel 3. This first surface is at least partially or partly flat or planar. Figure 2 illustrates by way of example that the first surface is planar overall, which is to say that the first surface is inclined at a constant angle relative to the longitudinal axis L. As Figure 2 also shows, the inlet portion has an inner end region with respect to the radial direction R, this inner end region being next to the longitudinal axis L, and an outer end region with respect to the radial direction R, this outer end region being remote from the longitudinal axis L. Optionally, the inlet-portion first surface is planar at least in the outer end region. Since the expansion chambers 4 extend around the longitudinal axis L, when the inlet-portion first surface extends in planar fashion as shown by way of example in Figure 2 it defines a cone extending around the longitudinal axis L.

[0055] The angle can be measured in particular between the inlet-portion first surface next to the inlet opening 31 of the channel 3 and the longitudinal axis L. The angle preferably ranges between 25 degrees and 70 degrees, particularly preferably between 30 degrees and 60 degrees. In Figure 2, the angle is for example 45 degrees. As Figure 1 in particular shows, the inlet portion extends at an angle such that the inner end region of the inlet portion is at a smaller spacing from the inlet

opening 31 of the channel 3 along the longitudinal axis L than the outer end region of the inlet portion is. Accordingly, the radial spacing of the inlet-portion first surface from the longitudinal axis L increases in a direction from the inlet opening 31 of the channel 3 to the outlet opening 32 of the channel 3.

[0056] As Figure 2 schematically illustrates, the damping portion 42 of a respective expansion chamber 4 is formed by a curved wall region of the main body 2 and defines a circular cavity. The curved wall region has an inner surface which defines the circular cross-sectional form of the cavity. In Figure 2, the circular cross-sectional form of the cavity is realized by way of example as an oval form with curved portions and straight portions. The wall region of the main body 2 that defines the damping portion can, on the surface that defines the cavity, have for example an average roughness Ra which ranges between 1 and 50, preferably between 5 and 20.

[0057] The opening 5 is delimited for example with respect to the longitudinal axis L by the outer end region of the inlet portion on the side remote from the inlet opening 31 of the channel 3 and by a wall projection of the damping portion on the side next to the inlet opening 31 of the channel 3. The wall projection of the damping portion and the outer end region of the inlet portion thus overall define a gap or slot surrounding the longitudinal axis L. Owing to the circular shape of the cavity, a circulating flow that flows through the cavity repeatedly is formed within the cavity.

[0058] As Figure 2 also illustrates by way of example, the wall projection of the damping portion may extend in particular along the longitudinal axis L. With preference, the wall projection has a surface which is remote from the longitudinal axis L, i.e. next to the interior of the cavity, and is flat, i.e. forms a straight portion of the circular cross section. This makes it easier for the flow to recirculate inside the cavity, in particular in the supersonic range. Optionally, the wall projection is inside the outer end region of the inlet portion with respect to the radial direction R. In Figure 2, the level of the surface of the wall projection with respect to the radial direction R is illustrated by a dashed line. As Figure 2 shows, the outer end region, identified in Figure 2 by a curly bracket, of the inlet portion extends beyond this level with respect to the radial direction R. If the outer end region of the inlet portion is flat or planar, as illustrated by way of example in Figure 2, this advantageously leads to a gas flow flowing from the wall projection in the direction of the outer end region of the inlet portion being deflected reliably into the cavity. In particular in the supersonic range, shock waves circulating as a result propagate into the cavity, and therefore the volume of the cavity can be utilized to an improved extent for pressure reduction and thus for silencing.

[0059] Figure 2 illustrates two expansion chambers 4 located one behind the other, i.e. adjoining one another, along the longitudinal axis L. As Figure 2 shows, the cavities of the damping portions may have a shared

partition with respect to the longitudinal axis L. Figure 2 also illustrates by way of example that the cavities each have the same volume. It is alternatively conceivable for the volume defined by the cavity of the respective damping portion to decrease along the longitudinal axis L. It is possible, for example, for a first group of cavities to have a first volume and a second group of cavities to have a second volume smaller than the first volume, the first group of cavities being in the region of the inlet opening 31 of the channel 3 and the second group of cavities following the first group of cavities and being closer to the outlet opening 32 of the channel than the first group. Furthermore, the volume of the cavities may also decrease, i.e. become smaller, continuously from the inlet opening 31 of the channel 3 towards the outlet opening 32 of the channel 3.

[0060] Figure 3 shows a schematic sectional view of a silencer 1 for a firearm 100 according to a further exemplary embodiment of the present invention.

[0061] The silencer 1 comprises a main body 2 which defines a longitudinal axis L. The main body 2 contains a channel 3, extending along the longitudinal axis L between an inlet opening 31 and an outlet opening 32, and a multiplicity of expansion chambers 4 located one after another along the longitudinal axis L. The expansion chambers 4 each have an opening 5 next to the longitudinal axis L.

[0062] The silencer 1 also comprises at least one closure device 10 which is connected to the main body 2. The at least one closure device 10 is located on an outer wall 21 of the main body 2 and is designed to reversibly close at least one region of the main body 2.

[0063] For example, the at least one closure device 10 may change between an open position and a closed position depending on a pressure ratio between a pressure inside the expansion chamber 4 and an ambient pressure. This allows the at least one closure device 10, i.e. the closing mechanism, to open up the at least one cutout 22 in the open position so that water can drain out of the expansion chamber 4 through the cutout 22.

[0064] The main body 2 and the at least one closure device 10 are formed in one piece, i.e. monolithically, in this case by way of example.

[0065] As illustrated in Figure 3 by way of example, the at least one closure device 10 may project into the expansion chamber 4 in the open position. Similarly, the at least one closure device 10 can close the at least one cutout 22 in the closed position, with the result that an exchange of fluid between the expansion chamber 4 and the surrounding area is greatly reduced or completely prevented. Consequently, the at least one closure device 10 can be in the open position or the closure device 10 can open when the ambient pressure is higher than or approximately the same as the pressure inside the expansion chamber 4. When the pressure inside the expansion chamber 4 is higher than the ambient pressure, the at least one closure device 10 can close or be in the closed position. In the closed position, the outflow of

combustion gases from the expansion chamber 4 is considerably reduced or prevented.

[0066] Furthermore, in the closed position, a predetermined leakiness in a region of contact of the at least one closure device 10 with the at least one cutout 22 may be set by means of a porosity of the contact region and/or an increased surface roughness in the contact region.

[0067] Optionally, multiple closure devices 10 can interact to close the cutout 22, the outlet opening 32 or another cutout.

[0068] The at least one closure device 10 may also, for example, be mounted in articulated fashion in each case, so that the at least one closure device 10 can be pivoted relative to the outer wall 21. The at least one closure device 10 may have, for example, a hinge joint and a rigid, for example flat, portion.

[0069] The at least one closure device 10 may also have a spring device, the spring device being designed and arranged with respect to the at least one closure device 10 such that the at least one closure device 10 is kept in the open position without pressure loading.

[0070] A form and/or a size of the at least one closure device 10 may vary along the longitudinal axis L. In this way, the at least one closure device 10 can act more efficiently depending on its location in the silencer 1. In particular, the form, for instance the thickness, and/or the size of the at least one closure device 10 may get smaller along the longitudinal axis L. This makes it possible for the at least one closure device 10 to be more robust, for example heavier and/or larger, close to the highest loading in the region of the inlet opening 31. The more robust closure device 10 can withstand higher pressures, it being possible for the closure device 10 to become less robust and more lightweight towards the outlet opening 32. In this way, the closing function can be provided in every expansion chamber 4 as efficiently as possible in weight terms.

[0071] By way of example, in the region of the inlet opening 31 of the channel 3, in this case the main body 2 has a connecting portion 7 for connecting the main body 2 to a tube, in particular to a barrel 110 of a firearm 100.

[0072] The main body and the at least one closure device may be made of a metal alloy. The metal alloy used may be for example an aluminium alloy, e.g. an aluminium-magnesium-scandium alloy marketed under the trade name "Scalmalloy", a titanium alloy, e.g. Ti6Al4V, a steel alloy, in particular 316L stainless steel, or a nickel-based alloy marketed under the trade name "Inconel". As an alternative, the main body and the at least one closure device may be made of a plastics material. In particular, the main body may be made of a fibre-reinforced plastics material such as printed CFRP material.

[0073] Figure 4 shows a schematic perspective view of a silencer 1 for a firearm 100 according to a further exemplary embodiment of the present invention. The silencer 1 in Figure 4 may have substantially the features of the silencer 1 from Figure 3 unless described other-

wise.

[0074] In this case and by way of example, the outer wall 21 is in the form of a lateral surface with at least one cutout 22, the at least one cutout 22 being reversibly closable by means of the at least one closure device 10. For example, each expansion chamber 4 may be assigned at least one cutout 22 or a single cutout 22. Furthermore, each expansion chamber 4 may be assigned at least one closure device 10 or a single closure device 10.

[0075] As illustrated by way of example in Figure 4, the closure devices 10 may be arranged in multiple rows, in particular offset from one another.

[0076] Figure 5 shows an enlarged sectional view of an outlet opening 32 of a silencer 1, the outlet opening 32 being closeable by a closure device 10.

[0077] The at least one closure device 10, i.e. the at least one closing mechanism, may be located at the outlet opening 32 and have a concertina-like structure. The concertina-like structure can be located, i.e. formed, in particular on a transition region from the main structure 2 to the closure device 10, in order to make it easier for the closure device 10 to close in combination with a relatively large outlet opening 32. Furthermore, the concertina-like structure can positively influence an elastic deformability.

[0078] After a shot, the closure device 10 can change into the closed position, illustrated in Figure 5 by way of example in dashed line, for example by means of a suction effect exerted by the bullet and/or by means of the high pressure in the channel 3.

[0079] As an alternative, the at least one closure device 10 may for example have an iris-like structure or be in the form of an iris diaphragm. The iris diaphragm comprises, by way of example, multiple leaves which can be conjointly rotated inwards or outwards via a mechanism. Each leaf can be mounted on a pin, the leaves being connected to a ring via a respective further pin, in order that they move conjointly. As a further alternative, the at least one closure device may have a flower-like form, the flower-like closure device being able to close like a flower. For example, the at least one closure device 10 may change between an open position and a closed position depending on a pressure ratio between a pressure in the channel 3 and an ambient pressure.

[0080] This closure device 10 located at the outlet opening 32 can optionally be provided on the silencer 1 from Figure 1, Figure 3, Figure 4 or comparable configurations.

[0081] Figures 6A and 6B show results of a linear static simulation of deformations of the closure device 10 when a single shot is fired from a firearm 100.

[0082] A linear static finite element analysis was carried out for a single isolated closure device, i.e. cover opening. The effect of this was a sensible result and a visualization of the deformations in the form of dark regions. The elastic deformation shown in Figure 6B is caused by the pressure generated by a single shot from a firearm. The pressure that a silencer 1 must withstand

depends on the type and size of a calibre or ammunition. In general, larger calibres generate a higher pressure and the use of supersonic bullets generates a higher pressure than subsonic bullets. By way of example, Figure 6A shows an elastically deformed position of the closure device 10 in the closed position in relation to a standard position of the closure device 10, for example the open position, with the standard position being illustrated as seethrough and with dashed lines.

[0083] For example, the closure device 10 may be integral with the main body 2 and elastically deformable. Therefore, because of its elastic deformability, the closure device 10 can change reversibly between the open position and the closed position.

[0084] As illustrated by way of example in Figures 6A and 6B, the closure device 10, i.e. the closing mechanism, may have a board-like form. The board-like structure advantageously makes it possible to arrange a very high number of closure devices 10 on the outer wall 21, in particular on the lateral surface of the outer wall 21. This makes it possible to increase an outflow rate of the fluid by maximizing the number of cutouts 22, a form of each cutout 22 corresponding to a form of the closure device 10. In particular, the very high number of closure devices 10 may be aligned and oriented along the longitudinal axis L.

[0085] The closure device 10 may also for example have a free end 11 aligned in the direction of the outlet opening 32. If there is a multiplicity of closure devices 10, they may be conjointly oriented in the direction of the outlet opening 32. The cutout 22 may substantially correspond for example in its form to the closure device 10, which is to say have a similar form to the closing closure device 10.

[0086] Optionally, the closure device 10 may have an arcuate, i.e. curved, starting form in the open position, so that the expansion chambers 4 are open at ambient pressure. The curved starting form allows the fluid to flow out of the expansion chambers 4 even more easily. As soon as the pressure in the expansion chamber 4 is considerably higher than the ambient pressure, the high pressure causes the closure device 10 to elastically deform into the closed position, i.e. the closed state.

[0087] The closure device 10 may also be polygonal, quadrangular, round or elliptical. In this way, the outflow rate of the water can be controlled. For example, as viewed in a cross section, the closure device 10 may engage in the cutout 22 of the main structure 2 like a wedge, so that a resulting contact surface between the closure device 10 and the cutout 22 in the closed position optimizes a sealing effect. This means that the closure device 10 can engage in a frame of the cutout 22 in the manner of a wedge, in order to achieve as high a sealing effect as possible. The closure device 10 may be designed in such a way that substantially a surface-area contact, and not just a linear contact, between the closure device 10 and the cutout 22 occurs. The closure device 10 and the cutout 22 interacting with the closure device

10 can thus form a window design. A thickness of the at least one closure device 10 may be selected such that the at least one closure device 10 can withstand conventional pressures in the silencer 1 for a firearm 100. Dimensions of the at least one closure device 10 may be provided for example depending on a respective height, which is to say a respective spacing between two leaves, of the multiplicity of expansion chambers 4, as illustrated for example in Figure 3. The respective height is, however, not limited to the spacing between two leaves, but rather can extend over two or more expansion chambers 4, with a leaf, which can also be referred to as intermediate leaf, that crosses the closure device 10 having, in the region of the outer wall, a gap so that the water can be released from the two or more expansion chambers 4 through the closure device 10.

[0088] The closure device described in connection with Figures 6A and 6B may be provided in particular in the silencer 1 from Figure 1, Figure 3, Figure 4 or comparable configurations.

[0089] Figure 7 shows schematic front views of five different alternative configurations V0_1, V2_1, V2_5, V3_8 and V3_9 of a closure device 10 of a silencer 1 according to further exemplary embodiments of the present invention. Figure 8 shows schematic side views of the five different alternative configurations V0_1, V2_1, V2_5, V3_8 and V3_9 of the closure device 10 from Figure 7. Figure 9 shows schematic plan views of the five different alternative configurations V0_1, V2_1, V2_5, V3_8 and V3_9 of the closure device 10 from Figures 7 and 8. Figure 10 shows schematic plan views of the five different alternative configurations V0_1, V2_1, V2_5, V3_8 and V3_9 of the closure device 10 in cross section from Figures 7, 8 and 9.

[0090] The alternative configurations V2_5 and V2_1 have, for example, a board-like closure device 10. In particular, the closure device 10 in the alternative configuration V2_5 may be realized as a cross-sectionally flat structure. The free end 11 may be rectangular or square. Furthermore, the closure device 10 may have a narrowing and/or a curvature in a transition region to the main structure 2, in order to provide or increase the elastic deformability.

[0091] The alternative configuration V0_1 has, for example, a board-like closure device 10. The free end 11 may be rounded or dome-shaped.

[0092] The alternative configurations V3_8 and V3_9 have, for example, a blade-like structure connected to the main body 2, i.e. the main structure, via a bar 12. A surface of the blade-like structure can be designed such that a certain minimum pressure inside the expansion chamber 4 is sufficient to elastically deform the closure device 10 into the closed position. Furthermore, the bar 12 can be designed such that it affords the deformation necessary for shooting and withstands a minimum number of shooting loads. This means that a service life and robustness of the at least one closure device 10 can be set via the bar 12. A fatigue strength can be taken into

account in the design of the at least one closure device 10, in order to ensure that the minimum number of shooting loads can be achieved without structural failure.

[0093] As an alternative or in addition, the closure device 10, i.e. the closing mechanism, may have a concertina-like structure. The concertina-like structure can be located, i.e. formed, in particular on a transition region from the main structure 2 to the closure device 10, in order to make it easier for the closure device 10 to close in combination with a large cutout 22. Furthermore, the concertina-like structure can positively influence an elastic deformability.

[0094] Figure 11 shows, by way of example, a firearm 100 in the form of a rifle with a barrel 110. The silencer 1 is located in the region of a muzzle of the barrel 110 and can in particular be fastened to the barrel 110, e.g. via the optional connecting portion. In Figure 11, the silencer 1 is used to damp a muzzle blast which occurs owing to a gas flow produced by the explosion of a propellant for accelerating a projectile. This gas flow is conveyed in the above-described way for example through the openings 5 into the expansion chambers 4, in order to expand there.

[0095] Figure 12 illustrates, by way of example and schematically, a method for producing the silencer 1. In the process, the main body 2 of the silencer 1 is created, i.e. built up, in layers by an additive production method. The silencer can in particular have the features of the sound absorber 1 from Figure 1, 2, 3 or 4.

[0096] Figure 12 schematically shows, by way of example, a 3D printing apparatus 200. To additively manufacture the main body 2, modelling material M is fed to the 3D printing apparatus 200, as schematically depicted in Figure 12. To this end, the modelling material M may be in powder form, for example. In principle, the present invention provides a wide variety of possible ways of liquefying the modelling material M which involve the selective local introduction of heat into deposited modelling material M. Especially the use of lasers and/or particle beams, e.g. electron beams, is advantageous because that makes it possible to generate heat very selectively and controlledly. The additive production method can thus be selected for example from the group comprising selective laser sintering, selective laser melting, selective electron beam sintering and selective electron beam melting, or the like. In principle, however, any additive method can be used, such as deposition welding.

[0097] The method for producing the silencer 1 will be explained below by way of example in connection with selective laser melting (SLM), during which the modelling material M is applied in powder form to a work platform 201 of the 3D printing apparatus and selectively liquefied by local laser irradiation with a laser beam 202, resulting in a cohesive main body 2 after cooling.

[0098] An energy source in the form of a laser 203, for example an Nd:YAG laser, emits a laser beam 202 location-selectively onto a specific part of a powder surface of

the powdered modelling material M, which lies on the work platform 201 in a working chamber 204. For this, it is possible to provide an optical deflection apparatus or a scanner module, such as a movable or tiltable mirror 205, which depending on the position to which it is tilted deflects the laser beam 202 onto a specific part of the powder surface of the modelling material M. At the point of incidence of the laser beam 202, the modelling material M is heated, so that the powder particles are locally melted and form an agglomerate as they cool. A provided digital model of the main body 2, which might be prepared further still, is taken as a basis for the laser beam 202 to sweep the powder surface. After the selective melting and local agglomeration of the powder particles in the surface layer of the modelling material M, excess non-agglomerated modelling material M can be separated out. After that, the work platform 201 is lowered by means of a lowering piston 206 (see arrow A200 in Figure 12) and a powder feed 207 or another suitable device is used to transfer new modelling material M from a reservoir into the working chamber 204. In this way, in an iterative generative build-up process, a three-dimensional sintered, i.e. "printed", main body 2 is produced in layers from agglomerated modelling material M. The surrounding powdered modelling material M can serve to support that part of the main body 2 that has been built up to this point. The continuous downward movement of the work platform 201 causes the main body 2 to be produced by creating a model in layers. Figure 12 illustrates by way of example that the main body 2 is built up in layers along the longitudinal axis L, starting with the optional plenum 6.

[0099] Although the present invention has been explained above by way of example on the basis of exemplary embodiments, it is not restricted thereto, and instead can be modified in a wide variety of ways. In particular, combinations of the preceding exemplary embodiments are also conceivable.

List of reference signs

[0100]

1	Silencer
2	Main body
3	Channel
4	Expansion chambers
5	Opening
6	Plenum
7	Connecting portion
10	Closure device
11	Free end of the closure device
12	Bar
21	Outer wall
22	Cutout
31	Inlet opening
32	Outlet opening
100	Firearm
110	Barrel

200	3D printing apparatus
201	Work platform
202	Laser beam
203	Laser
204	Working chamber
205	Mirror
206	Lowering piston
207	Powder feed
A200	Arrow
G	Flow direction
L	Longitudinal axis
M	Modelling material
R	Radial direction

15 Claims

1. Silencer (1) for a firearm (100), comprising:

a main body (2) which defines a longitudinal axis (L) and which contains a channel (3), extending along the longitudinal axis (L) between an inlet opening (31) and an outlet opening (32), and a multiplicity of expansion chambers (4) located one after another along the longitudinal axis (L), the expansion chambers (4) each having an opening (5) next to the longitudinal axis (L); and at least one closure device (10) which is connected to the main body (2), is located on an outer wall (21) of the main body (2) and is designed to reversibly close at least one region of the main body (2).

2. Silencer (1) according to Claim 1, wherein the outer wall (21) has a lateral surface with at least one cutout (22), the at least one cutout (22) being reversibly closable by means of the at least one closure device (10).

3. Silencer (1) according to Claim 1 or 2, wherein the at least one closure device (10) changes between an open position and a closed position depending on a pressure ratio between an internal pressure in the expansion chamber (4) and an ambient pressure.

4. Silencer (1) according to Claim 3, wherein the at least one closure device (10) has an arcuate, i.e. curved, starting form in the open position, so that the expansion chambers (4) are open at ambient pressure.

5. Silencer (1) according to one of the preceding claims, wherein in the closed position, a predetermined leakiness in a region of contact of the at least one closure device (10) with the at least one cutout (22) is set by means of a porosity of the contact region and/or an increased surface roughness in the contact region.

6. Silencer (1) according to one of the preceding

claims, wherein the at least one closure device (10) is integral with the main body (2) and elastically deformable.

7. Silencer (1) according to one of the preceding claims, wherein the at least one closure device (10) has a respective free end (11) aligned in the direction of the outlet opening (32). 5
8. Silencer (1) according to one of the preceding claims, wherein the at least one closure device (10) is polygonal, quadrangular, round or elliptical. 10
9. Silencer (1) according to one of the preceding claims, wherein the at least one closure device (10) is mounted in articulated fashion in each case, so that the at least one closure device (10) can be pivoted relative to the outer wall (21). 15
10. Silencer (1) according to one of the preceding claims, wherein a form and/or a size of the at least one closure device (10) varies along the longitudinal axis (L). 20
11. Silencer (1) according to one of the preceding claims, wherein, in the region of the inlet opening (31) of the channel (3), the main body (2) has a connecting portion (7) for connecting the main body (2) to a tube, in particular to a barrel (110) of a firearm (100). 25
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12. Silencer (1) according to one of the preceding claims, wherein the main body (2) and the at least one closure device (10) are made of a metal alloy, in particular an aluminium alloy, a titanium alloy, a steel alloy or a nickel-based alloy, or are made of a plastics material, in particular a fibre-reinforced plastics material. 35
13. Method for producing a silencer (1) according to one of the preceding claims, wherein the main body (2) is built up in layers by an additive production method. 40
14. Method according to Claim 13, wherein the main body (2) is built up in layers along the longitudinal axis (L). 45
15. Method according to either of Claims 13 and 14, wherein the additive production method comprises a selective laser melting method, an electron beam melting method or a deposition welding method. 50

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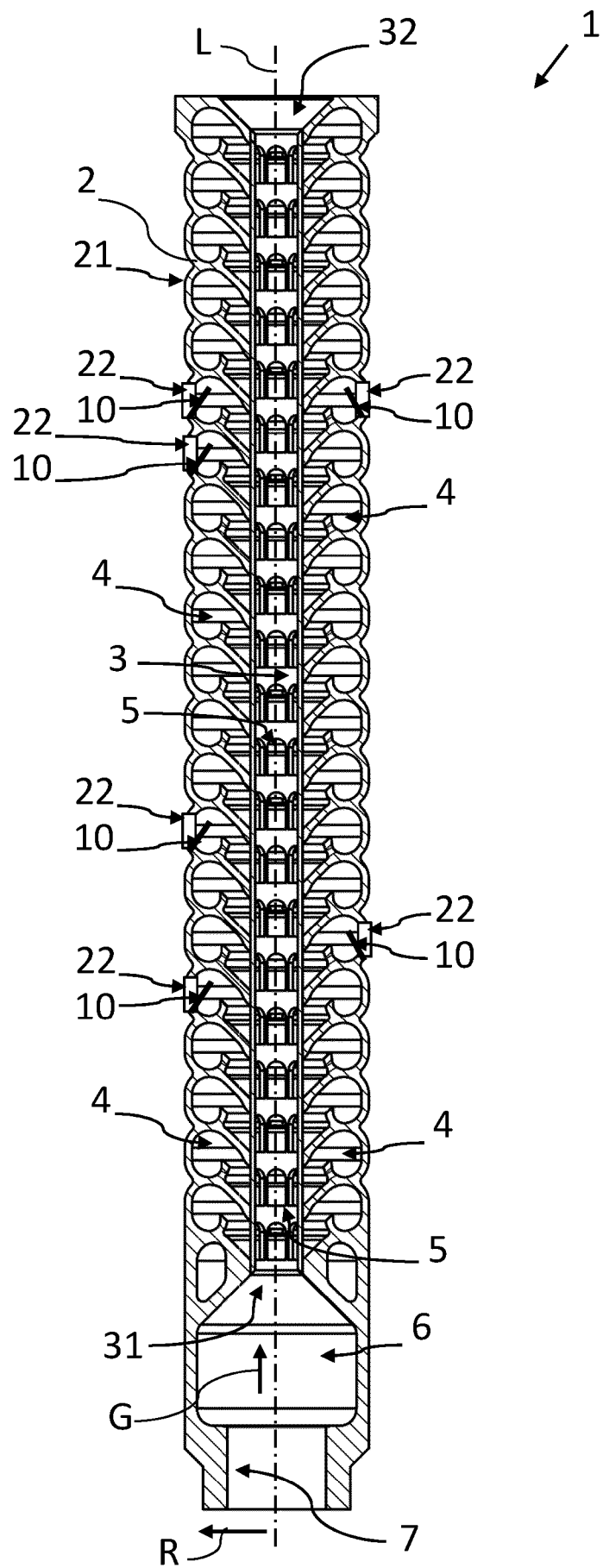


Fig. 1

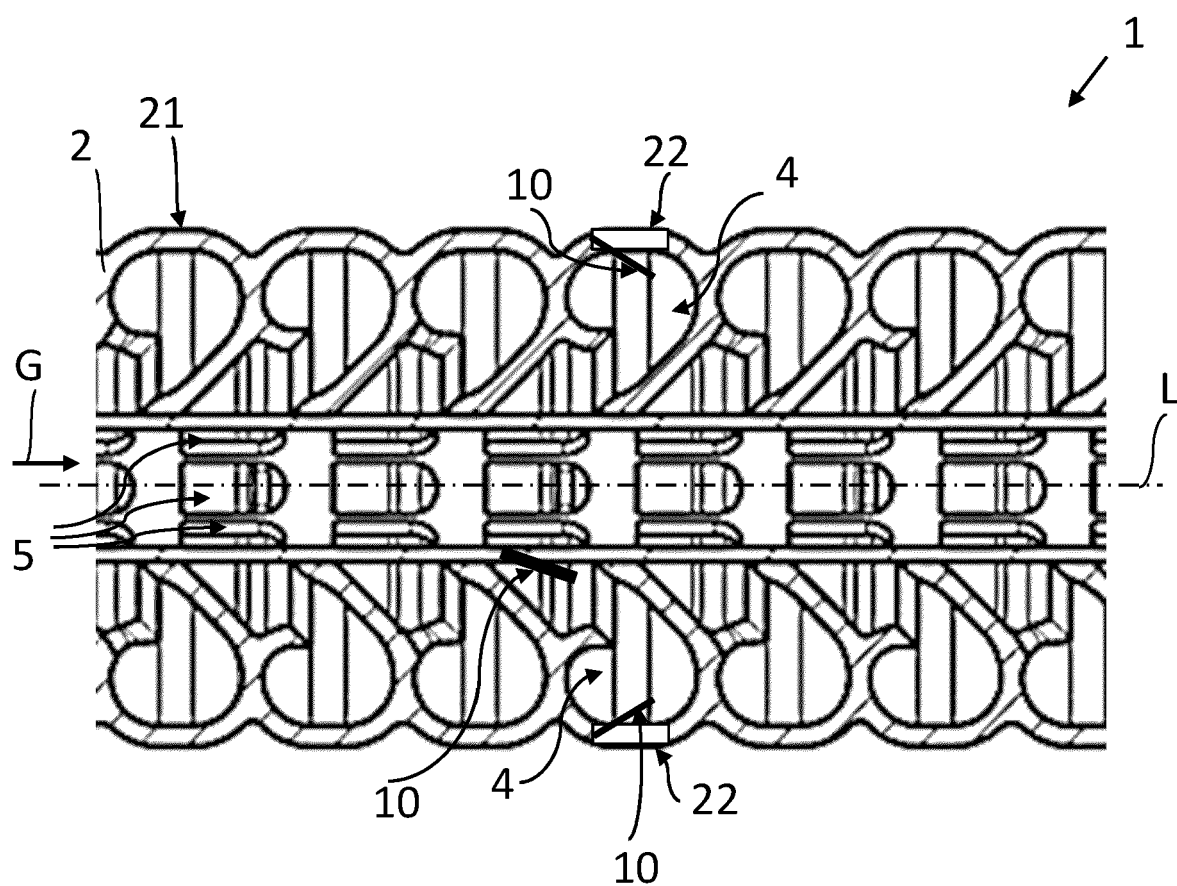


Fig. 2

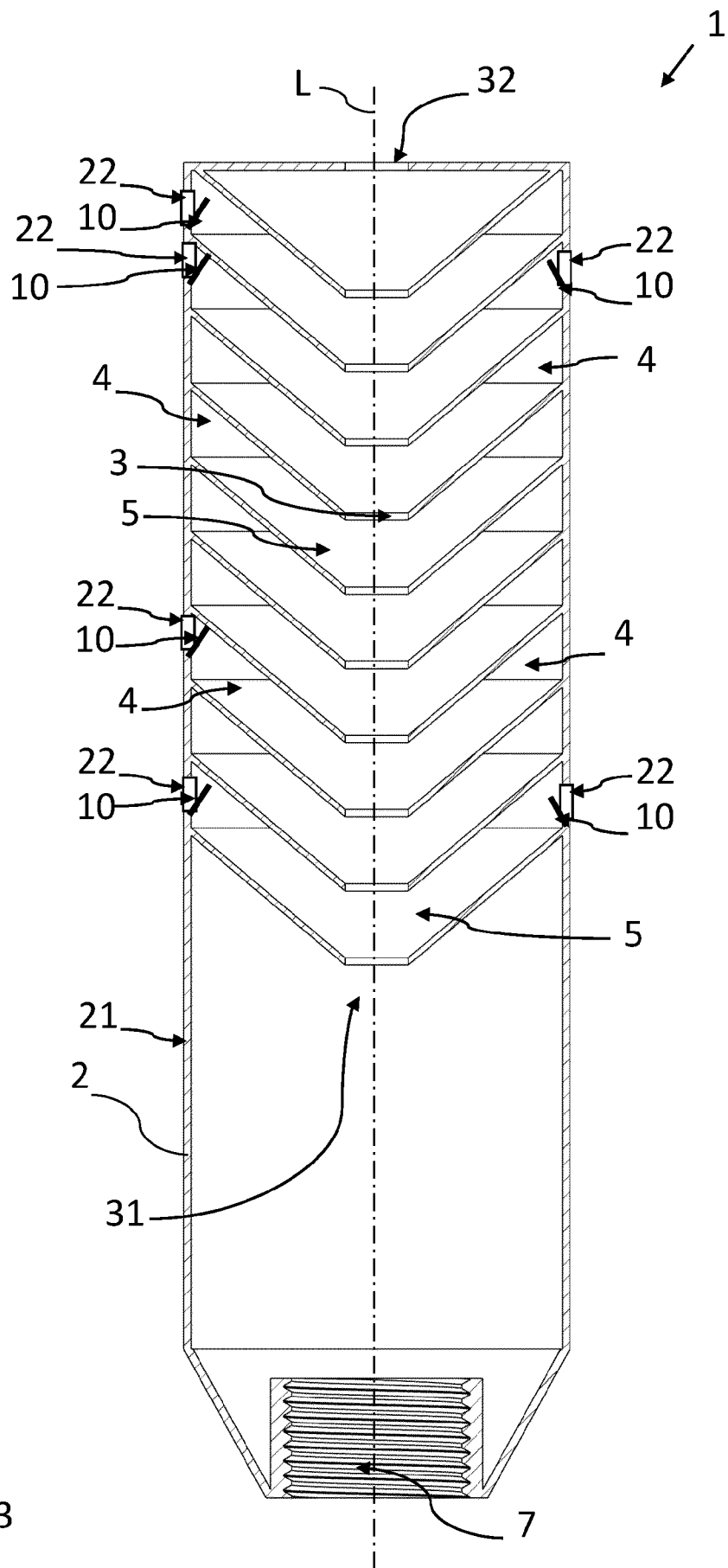


Fig. 3

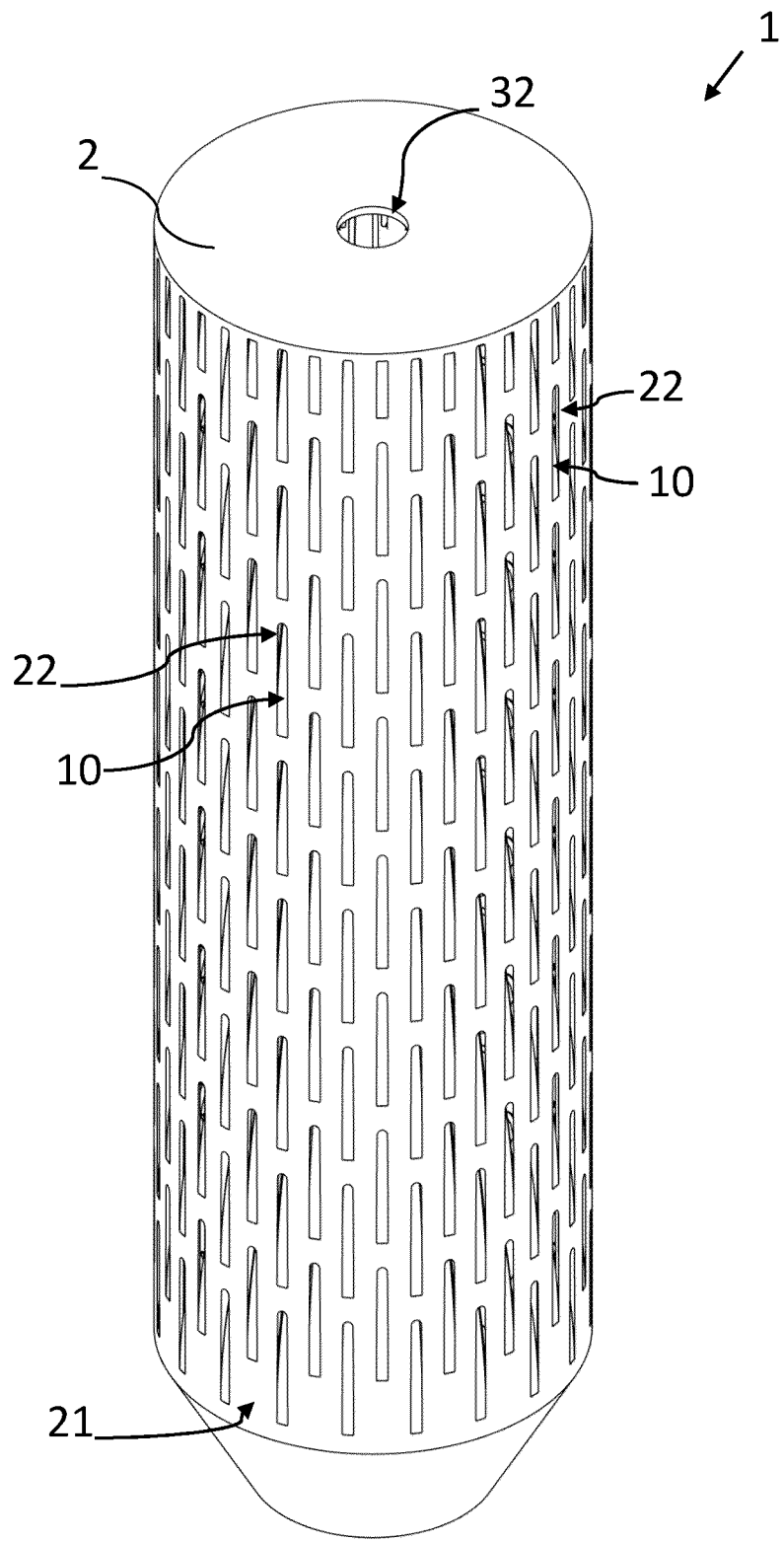


Fig. 4

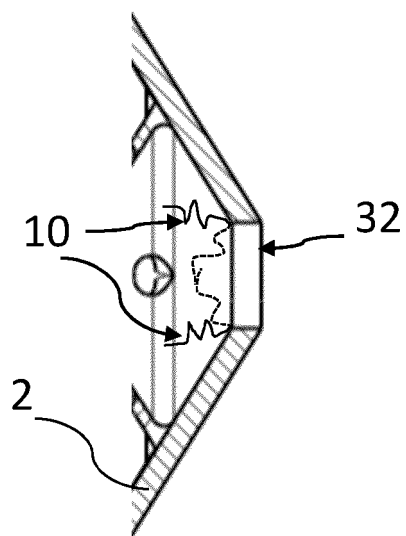


Fig. 5

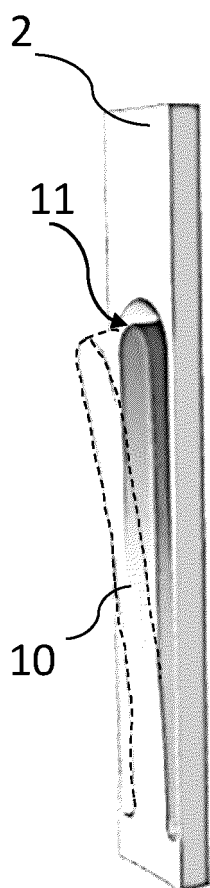


Fig. 6A

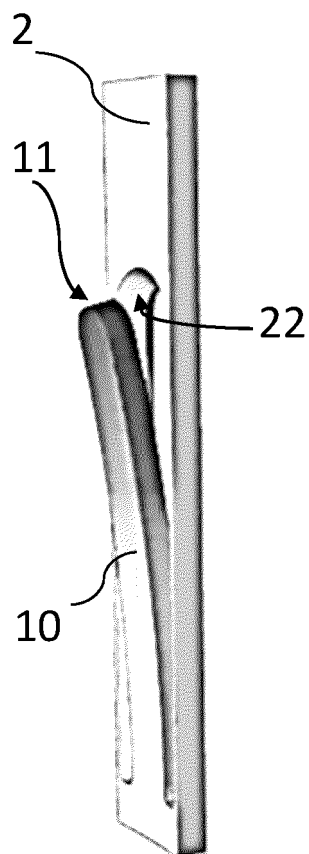
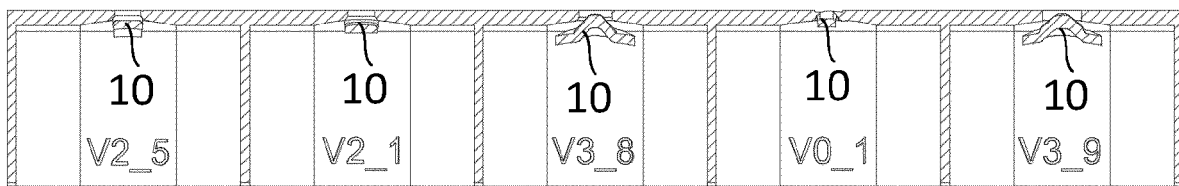
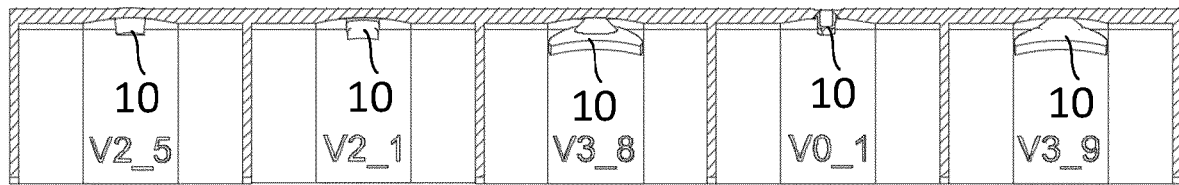
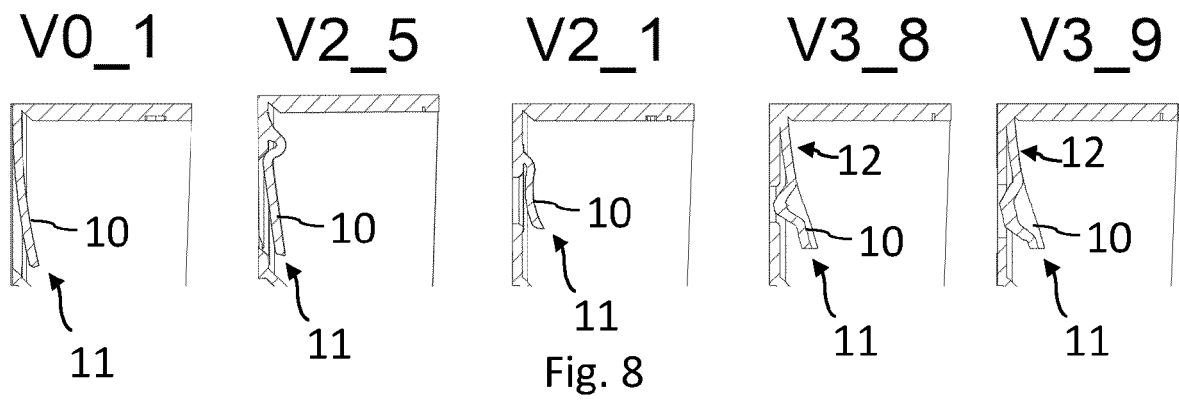
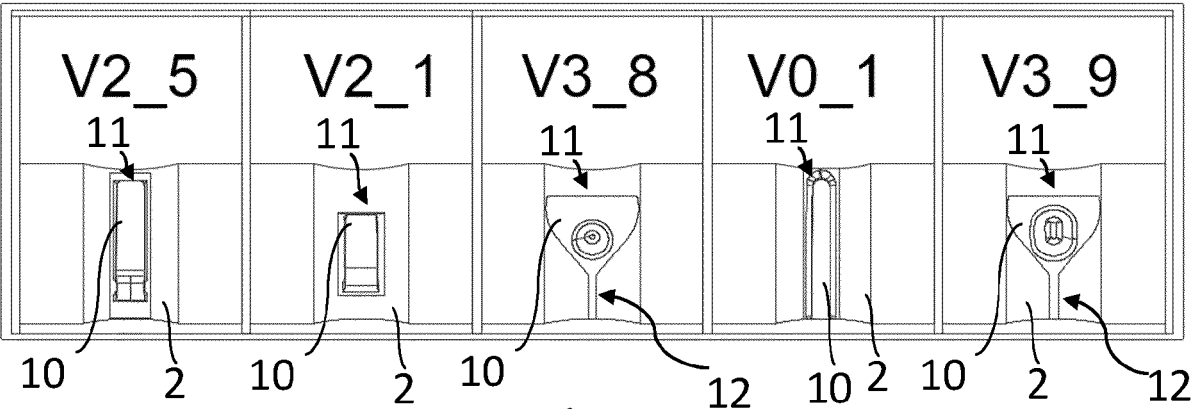


Fig. 6B



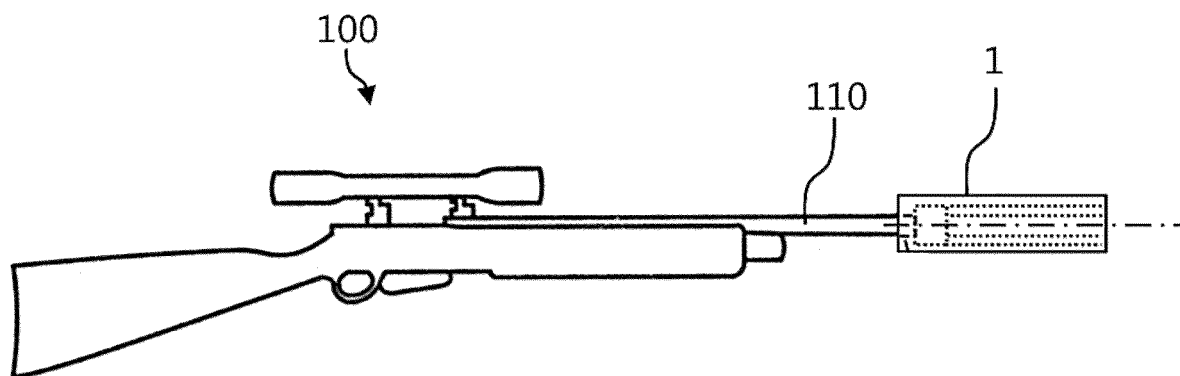


Fig. 11

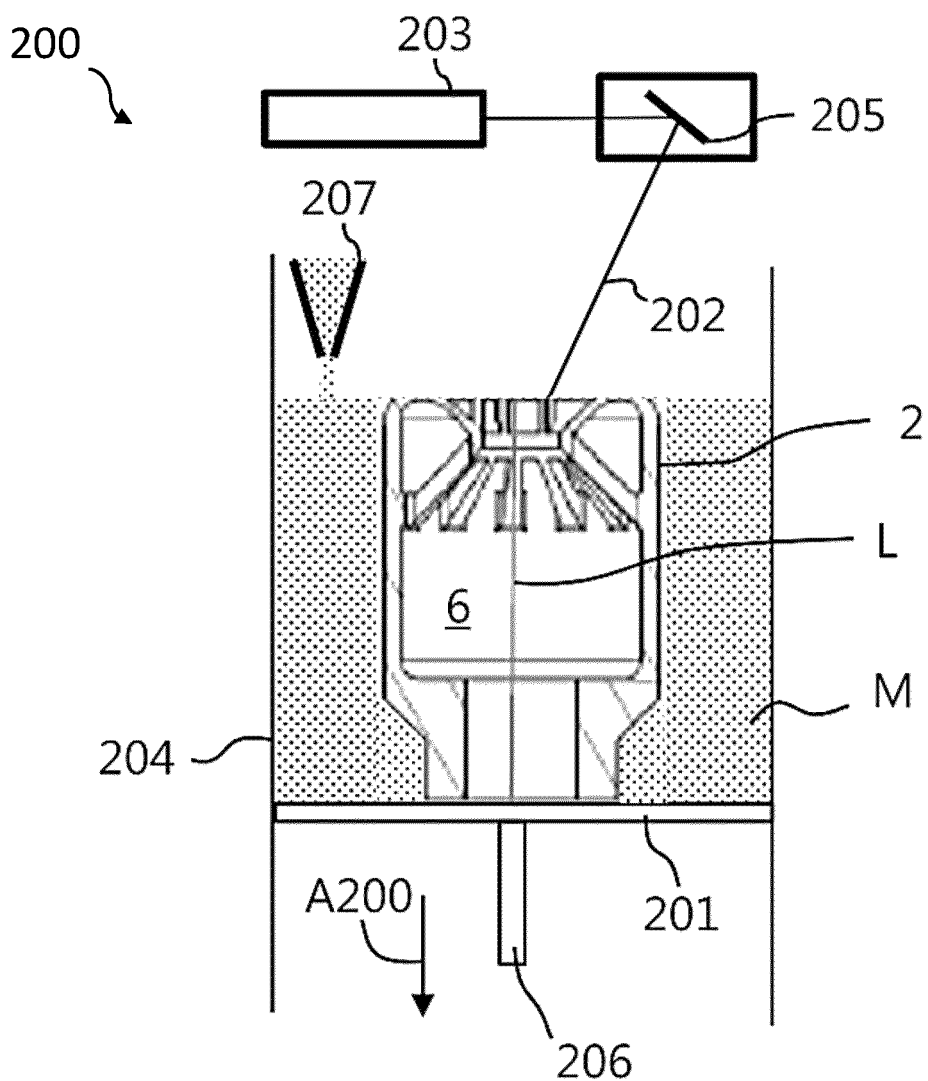


Fig. 12



EUROPEAN SEARCH REPORT

Application Number

EP 25 19 0195

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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
The Hague		14 November 2025	Lahousse, Alexandre
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