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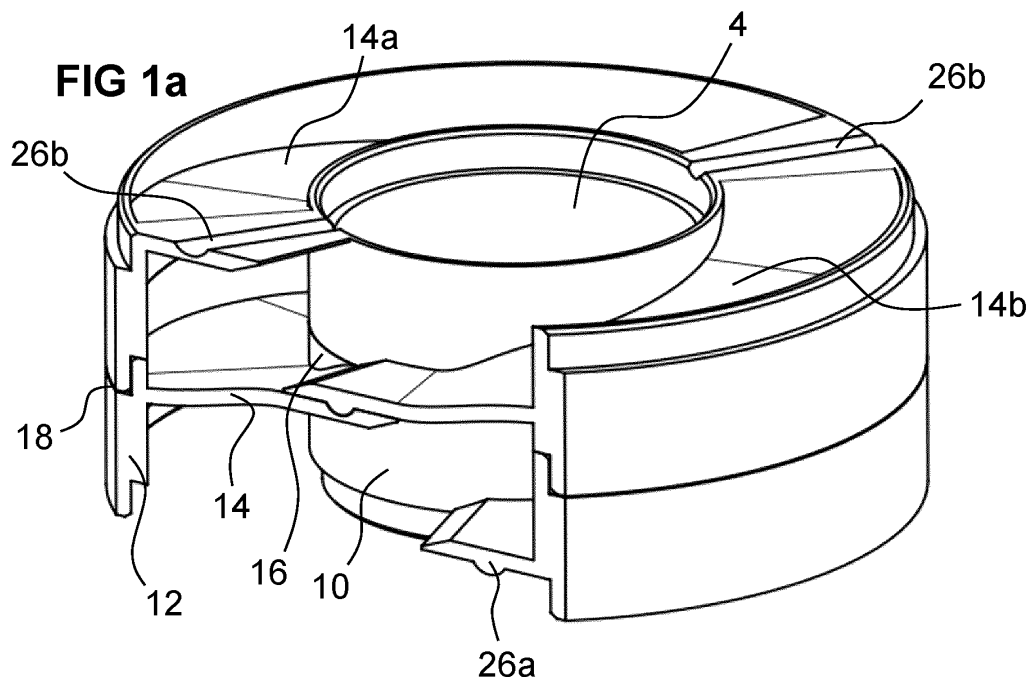
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(54) **SPIRAL MUFFLER**

(57) A spiral muffler (2) comprising a channels housing (8) and formed therein a centre channel (4) and at least one outer spiral channel (6), the channels housing having an inner tube wall (10) surrounding the centre channel (4) and an outer tube wall (12) forming an outer wall of the at least one outer spiral channel (6), the at least one outer spiral channel (6) being formed between the outer tube wall (12) and the inner tube wall (10), the channels housing further comprising at least one spiral wall (14) defining a spiral form of the at least one outer spiral channel (6) spiraling from a first axial side of the

muffler to a second axial side of the muffler. The channels housing is formed of a plurality of stacked muffler modules (3), each muffler module comprising one or more spiral blades (14a, 14b), each spiral blade extending from a first end at a first axial side of the muffler module to a second end (22) at a second axial side of said muffler module, first and second ends of adjacent stacked muffler modules joining together in a contacting manner at said interfaces such that said at least one spiral wall (14) is formed from a plurality of stacked said spiral blades (14a, 14b).

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Description

[0001] The present invention relates to a muffler, in particular a spiral muffler.

[0002] Spiral mufflers are known, for instance, in WO2019216564, EP3985263, and CN201170125. One of the advantages of spiral mufflers is their ability to dampen acoustic waves with negligible influence on airflow compared to typical reflective or absorbing mufflers with perforated and damping materials. Spiral mufflers cancel sounds in a certain frequency band depending on their geometry. The sound cancellation is based on Fano-like interference and the differences in the acoustic impedances of two acoustic channels created by the structure. With different acoustic impedances in the center channel versus the spiraled outer channel, the waves from the two channels merge and for specific frequency bands cancel each other through destructive interference. The transmission loss effect appears also for harmonic frequency bands therefore if the improvement of the transmission loss is achieved for one frequency band in low frequencies, the effect is repeated in higher frequency bands in equal distances.

[0003] One of the drawbacks of such spiral mufflers is that they are limited to a specific frequency band for which they are designed. Producing mufflers with different sound cancellation properties for use in different applications or different regions of a device requires different mufflers with variable effectiveness. Changing the size of the respective channels as well as the length of the channels of spiral mufflers requires expensive re-tooling. It limits the use of such mufflers in a wide variety of applications and configurations.

[0004] In view of the foregoing, an object of this invention is to provide a spiral muffler that is economical to produce and that can be easily modified to meet different requirements.

[0005] It is advantageous to provide a spiral muffler that is easy to install in a wide variety of applications.

[0006] It is advantageous to provide a spiral muffler that is robust and reliable.

[0007] It is advantageous to provide a muffler that provides highly effective sound cancellation for a frequency band of interest.

[0008] Objects of the invention have been achieved by providing a system according to claim 1.

[0009] Dependent claims set out various advantageous features of embodiments of the invention.

[0010] Disclosed herein is a spiral muffler comprising a channels housing and formed therein a centre channel and at least one outer spiral channel, the channels housing having an inner tube wall surrounding the centre channel and an outer tube wall forming an outer wall of the at least one outer spiral channel, the at least one outer spiral channel being formed between the outer tube wall and the inner tube wall, the channels housing further comprising at least one spiral wall defining a spiral form of the at least one outer spiral channel spiraling from a first axial side of the muffler to a second axial side of the muffler.

[0011] The channels housing is formed of a plurality of stacked muffler modules, each muffler module comprising a plurality of spiral blades, each spiral blade extending from a first end at a first axial side of the muffler module to a second end at a second axial side of said muffler module, first and second ends of adjacent stacked muffler modules joining together in a contacting manner at said interfaces such that said at least one spiral wall is formed from a plurality of stacked said spiral blades.

[0012] In an advantageous embodiment, the centre channel extends in an axial linear direction.

[0013] In an advantageous embodiment, the inner tube wall has a circular, square, ovoid or polygonal cross-sectional profile.

[0014] In an advantageous embodiment, the outer tube wall has a circular, square, ovoid or polygonal cross-sectional profile.

[0015] In an advantageous embodiment, each spiral blade extends angularly around the centre axis between a first end edge of the spiral blade to a second end edge of the spiral blade by an angle β that is less than 360° divided by a number n of spiral blades: $\beta < 360^\circ/n$, configured to form a gap seen in an axial direction, said gap being between a first end edge of the spiral blade and a second end edge of the spiral blade if the number n of spiral blades is one, and if the number n of spiral blades is greater than one, the gap seen in an axial direction, is formed between a first end edge of one of the spiral blades and a second end edge of another one of the spiral blades.

[0016] In an advantageous embodiment, the gap has a rotational angle ϕ in a range between 1° and 10° , preferably in a range between 1° and 5° .

[0017] In an advantageous embodiment, the first end of each of the spiral blades comprises a first locating element and the second end of each of the spiral blades comprises a second locating element complementary to the first locating element such that when modules are stacked together the first and second locating elements register and locate the stacked modules angularly with respect to each other.

[0018] In an advantageous embodiment, one of the first and second locating elements is a protrusion and the other of the first and second locating elements is a complementary recess.

[0019] In an advantageous embodiment, the tubular wall joining interfaces and/or the interfaces between the stacked ends of the spiral blades are bonded adhesively or welded together.

[0020] In an advantageous embodiment, joining interfaces and/or the interfaces between the stacked ends of the spiral

blades, comprise sealing joints.

[0021] In an advantageous embodiment, each muffler module is formed by molding of a thermoplastic or thermosetting polymer.

[0022] In an advantageous embodiment, the muffler comprises a two-component molded polymer structure.

[0023] In an advantageous embodiment, the plurality of muffler modules includes at least first and second muffler modules with different axial heights $L1$, $L2$, $L3$, $L4$.

[0024] In an advantageous embodiment, sound damping materials are provided on surfaces bounding the centre channel and/or said at least one outer spiral channel.

[0025] In embodiments:

- > both the centre and the one or more spiral outer channels are open at both axial ends, or
- > the centre channel and the one or more outer spiral channels are closed by an end wall at one axial end.

[0026] In an advantageous embodiment, the plurality of muffler modules is tuned to a target frequency cancellation band by adjusting parameters of any one or more of inner tube cross section surface area Si , outer tube cross section area So , inner tube Ri , outer tube radius Ro , axial heights $L1$ to $L4$ of the stacked muffler modules, number of stacked modules, number of spiral blades and associated number of outer spiral channels.

[0027] Further advantageous features of the invention will be apparent from the following detailed description of embodiments of the invention and the accompanying illustrations.

Brief description of the figures

[0028]

Figure 1a is a perspective view with partial cutaway of a muffler having stacked muffler modules according to an embodiment of the invention, whereby in this example the muffler has two outer spiral channels;

Figure 1b is a side view of the embodiment of figure 1a;

Figure 1c is a top view of the embodiment of figure 1a;

Figure 1d is a perspective view of a muffler having stacked muffler modules according to the embodiment of figure 1a, but in a greater number;

Figure 1e is a perspective exploded view of the muffler of figure 1d;

Figure 2a is a perspective view of a muffler having stacked muffler modules according to another embodiment of the invention, whereby in this example the muffler has a single outer spiral channel;

Figure 2b is a perspective exploded view of the muffler of figure 2a;

Figure 3a is a perspective view of a muffler having stacked muffler modules according to another embodiment of the invention, whereby in this example the muffler has a three outer spiral channels;

Figure 3b is a perspective exploded view of the muffler of figure 3a;

Figures 4a to 4d are cross-sectional views of different embodiments of mufflers according to the invention, showing mufflers with different numbers of stacked modules and modules of different heights;

Figures 5a and 5b are perspective schematic views of a molding die and a module of a muffler according to an embodiment of the invention;

Figure 6a is a perspective view of another embodiment of a muffler according to the invention;

Figure 6b is a perspective exploded view of the muffler of figure 6a;

Figure 7 is a simplified plan view of a separating structure with a plurality of mufflers according to an embodiment of the invention;

Figure 8 is a cross-sectional view of a muffler having stacked muffler modules according to an embodiment of the invention, whereby in this example the muffler centre and outer spiral channels have a closed axial end.

[0029] Referring to the figures, a muffler 2 comprises a plurality of muffler modules 3 stacked one upon the other in an axial direction A . The plurality of stacked muffler modules 3 forming the muffler 2 may comprise muffler modules of identical dimensions, or at least two of the muffler modules of the stack may have dimensions that differ from each other. In particular, an axial height $L1$, $L2$, $L3$, $L4$ of the muffler module, illustrated in figures 4a-4d, may vary from one muffler module to the next, and/or the internal geometry of the muffler modules may vary, in particular the shapes of the channels within the muffler modules may vary from one muffler module to the next.

[0030] The muffler 2 comprises a centre channel 4 and at least one outer spiral channel 6 spiraling around the centre channel 4. The centre channel 4 is configured for the transmission of sound waves with a different acoustic impedance than the one or more outer spiral channels 6, leading to destructive interference of the sound exiting the outlet end of the muffler from the inlet end through which the sound enters. This principle of destructive interference for a given frequency band is

per se well known in the field of mufflers.

[0031] As mentioned above, the muffler may have one or more outer spiral channels, for instance:

- figures 1a to 1e illustrate an example of a muffler comprising two outer spiral channels,
- figures 2a, 2b illustrate an example of a muffler comprising one outer spiral channel, and
- figures 3a to 3b illustrate an example of a muffler comprising three outer spiral channels.

[0032] The length of outer spiral channel(s) 6 and cross-sectional area of the outer spiral channel(s) 6, compared to the length and cross-sectional area of the centre channel 4, is adapted for a particular frequency band for cancellation of sound. Thus, the number of modules stacked upon each other, which changes the length of the centre channel 4 and outer spiral channel(s) 6, will effect the sound cancellation properties of the muffler. In embodiments with one, two, three or more outer spiral channels, each outer spiral channel may be adapted for cancellation of a same frequency band with respect to the centre channel, or each outer spiral channel may be adapted for cancellation of a slightly different frequency band with respect to the centre channel, such that a larger frequency band for cancellation may be covered.

[0033] The centre and outer channels 4, 6 are formed by a channels housing 8 comprising

- an inner tube wall 10 forming a boundary between the centre channel 4 and outer spiral channel(s) 6,
- an outer tube wall 12 defining an outer boundary of the outer spiral channel(s) 6, and
- at least one spiral wall 14 extending between the inner tube wall 10 and outer tube wall 12 to define the spiral form of the at least one outer spiral channel 6 as it spirals through the muffler from a first axial and to a second axial end.

[0034] In the illustrated embodiments, the inner tube wall 10 has a circular cross-sectional profile, and the outer tube wall 12 also has a circular cross-sectional profile the inner tube wall 10 (figures 1a to 3c), or the inner tube wall 10 has a square cross-sectional profile, and the outer tube wall 12 also has a square cross-sectional profile (figures 6a, 6b). Nevertheless, within the scope of the invention, the cross-sectional profiles of the inner and outer walls may include other cross-sectional shapes such as ovoid, and polygonal for instance pentagonal, hexagonal, octagonal.

[0035] It may further be noted that the cross-sectional shape of the inner tube wall and the outer tube wall may also be different from each other, for instance the inner tube wall may have a polygonal shape and the outer tube wall a circular cross-sectional shape, or vice-versa the inner tube wall has a circular shape and the outer tube wall a polygonal for instance a hexagonal shape.

[0036] In an embodiment, as illustrated for instance in figure 7, a plurality of mufflers 2 may be provided in a separating structure 1, for instance a wall, a panel, a door, to enable a larger amount of air or other gases to pass from one side of the structure to the other. Also, mufflers with different cancellation characteristics may be positioned in different positions depending on the properties and sources of sound to be cancelled. In particular, the noise frequencies in a certain environment may differ in frequency and amplitude depending on the position of the separating structure (panel, wall) relative to the sound sources.

[0037] In embodiments where the outer tube wall has an outer shape of a hexagon or square, a plurality of mufflers may be mounted assembled together in a compact configuration with minimal spacings therebetween to form a muffler assembly with a larger cross sectional surface area (the cross section being taken orthogonal to the axial direction defining the direction of the centre channel) than a single muffler.

[0038] A plurality of mufflers assembled together or positioned at different positions in a structure between a side facing a source of acoustic waves and a side in which the acoustic waves over a certain frequency band should be cancelled, may have mufflers of different configurations, or of similar or identical configurations.

[0039] The inner and outer tube walls each have, at both axial ends, joining interfaces 16, 18 respectively that close the inner and outer tube walls around the respective channels preferably in a sealing manner when the modules are stacked one on top of the next. The joining interface may in particular comprise a stepped shape that allows the stacked modules to be centered with respect to the each other. The joining interface may be fixed together by adhesive bonding, welding, soldering, press-fitting or by mechanical clamping, for instance by means of elastic latches and complementary latching shoulders that clip together when the modules are stacked one of the top of the other. The joining interface may, in certain variants, be provided with a sealing ring, for instance of a soft elastic material, between the joining interfaces of the inner and outer tubular walls. The sealing rings are particularly useful in embodiments where the modules are mechanically clamped together with latches, screws, or other clamping and fixing devices.

[0040] The spiral wall 14 of the muffler is formed by spiral blades 14, 14a, 14b, 14c whereby each muffler module comprises the same number of spiral blades that as there are spiral channels. For a number *n* of spiral blades, there are the number *n* of outer spiral channels. Therefore, if there are two spiral blades 14a, 14b, there are two outer spiral channels 6, and if there are three spiral blades 14a, 14b, 14c, there are three outer spiral channels 6.

[0041] The spiral blades are configured to enable the muffler module to be easily molded in a molding die 40 having two separable die parts 40a, 40b in a simple configuration as will be better understood from the description below.

[0042] Each spiral blade 14, 14a, 14b, 14c extends in a spiraling manner from a first end 20 at one axial side of the muffler module, to a second end 22 at a second axial side of the muffler module. The first end 20 starting from a first end edge 28 extends to the second end 22 ending at a second end edge 30. The rotational angle β from the first end edge 28 to the second end edge 30 is less than $360^\circ/n$.

[0043] For instance, in a preferred embodiment with two spiral blades 14a, 14b forming two outer spiral channels, the rotational angle β from the first end edge 28 to the second end edge 30 is less than 180° and greater than 90° , preferably in a range from 160° to 179° , more preferably for a circular cross-sectional shape in a range from 175° to 179° . The angular range of the first and second spiral blades in a preferred embodiment, seen in the axial direction, is symmetrically arranged such that, seen in the axial direction, there is a gap 24 between the first end edges 28 and second end edges 30 of the first and second spiral blades.

[0044] The rotational angle ϕ over which the gap extends, seen in the axial direction, is preferably in a range from 1° to 5° .

[0045] Thus, a two-part molding die 40 can be used to mold (for instance injection mold or compression mold) the muffler module without requiring complex additional extraction pins within the die parts 40a, 40b.

[0046] The muffler module arrangement as described herein is also well suited for forging the muffler module.

[0047] The first end 20 of each spiral blade 14, 14a, 14b, 14c comprises a first locating element 26a and the second end 22 of each spiral blade 14, 14a, 14b, 14c comprises a complementary second locating element 26b. The first locating element 26a of one muffler module engages in the complementary second locating element 26b of another muffler module stacked thereupon. The first and second locating elements may comprise for instance complementary protuberance and recess as illustrated, or any other complementary forms locating rotationally one module with respect to the adjacent stacked module.

[0048] Due to the angle β of less than $360^\circ/n$, for instance less than 180° for a double outer spiral channel embodiment, between the first end edge and second end edge of each spiral blade 14a, 14b, adjacent stacked muffler modules are rotated angularly with respect to each other by an amount corresponding to the difference between the angular range β and $360^\circ/n$ degrees.

[0049] The first and second ends of the spiral blades are configured such that when muffler modules are stacked one upon each other, the first end of a spiral blade of a first muffler module contacts the second end of a spiral blade of the adjacent second muffler module stacked thereagainst, the angular position of one muffler module with respect to the adjacent stacked muffler module being defined by the complementary first and second locating elements 26a, 26b that engage each other.

[0050] The joining interfaces between stacked modules are preferably fixed together in a hermetic manner by adhesive bonding or by welding. The hermetic joining of the interfaces between the muffler modules ensuring that the channels 4, 6, in particular the outer spiral channel(s) 6, is (are) well sealed along the transmission length, reduces noise and uncontrolled losses, thus improving effective destructive interference between the centre channel and outer spiral channel(s) acoustic waves. In other words, sealing of the joining interfaces 16, 18 and of the interfaces between the spiral blades stacked upon each other ensures low loss and thus well controlled transmission of sound through the inner and outer channels for effective and well controlled destructive interferences on the outlet side of the muffler.

[0051] The (centreline) length of an outer spiral channel depends *inter alia* on the pitch of the spiral, and therefore on the axial height of the muffler module for a given number of blades and rotational angle β . The ratio between the length of the outer spiral channel 6 and centre channel 4 may be thus be defined *inter alia* by the axial height of the muffler module **L1**, **L2**, **L3**, **L4**. In a one spiral blade embodiment, the muffler module in essence defines one 360° spiral minus the angular reduction ϕ to provide the molding gap 24. In a two spiral blade embodiment, the muffler module in essence defines one 180° degree spiral minus the angular reduction ϕ to provide the molding gap 24. In a three spiral blade embodiment, the muffler module in essence defines one 120° degree spiral minus the angular reduction ϕ to provide the molding gap 24.

[0052] It may be noted in variants that the angle between the first end edge and second end edge of each spiral blade may be reduced such that each muffler module only constitutes a portion of a $360^\circ/n$ spiral, thus requiring a greater number of stacked modules to perform the same number of spiral turns of the outer spiral channel compared to a muffler module with spiral blades that extend nearly $360^\circ/n$ around the centre channel.

[0053] The first end edge 28 and second end edge 30 of the spiral blades may be provided with a chamfer 29, 31 so as to have a smoother channel surface at the joining interfaces, thus reducing internal reflections and turbulence that may arise due to sharp edges and roughness within the channel surface.

[0054] The acoustic impedance of the centre channel 4 and outer spiral channel(s) 6 may further be defined by the relative inner tube cross section surface area **Si** and outer tube cross section area **So** defined *inter alia* by the radius of the inner tube **Ri** and the radius of the outer tube **Ro**. The acoustic impedance will also be dependent on the axial heights **L1** to **L4** of the stacked muffler modules.

[0055] The plurality of muffler modules may thus be tuned to a large range of desired target frequency cancellation bands by varying parameters of inner tube cross section surface area **Si**, outer tube cross section area **So**, inner tube **Ri**, outer tube radius **Ro** axial heights **L1** to **L4** of the stacked muffler modules, number of stacked modules, number of spiral blades and associated number of outer spiral channels.

[0056] In order to adjust for different noise cancellation requirements but also structural requirements defined by the thicknesses of walls, doors, panels or other separating structures between a first noise bearing environment and a second environment in which certain frequencies should be attenuated, the muffler modules may be stacked with a lower or greater number according to the needs. For instance, a muffler may comprise a stack of only two muffler modules 3, or a stack of a greater plurality of muffler modules 3, for instance 3, 4, 5, 10 or more stacked muffler modules. The modular stacking of muffler modules to form a muffler 2 allows to provide muffler modules with different axial heights **L1, L2, L3, L4** that may be stacked together to adjust for a desired frequency band attenuation. There may for instance be provided a set of muffler modules including three different heights, and therefore three different spiral pitches that may be combined together in various numbers and configurations to change the length of the outer spiral channel compared to the inner channel and thus the frequency bands attenuated by the muffler. Stacking of different height muffler modules in various configurations is illustrated for instance in figures 4a to 4d.

[0057] The muffler module may advantageously be injected from thermoplastic or thermosetting polymers, with or without reinforcement fibers, but may also be molded from other materials such as injectable metal materials. The muffler module may also be manufactured by casting or forging, for instance casting or forging of metal materials.

[0058] Two component molding processes may also be used in order to include a softer polymer component forming the interface at the joining interfaces 18, 16 of the outer tube wall and inner tube wall as well as the interfaces between the stacked ends of the spiral blades.

[0059] Sound damping materials may be provided on the surfaces bounding the centre channel 4 and/or outer spiral channel 6 in order to attenuate certain acoustic frequencies through the muffler, different from the acoustic frequencies that are cancelled by destructive interference exiting the muffler. For instance the sound absorbing layers within the centre channel 4 and outer spiral channel 6 may dampen higher frequency acoustic noise than the frequency bands attenuated by destructive interference passing through and exiting the muffler.

[0060] The sound damping materials may be coated on the channel bounding surfaces for instance by dipping, or spraying, or by co-molding with a two-component molding process.

[0061] The spiral muffler is a resonance-based acoustic metamaterial muffler constructed by coiling up the space around the centre channel while maintaining the subwavelength dimensions of the solution. The broadband transmission loss effect is based on tuning the specific eigenfrequencies of the solution and the surface response to achieve a balanced system's response between subsequent eigenmodes. In the frequency range of interest, the closer the surface response for subsequent modes is to each other, the greater transmission loss values can be obtained. The highest possible transmission loss amplitudes can be observed when the system's responses for two modes are equal. The structure is divided into two main parts: center channel and spiral channels. The primary rule applied to the solution is that each part of the structure is separated from the other in order to achieve the desired effect at the axial end of the structure. The effectiveness of the presented muffler depends on several parameters which influence frequency range and transmission loss amplitude. The solution's effectiveness depends on the outer and inner diameter, length of the muffler, number of blades, and blade pitch. While a similar effective frequency range of solution can be obtained for several configurations of geometrical parameters, obtaining maximum transmission loss amplitude is possible substantially only for one specific parameter configuration. Therefore it is necessary to vary all the parameters described above in order to achieve a specific frequency range while maximizing the transmission loss amplitude. Several dependencies could be considered in order to simplify the characterization of muffler effectiveness:

- > increasing the pitch value (by increasing muffler module height **L1, L2, L3, L4**) and number of blades **n** shifts the operating range towards higher frequencies,
- > increasing the muffler length **L** shifts the range of operation towards lower frequencies,
- > decreasing the inner diameter **Ri** and outer diameter **Ro** ratio shifts the effective range towards the lower frequency region.

[0062] In other embodiments, the muffler 2 may have one axial end of the centre and outer spiral channels that is closed by an end wall 42, which may form part of the muffler for instance as illustrated in figure 8, or which may be a wall of a structure to which the muffler is assembled. In these embodiments, sound travelling in the channels may be reflected, at least partially, off the end wall such that destructive interference occurs at the inlet side where the sound enters the muffler.

List of references

[0063]

Separating structure (e.g. wall, panel, door) 1
Muffler 2

Muffler modules 3

5 Centre channel 4
Outer spiral channel 6
Channels housing 8

10 Inner tube wall 10

Joining interface 16

Step

Outer tube wall 12

15 Joining interface 18

Step

20 Spiral wall 14

Spiral blades 14, 14a, 14b, 14c
(first and second spiral blades)

25 First end 20

First locating element 26a

Protrusion

30 First end edge 28

First chamfer 29

Second end 22

35 Second locating element 26b recess

Second end edge 30

First chamfer 31

40 Molding gap 24

End wall 42

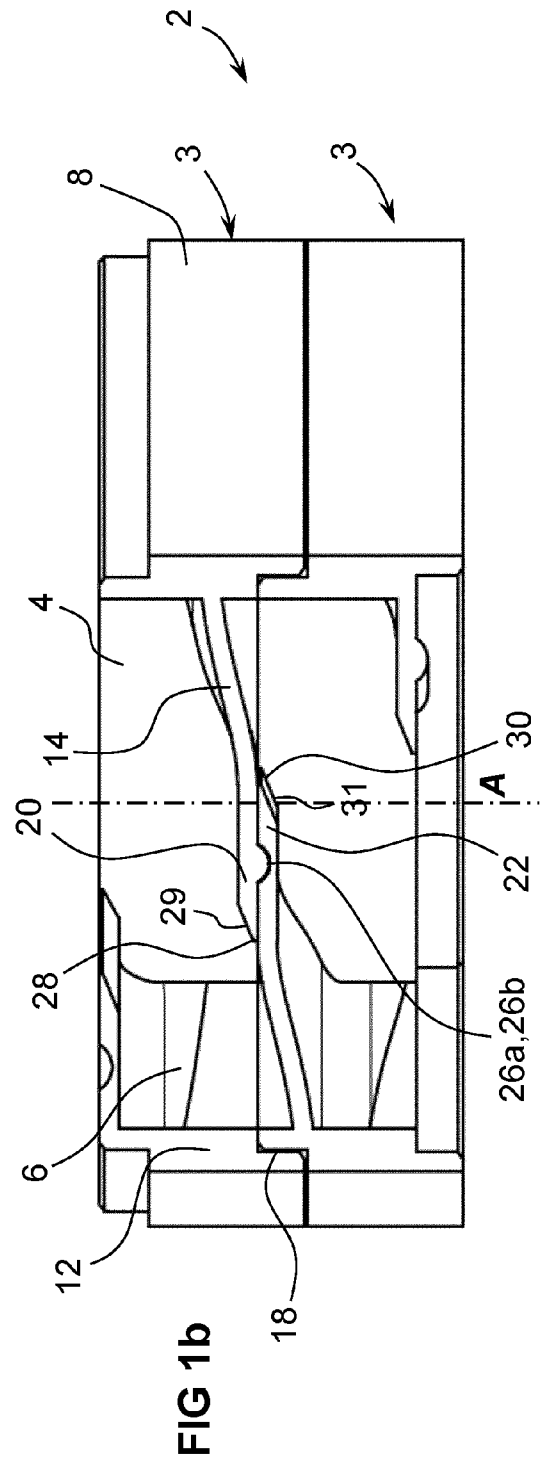
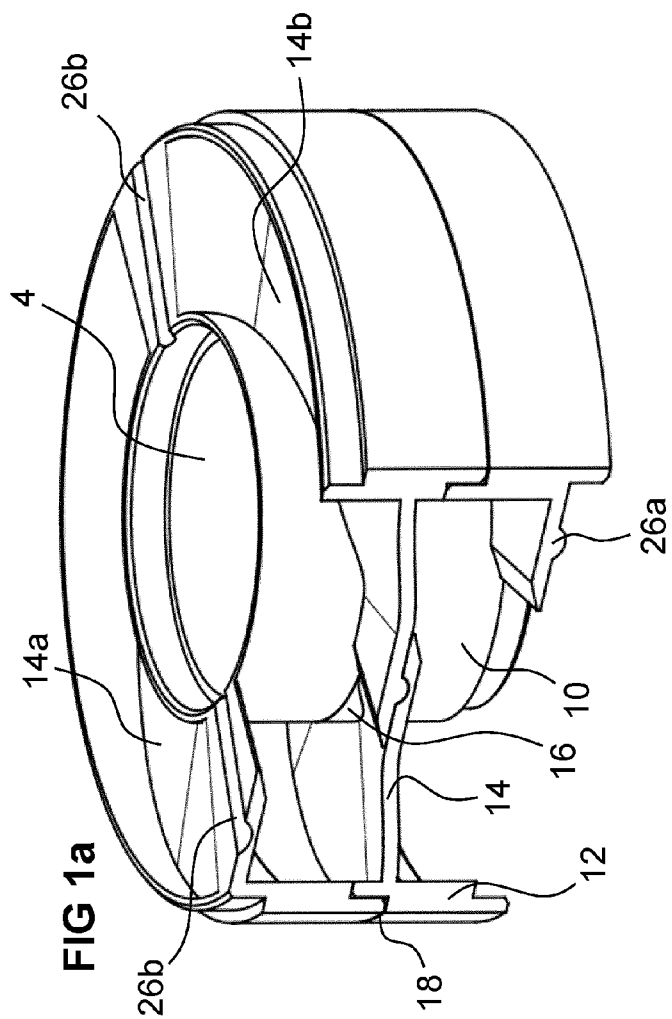
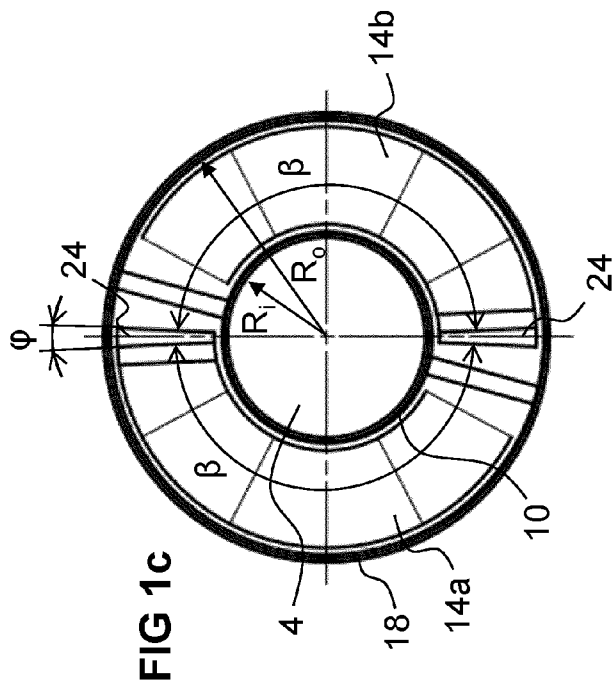
45 *axial height of muffler L*
axial height of muffler module $L1, L2, L3, L4$
angle between first end edge and second end edge of each spiral blade β
gap angle φ
radius inner tube Ri
50 *inner tube cross section surface area Si*
radius outer tube Ro
outer tube cross section surface area So

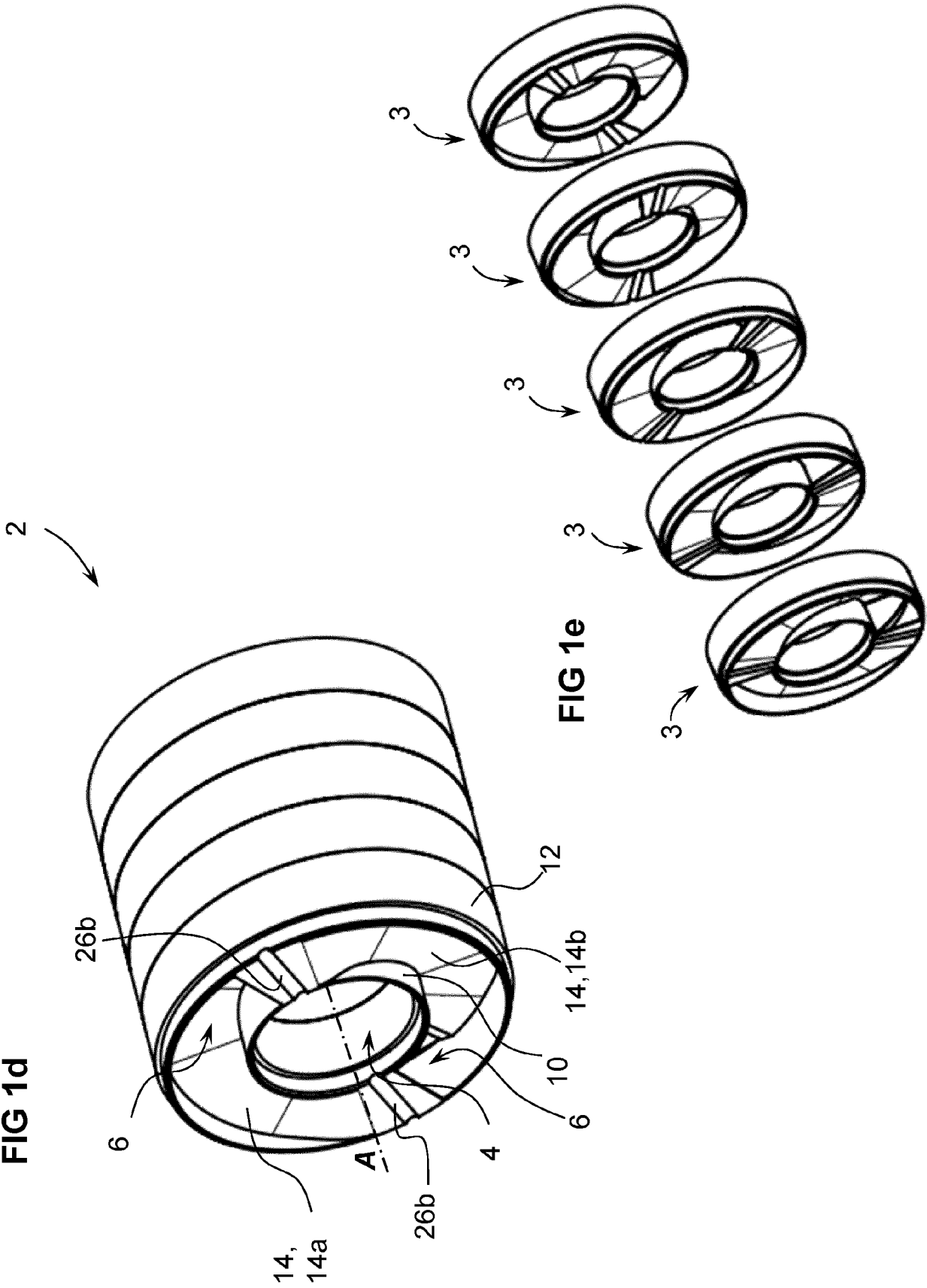
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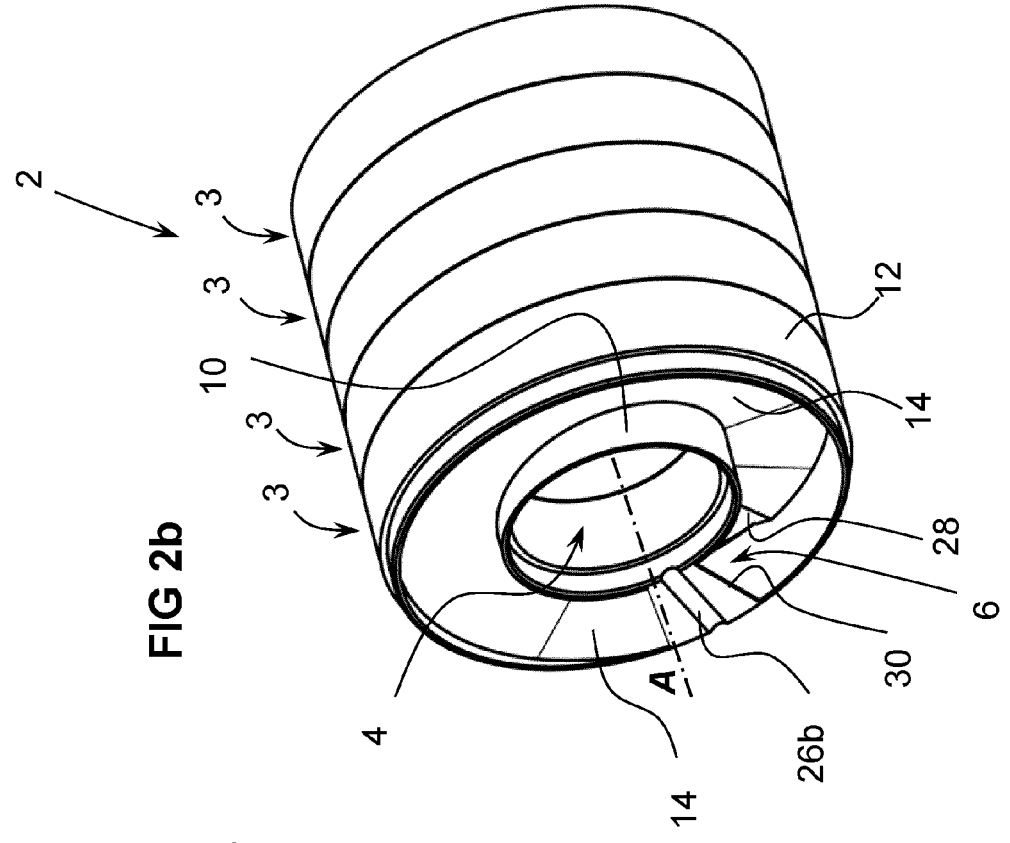
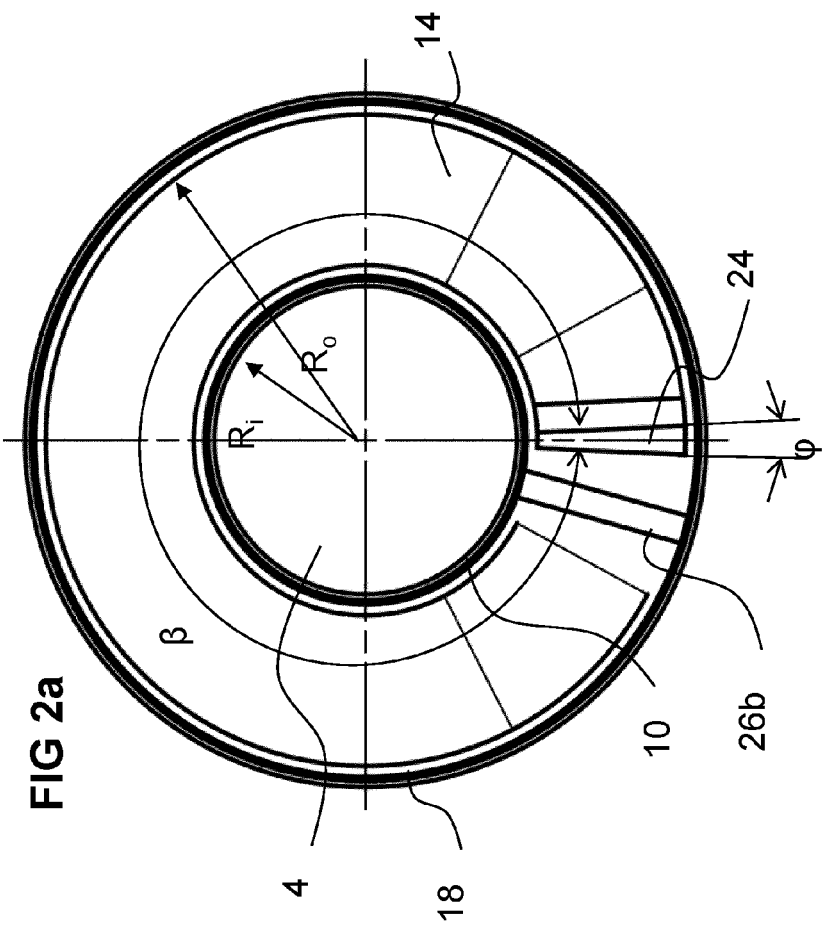
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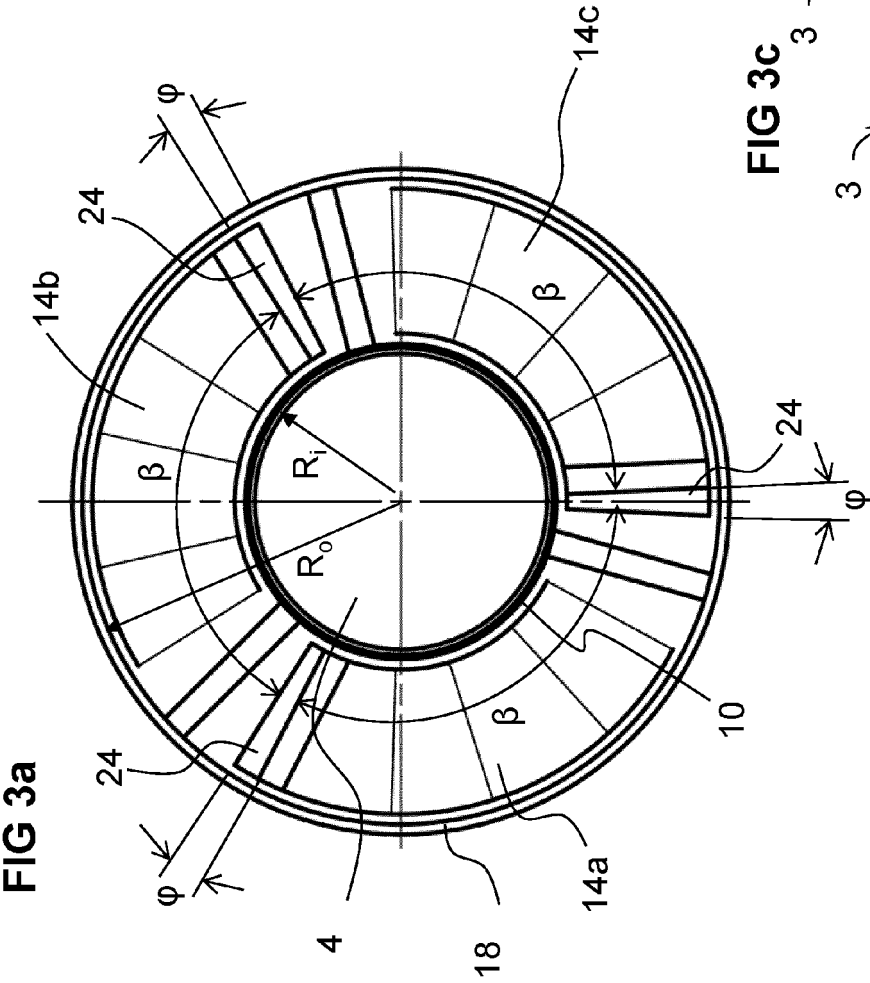
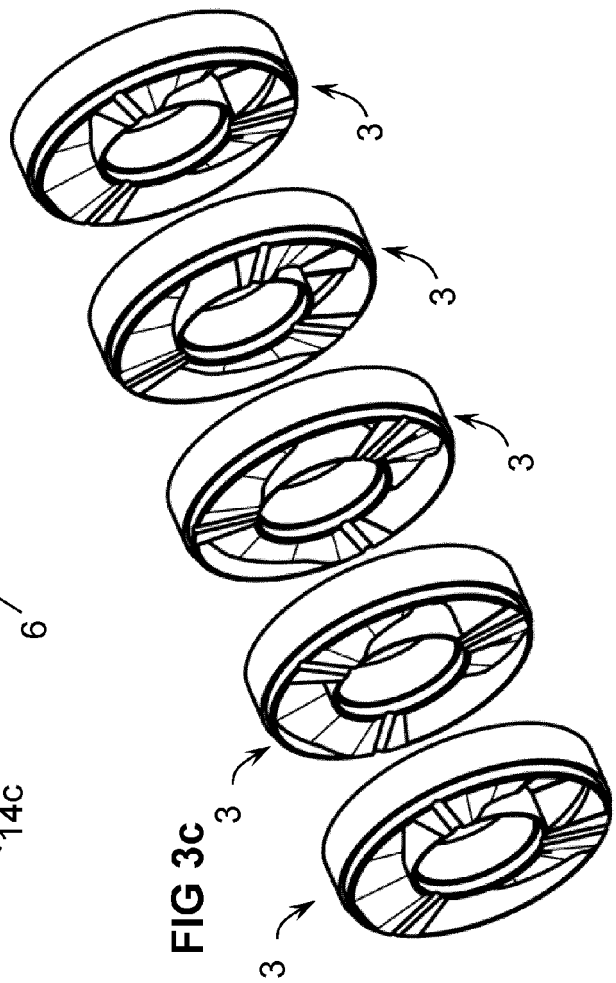
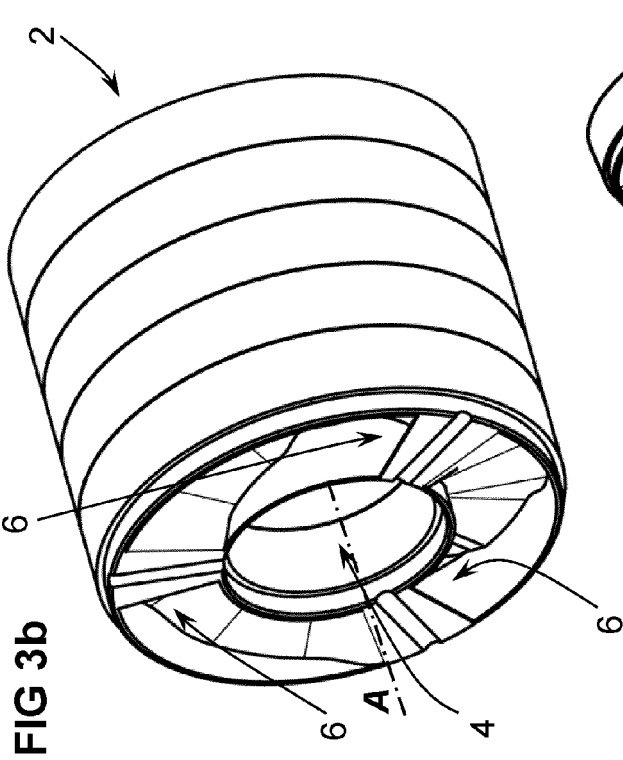
tube wall (12) forming an outer wall of the at least one outer spiral channel (6), the at least one outer spiral channel (6) being formed between the outer tube wall (12) and the inner tube wall (10), the channels housing further comprising at least one spiral wall (14) defining a spiral form of the at least one outer spiral channel (6) spiraling from a first axial side of the muffler to a second axial side of the muffler, wherein the channels housing is formed of a plurality of stacked muffler modules (3), each muffler module comprising at least one spiral blade (14, 14a, 14b, 14c), each spiral blade extending from a first end at a first axial side of the muffler module to a second end (22) at a second axial side of said muffler module, first and second ends of adjacent stacked muffler modules joining together in a contacting manner at said interfaces such that said at least one spiral wall (14) is formed from a plurality of stacked said at least one spiral blades.

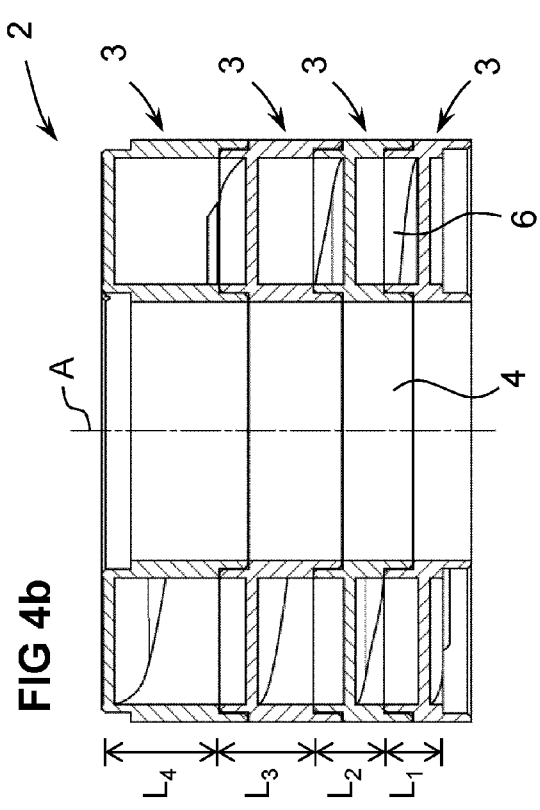
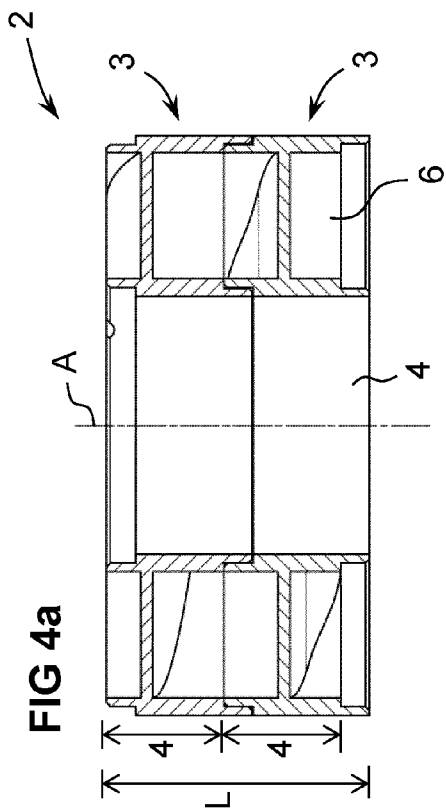
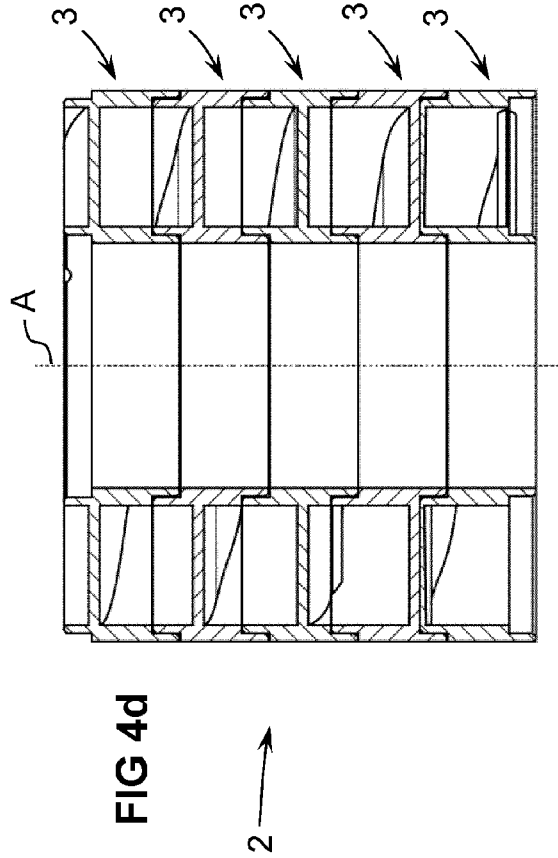
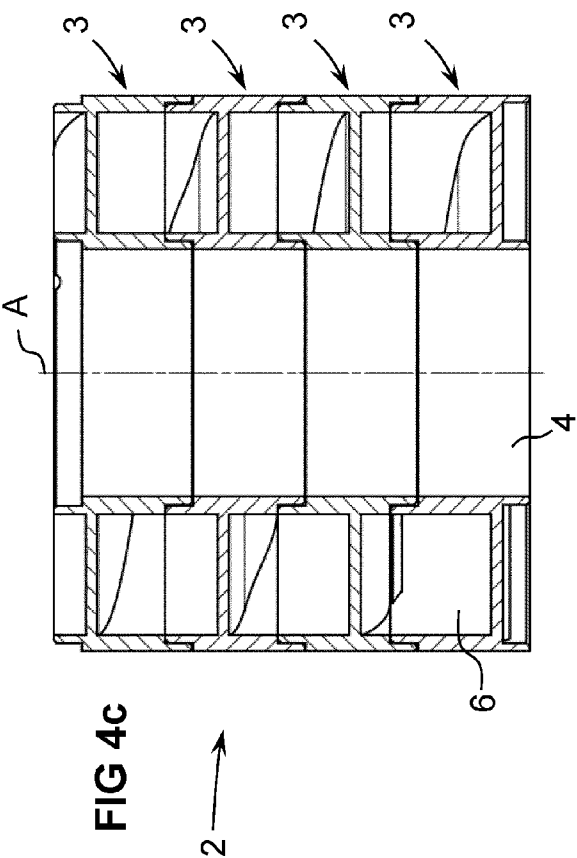
2. The muffler according to the preceding claim wherein the centre channel (4) extends in an axial linear direction.
3. The muffler according to any preceding claim wherein the inner tube wall (10) has a circular, square, ovoid or polygonal cross-sectional profile.
4. The muffler according to any preceding claim wherein the outer tube wall (12) has a circular, square, ovoid or polygonal cross-sectional profile.
5. The muffler according to any preceding claim wherein each spiral blade extends angularly around the centre axis between a first end edge (28) of the spiral blade to a second end edge (30) of the spiral blade by an angle β that is less than 360° divided by a number n of spiral blades: $\beta < 360^\circ/n$, configured to form a gap (24) seen in an axial direction, said gap being between a first end edge of the spiral blade and a second end edge of the spiral blade if the number n of spiral blades is one, and if the number n of spiral blades is greater than one, the gap (24) seen in an axial direction, is formed between a first end edge of one of the spiral blades and a second end edge of another one of the spiral blades.
6. The muffler according to the preceding claim wherein the gap (24) has a rotational angle ϕ in a range between 1° and 10° preferably in a range between 1° and 5° .
7. The muffler according to any preceding claim wherein the first end (20) of each of the spiral blades comprises a first locating element (26a) and the second end (22) of each of the spiral blades comprises a second locating element (26b) complementary to the first locating element (26a) such that when modules are stacked together the first and second locating elements (26a, 26b) register and locate the stacked modules angularly with respect to each other.
8. The muffler according to the preceding claim wherein one of the first and second locating elements is a protrusion and the other of the first and second locating elements is a complementary recess.
9. The muffler according to any preceding claim wherein the tubular wall joining interfaces (16, 18) and/or the interfaces between the stacked ends of the spiral blades are bonded adhesively or welded together.
10. The muffler according to any preceding claim wherein joining interfaces (16, 18) and/or the interfaces between the stacked ends of the spiral blades comprise sealing joints.
11. The muffler according to any preceding claim wherein each muffler module is formed by molding of a thermoplastic, thermosetting polymer or metal.
12. The muffler according to the preceding claim wherein the muffler comprises a two-component molded polymer structure.
13. The muffler according to any preceding claim wherein the plurality of muffler modules includes at least first and second muffler modules with different axial heights.
14. The muffler according to any preceding claim wherein sound damping materials are provided on surfaces bounding the centre channel (4) and/or outer spiral channel (6).
15. The muffler according to any preceding claim wherein the centre channel (4) and the at least one outer spiral channel (6) are closed by an end wall (42) at one axial end.











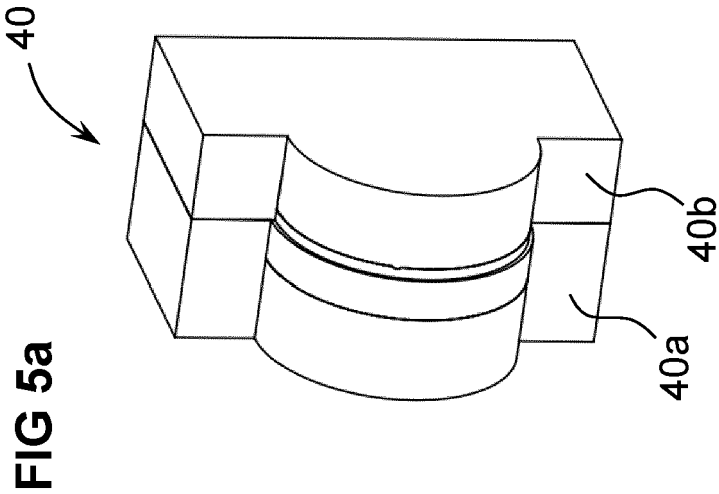


FIG 5b

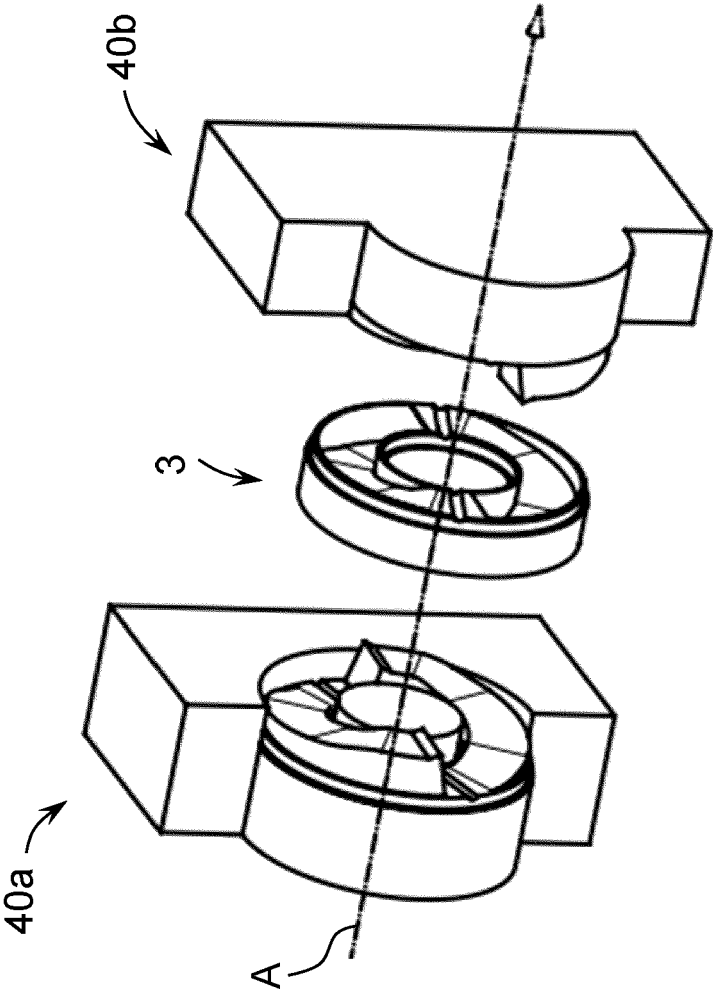


FIG 6a

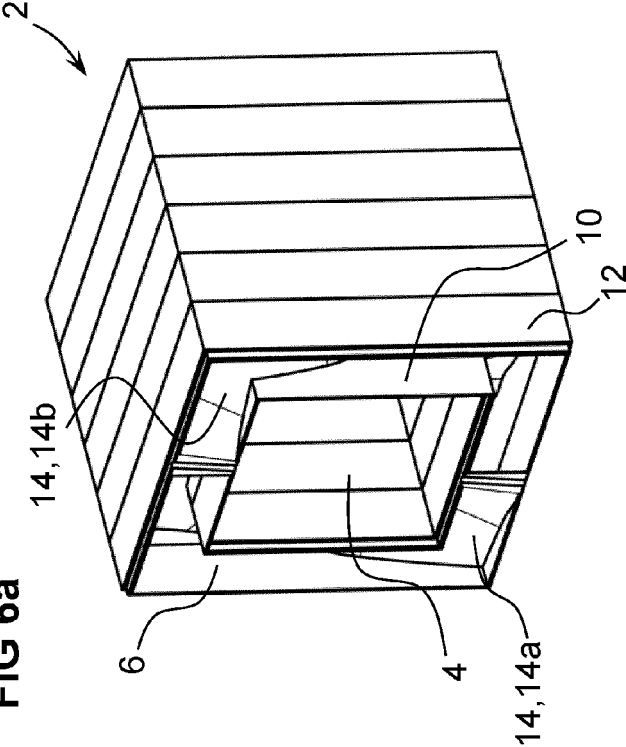
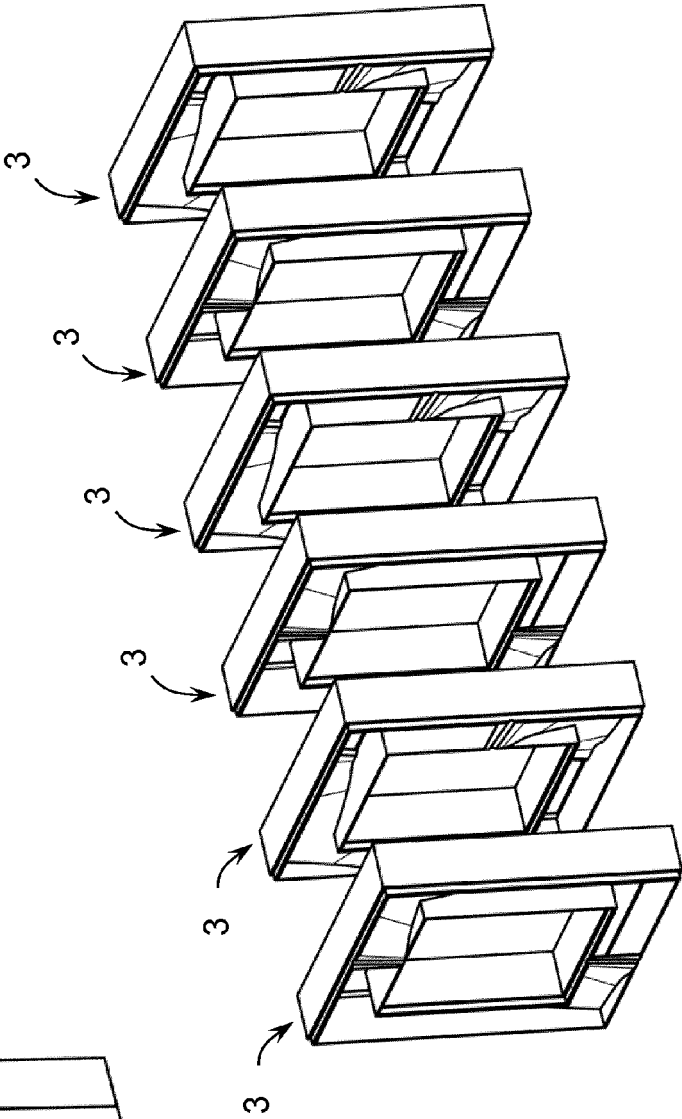


FIG 6b



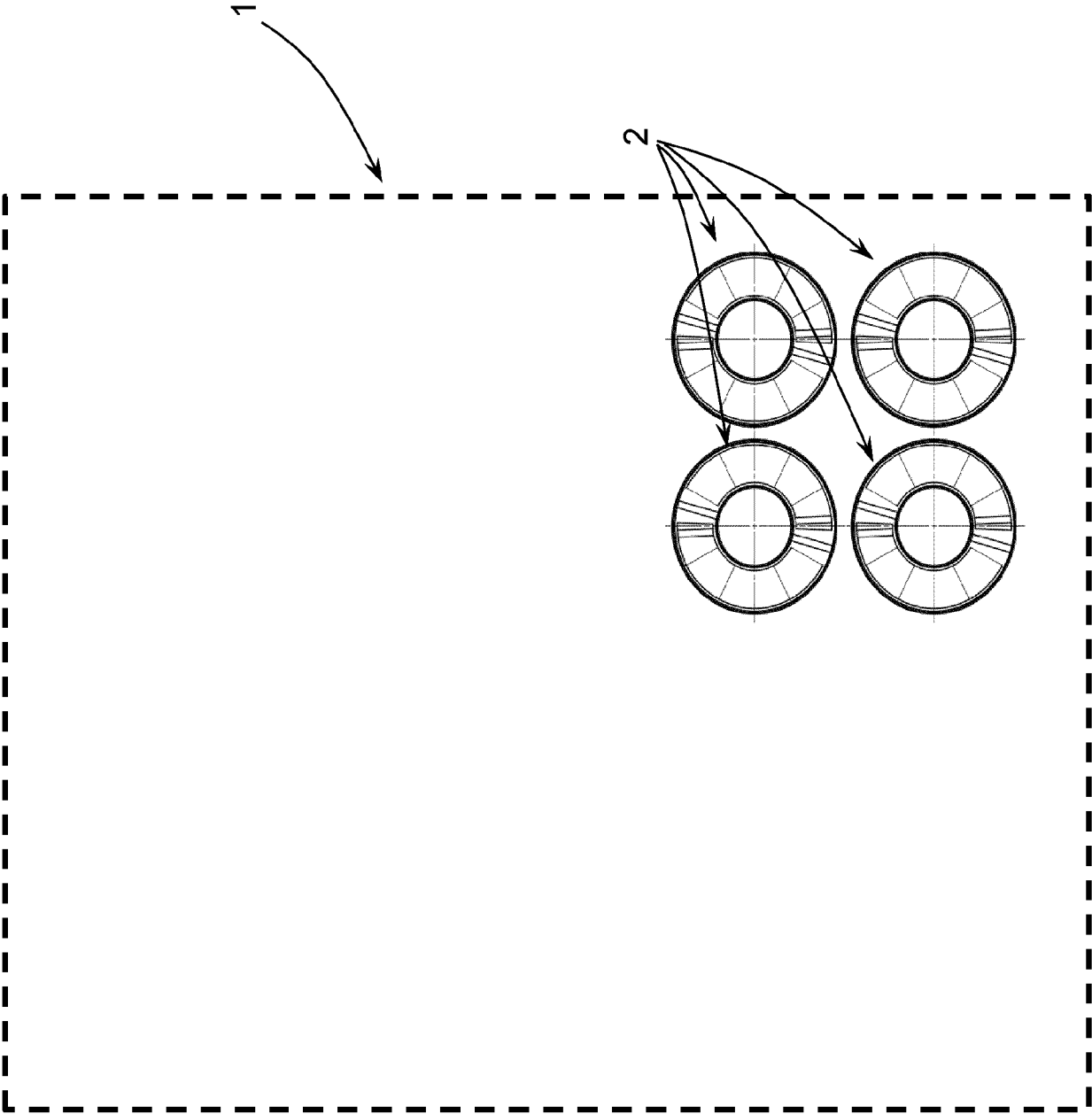


FIG 7

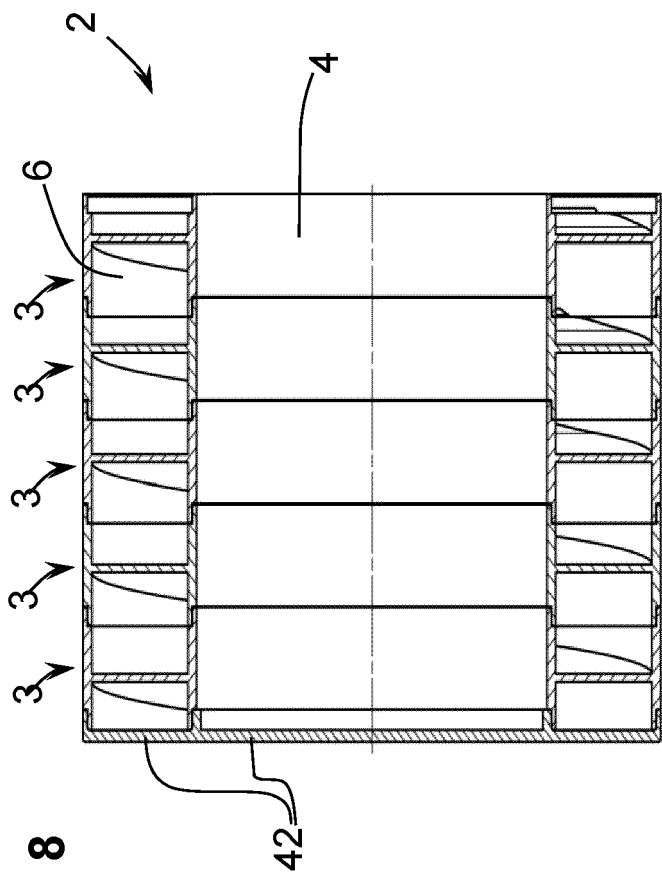


FIG 8



EUROPEAN SEARCH REPORT

Application Number

EP 23 18 8353

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	* abstract; figure 7a * * paragraphs [0030] - [0032] *		
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Place of search	Date of completion of the search	Examiner
The Hague	20 December 2023	de Jong, Frank
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document		



EUROPEAN SEARCH REPORT

Application Number

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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	20 December 2023		de Jong, Frank
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
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