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(71) Applicant: **JAGUAR LAND ROVER LIMITED**
[GB/GB]; Abbey Road, Whitley, Coventry Warwickshire
CV3 4LF (GB).

(72) Inventors: **PETLEY, Dean**; c/o Jaguar Land Rover,
Patents Department W/1/073, Abbey Road, Whitley,
Coventry Warwickshire CV3 4LF (GB). **FLETCHER, Si-**
mon; c/o Jaguar Land Rover, Patents Department W/1/073,

Abbey Road, Whitley, Coventry Warwickshire CV3 4LF
(GB).

(74) Agent: **BORTON, Claire**; c/o Jaguar Land Rover, Patents
Department W/1/073, Abbey Road, Whitley, Coventry
Warwickshire CV3 4LF (GB).

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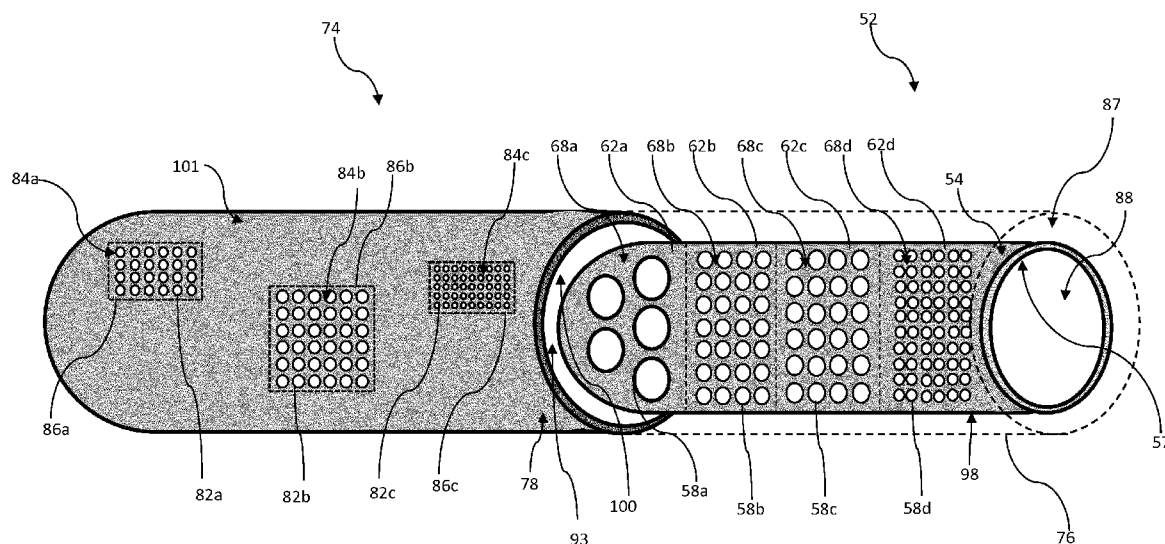


Fig. 2

(57) Abstract: A conduit (14) for reducing noise associated with gas conveyed by the conduit (14), the conduit (14) comprising a conduit assembly (52) which defines at least two sets (68a, 68b, 68c, 68d) of apertures (58a, 58b, 58c, 58d), wherein each set (68a, 68b, 68c, 68d) of apertures (58a, 58b, 58c, 58d) is configured to attenuate sound waves propagating through the gas. The conduit (14) further comprises a housing (74) which surrounds the conduit assembly (52), wherein the housing (74) which surrounds the conduit assembly (52) defines a first volume, and the conduit assembly (52) defines a second volume, the first volume being no more than twice the size of the second volume.

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CONDUIT FOR REDUCING NOISE

TECHNICAL FIELD

- 5 The present disclosure relates to a conduit for reducing noise associated with gas conveyed by the conduit. Aspects of the invention relate to a conduit, to a vehicle exhaust system comprising a conduit and to a vehicle comprising the conduit or the vehicle exhaust system.

10 BACKGROUND

Silencers, or mufflers, attenuate unwanted noise in ducted systems such as vehicle exhaust systems. Without silencers, noise would be expelled into the environment surrounding the exhaust system, contributing to noise pollution. While mitigation of
15 noise pollution is necessary, modern silencers create difficulties for the engineer. Namely, silencers tend to be large and bulky, and their incorporation requires If modification of adjacent components. For example, car designers must ensure that the underside of a car is arranged to allow a silencer to be safely located underneath the body of the car. This means that the space occupied by the silencer may not be easily
20 available, or may not be used for other, more useful equipment.

Furthermore, silencers are costly, heavy, and can inhibit performance of the system in which it is incorporated. For example, when used as part of an exhaust system of a vehicle, the weight of an exhaust silencer causes the efficiency of the vehicle to suffer,
25 a problem that is especially evident in higher performance vehicles where larger or even multiple silencers may be required. Similarly, the mechanisms by which the noise levels are reduced cause a build-up of back pressure within the exhaust system.

In previous attempts to address the above problems, a compromise is often sought
30 between noise attenuation and size. For example, United States Patent No. 5,371,331 describes a muffler that seeks to address some of the abovementioned problems. A central pipe of the muffler is the same diameter as the main exhaust pipe, and is surrounded by an outer pipe with a smaller diameter than traditional mufflers. Sound absorptive material and a plurality of perforations are incorporated to attempt to

attenuate noise travelling through the exhaust pipe. While the muffler described in US 5,371,331 has less of a spatial impact and is lighter than traditional silencers, it does not attenuate the noise sufficiently at all frequencies produced by a vehicle exhaust system.

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The present invention has been devised to mitigate or overcome at least some of the above-mentioned problems.

SUMMARY OF THE INVENTION

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According to an aspect of the present invention there is provided a conduit for reducing noise associated with gas conveyed by the conduit, the conduit comprising a conduit assembly which defines at least two sets of apertures, wherein each set of apertures is configured to attenuate sound waves propagating through the gas and a housing which surrounds the conduit assembly, wherein the housing which surrounds the conduit assembly defines a first volume, and the conduit assembly defines a second volume, the first volume being no more than twice the size of the second volume.

When the invention is used as part of an exhaust assembly of a vehicle, sound waves travelling through the gas conveyed by the assembly interact with the apertures to attenuate the noise. In this way the assembly acts as a silencer component to reduce the noise produced by the engine to an acceptable level. The configuration of the invention enables conventional silencers to be replaced with a conduit according to the invention which takes up less space and is lighter than a conventional silencer. Thereby enabling space previously occupied by prior art silencers to be used for other purposes or equipment.

The noise is attenuated across a wide range of frequencies, and beneficially, by altering the magnitude of the attenuation of the noise depending on its frequency, an overall impression of the resultant noise can be tuned by the assembly to achieve a desired, characteristic sound.

In certain embodiments, the sets of apertures may be configured to attenuate sound waves of a particular frequency propagating through the gas. Configuring all sets of

apertures to attenuate a particular frequency of the noise from the exhaust system advantageously allows for the targeting of a specific characteristic that may be unwanted and difficult to attenuate by other means.

- 5 Alternatively, each set of apertures may be configured to attenuate sound waves of a particular frequency propagating through the gas. By targeting different frequencies with each set of apertures, broadband attenuation is achieved, and the conduit may be used in place of a conventional muffler.
- 10 Preferably, the at least two sets of apertures includes four sets of apertures.

The apertures within each set may have a uniform size and the apertures of the at least two sets of apertures may have a uniform shape. Sets of apertures that have uniform size and shape are particularly beneficial in tuning the sets to the particular
15 frequency that they are configured to attenuate, improving the attenuation properties of each set.

Optionally, the size of the apertures in each set may be different to the sizes of the apertures in one or more of the other sets of apertures. Similarly, the shape of the
20 apertures of one set of the at least two sets of apertures may be different to the shape of the apertures within at least one of the other sets of apertures.

Each set of apertures may comprise apertures of a size in the range 0.1 mm to 5 mm. Apertures in this size range in particular, provide a reasonable amount of attenuation
25 without compromising the structure of the conduit.

The conduit assembly may define a hollow member, and the hollow member may define the second volume. Additionally, the conduit assembly may comprise a wall and at least one set of the at least two sets of apertures may extend through the wall.

30

The conduit assembly may have a circular cross-section and may comprise a pipe which may be defined by a wall. A circular cross-section beneficially allows for optimal aerodynamic flow properties and minimal pressure loss or turbulence within the conduit.

The housing may define a longitudinal axis. The longitudinal portion of the housing which surrounds the conduit assembly may define the first volume.

- 5 The housing may define at least one set of apertures configured to attenuate sound waves, the at least one set of apertures optionally extending through the housing. Incorporating apertures into the housing in this manner is particularly beneficial in reducing resonances or noise regenerated by the conduit in use.
- 10 The housing may define a hollow member within which the conduit assembly is located, may have a circular cross-section and may comprise a wall or a pipe which may be defined by a wall. Alternatively, the housing may comprises foil, and in certain embodiments, the foil may be a micro-perforated foil. Foils, and especially micro-perforated foils, have excellent sound absorption properties which significantly improve
- 15 the properties of the conduit, while simultaneously decreasing the weight of the assembly.

An annular intermediate volume may be defined between the conduit assembly and the housing, and a sound absorptive material may be disposed within the intermediate

20 volume. The sound absorptive material may be, for example, a mineral wool. Sound absorptive materials further enhance the sound attenuation properties of the conduit.

The conduit may comprise an inlet for gas ingress into the conduit and an outlet for gas egress from the conduit, and may extend between the inlet and the outlet. The

25 housing may also extend between the inlet and the outlet.

The conduit may comprise an end cap to maintain the position of the conduit assembly relative to the housing. Preferably, the end cap may be mounted to outlet of the conduit. The conduit may also comprise a plurality of spacers positioned within the

30 intermediate volume so as to maintain the position of the conduit assembly relative to the housing. Maintaining the position of the conduit assembly relative to the housing is important to reduce the likelihood of the assembly vibrating against the housing in use. Incorporating spacers and/or end caps are particularly advantageous ways of preventing unwanted interaction between the conduit assembly and the housing.

The length of the conduit may be greater than 1 m (one metre). In preferred embodiments, the diameter of the conduit may not be greater than 90 mm.

The size of the apertures may vary continuously along the length of the conduit.

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The conduit may comprise one or more windows in the wall of the conduit, each window being fitted with a sheet of material having apertures through it.

According to another aspect of the invention, there is provided a vehicle exhaust system incorporating a conduit according to the above embodiments.

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The vehicle exhaust system may comprise a first portion connected to a second portion. The first portion may comprise an exhaust manifold and/or at least one after-treatment device, and the second portion may be entirely comprised of the conduit.

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According to another aspect of the invention, there is provided a vehicle incorporating the conduit or the vehicle exhaust system as described above.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

20

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BRIEF DESCRIPTION OF THE DRAWINGS

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One or more embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a vehicle incorporating a conduit according to an embodiment of the present invention;

5 Figure 2 is a partial cut-away perspective view of a section of the conduit shown in Figure 1;

Figure 3 is a cross-sectional view of the conduit shown in Figure 1 and further illustrated in Figure 2;

10 Figure 4 is a perspective view of an end cap for use in the conduit shown in the preceding figures; and

Figure 5 shows a conduit having windows with thin sheets of aperture bearing material provided therein.

15

DETAILED DESCRIPTION

Figure 1 is a schematic block diagram of a vehicle 10 powered by an internal combustion engine 12, wherein the vehicle 10 comprises an conduit 14 for reducing
20 noise according to an embodiment of the invention.

The vehicle 10 comprises a pair of front wheels 16, 18 which are mounted at each end of a front steering axle 20, wherein the front wheels 16, 18 are controlled by a steering wheel (not shown) in a conventional manner. The internal combustion engine 12 is
25 coupled to a transmission 22 which transmits power generated by the engine 12 to a drive shaft 24. In turn, the drive shaft 24 transmits power to a rear axle 26 via a differential 28. A rear wheel 29, 31 is mounted at each end of the rear axle 26 to propel the vehicle 10.

30 Waste gas created by the combustion of fuel by the engine 12 is carried away from the engine 12 by a vehicle exhaust system 30. The vehicle exhaust system 30 comprises a first portion 32 and a second portion 34.

The first portion 32 incorporates an exhaust manifold 36 which is arranged to collect waste gas from the engine 12 and feed the waste gas into an initial pipe section 38 of an after-treatment device 40, for example a catalytic converter and/or a particulate filter. Waste gas processed by the after-treatment device 40 exits the after-treatment
5 device 40 via an end pipe section 42.

The second portion 34 comprises the conduit 14 for reducing noise associated with gas conveyed by the conduit according to the embodiment of the invention hereby described. The conduit 14 comprises an inlet 44 arranged to receive waste gas from
10 the end pipe section 42 of the first portion 32. The conduit 14 extends adjacent to the underside 46 of the body 48 of the vehicle 10 from the end pipe section 42 of the first portion 32 to the rear 50 of the vehicle 10. The conduit 14 further comprises an outlet 49 arranged to expel waste gas from the conduit 14 to the environment. The conduit 14 terminates beyond the rear body 50 of the vehicle 10 to ensure that waste gas is
15 expelled safely from the vehicle 10 by the exhaust system 30.

It will also be appreciated that the first portion 32 of the system 30 may optionally include additional after-treatment devices and pipe sections. It should be noted that the second portion 34 (and therefore the conduit 14) may be joined directly to an outlet of
20 an after-treatment device of the first portion 32.

It will also be appreciated that the conduit 14 comprises the entire length of the second portion 34 and is 2m (two metres) in length in this example. This illustrates only one possible configuration of the conduit 14, and alternative configurations will be
25 discussed later.

The conduit 14 will now be described with reference to Figures 2 and 3. Figure 2 illustrates a partial, cut-away, perspective view of the conduit 14 shown in Figure 1. Figure 3 illustrates a cross sectional view of the conduit 14 and is taken, for example,
30 along the line A-A in Figure 1.

The conduit 14 comprises a conduit assembly 52 defined by a cylindrical inner wall 54 which forms a hollow member in the form of an inner pipe. The inner pipe is defined by the inner wall 54 and has a circular cross-section. The inner wall 54 has an inner

surface 57 and an outer surface 98. The thickness of the inner wall 54 is constant along the length of the conduit assembly 52. The thickness of the inner wall 54 is in the range 0.25 mm to 0.8 mm.

- 5 A plurality of apertures 58a, 58b, 58c, 58d of varying sizes extend through the inner wall 54. Each aperture 58a, 58b, 58c, 58d has a circular cross-section of constant diameter so that each aperture 58a, 58b, 58c, 58d defines a cylindrical volume through the inner wall 54 of the conduit assembly 52.
- 10 The plurality of apertures 58a, 58b, 58c, 58d is arranged in first, second, third and fourth sets 68a, 68b, 68c, 68d of apertures 58a, 58b, 58c, 58d, wherein the apertures in a set have identical diameters, and therefore have a uniform size. A first region 62a contains the first aperture set 68a wherein each aperture 58a has a diameter of 3.5 mm; a second region 62b contains the second aperture set 68b wherein each aperture
- 15 58b has a diameter of 1 mm; a third region 62c contains the third aperture set 68c wherein each aperture 58c has a diameter of 1.8 mm; and a fourth region 62d contains the fourth aperture set 68d wherein each aperture 58d has a diameter of 0.3 mm. The first, second, third and fourth aperture regions 62a, 62b, 62c, 62d are separated in Figure 2 by dashed dividing lines. The regions 62a, 62b, 62c, 62d shown in Figure 2
- 20 extend around the circumference of the conduit assembly 52.

Each aperture 58a, 58b, 58c, 58d in an aperture set 68a, 68b, 68c, 68d is spaced from neighbouring apertures 58a, 58b, 58c, 58d in that aperture set 68a, 68b, 68c, 68d at a minimum aperture spacing distance of 0.1 mm. The minimum spacing distance is

25 calculated so as to make the most efficient use of material without structurally weakening the conduit assembly 52.

Each set 68a, 68b, 68c, 68d is spaced from neighbouring sets 68a, 68b, 68c, 68d at a minimal set spacing distance of 0.1 mm, so as not to weaken the conduit assembly 52.

30 The number of apertures 58a, 58b, 58c, 58d in each set 68a, 68b, 68c, 68d differs due to the size of the apertures 58a, 58b, 58c, 58d in the set 68a, 68b, 68c, 68d, and the size of each region 62a, 62b, 62c, 62d.

The size of each aperture 58a, 58b, 58c, 58d is configured to attenuate sound waves of a particular frequency propagating through gas conveyed by the conduit assembly 52, which is described in further detail below. The apertures 58a, 58b, 58c, 58d may therefore be tuned to have specific attenuation properties. In other embodiments of the invention, the diameter of each aperture 58a, 58b, 58c, 58d or the apertures 58a, 58b, 58c, 58d in each set 68a, 68b, 68c, 68d may lie in the range 0.1 mm to 5 mm. It will be appreciated that it is possible to incorporate apertures with larger and/or smaller diameters into the conduit assembly 52 if desired without departing from the scope of the invention as claimed.

In an alternative embodiment, the size of the apertures may vary continuously along the length of the conduit. For example, at any given longitudinal position (or range of longitudinal positions) along the conduit, one or more apertures of a common size may be provided. Starting from one end, the size of the apertures may generally increase with longitudinal position. The variation in size may in some cases be accompanied with a variation in separation between the apertures. For example, as the apertures grow larger, the distance between them may reduce (if the number of apertures per unit area is preserved). In other cases, it may be possible for the sizes of the apertures to remain substantially constant along the length of the conduit, but for the separation between them to vary.

The conduit assembly 52 is surrounded by and aligned with a housing 74. A portion of the housing 74, illustrated by dashed lines 76, is not shown in Figure 2 so that the conduit assembly 52 and its relationship with the housing 74 can be shown more clearly. The housing 74 of the currently described embodiment extends the entire length of the conduit assembly 52 so that the entire length of the conduit assembly 52 is surrounded by and aligned with the housing 74.

The housing 74 comprises an outer wall 78 defining a hollow member in the form of an outer pipe which has a circular cross-section. However, alternative cross-sections are envisioned in alternative embodiments of the invention. The outer wall 78 has an inner surface 100 and an outer surface 101. The thickness of the outer wall 78 of the housing 74 is constant along the length of the housing 74. The thickness of the outer wall 78 of the housing 74 is in the range 0.1 mm to 0.8 mm.

As can be seen in Figure 2, the housing 74 comprises a plurality of apertures 82a, 82b, 82c that extend through the outer wall 78 of the housing 74. Each aperture 82a, 82b, 82c defines a cylindrical volume in the outer wall 78 of the housing 74. The apertures 82a, 82b, 82c are separated into a first set or group 84a of apertures 82a, a second set or group 84b of apertures 82b and a third set or group 84c of apertures 82c. The apertures 82a, 82b, 82c of each group have identical diameters. Each group 84a, 84b, 84c is arranged in respective first, second and third aperture zones, 86a, 86b, 86c illustrated in Figure 2 as a dotted line that encloses each zone 86a, 86b, 86c. The apertures 82a, 82b, 82c of each group 84a, 84b, 84c are arranged equidistantly and uniformly within each zone 86a, 86b, 86c.

The first zone 86a contains the first aperture group 84a wherein each aperture 82a has a diameter of 0.3 mm; the second zone 86b contains a second aperture group 84b wherein each aperture 82b has a diameter of 0.6 mm; and the third zone 86c contains a third aperture group 84c wherein each aperture 82c has a diameter of 0.15 mm.

Each aperture 82a, 82b, 82c in an aperture group 84a, 84b, 84c is spaced from neighbouring apertures 82a, 82b, 82c in that group 84a, 84b, 84c at a minimum aperture spacing distance of 0.1 mm. The minimum spacing distance is calculated so as to make the most efficient use of material without structurally weakening the housing 74.

Each zone 86a, 86b, 86c is spaced from the other zones 86a, 86b, 86c by a minimal spacing distance of 0.1 mm, so as not to weaken the housing 74. The zones 86a, 86b, 86c are not of a uniform shape, and the number of apertures 82a, 82b, 82c within each zone 86a, 86b, 86c vary and the surface area of the housing 74 that each zone 86a, 86b, 86c occupies vary.

In other embodiments of the invention the number of apertures in one or more groups may be the same; one or more zones may have identical or similar shapes; one or more groups may occupy the same surface area.

The positioning of the zones 86a, 86b, 86c is related to the acoustic properties of the conduit 14, as is described in more detail below and may vary accordingly. It will be appreciated that the apertures in the housing and the apertures in the conduit assembly may be functionally identical.

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In other embodiments of the invention, the diameter of any aperture 82a, 82b, 82c will lie in the range 0.1 mm to 5 mm. As above, larger and/or smaller apertures may be incorporated without departing from the scope of the invention as claimed.

- 10 The internal diameter of the housing 74 is greater than the external diameter of the conduit assembly 52. In use, the housing 74 provides a level of protection for the conduit assembly 52 from the elements.

- 15 Similarly, the volume of the housing 74 which surrounds the conduit assembly 52 is greater than the volume of the conduit assembly 52. The longitudinal portion of the housing 84 which surrounds the conduit assembly 52 defines the first volume 87. It is envisaged that the ratio of the first, housing volume 87 to the second, will not be greater than 2:1.

- 20 The enclosure of the conduit assembly 52 within the housing 74 defines an annular intermediate volume 94 between the outer surface 98 of the conduit assembly 52 and the inner surface 100 of the housing 74. Focussing now on Figure 3, a plurality of spacers 96 is disposed between the conduit assembly 52 and the housing 74 to maintain the positions of the conduit assembly 52 and housing 74 relative to one another.
- 25

- Each spacer 96 is positioned equally radially around the outer surface 98 of the conduit assembly 52 such that the radial distance between the outer surface 98 of the conduit assembly 52 and the inner surface 100 of the housing is consistent at 30 mm.
- 30 In other embodiments of the invention, the radial distance between the outer surface 98 of the conduit assembly 52 and the inner surface 100 of the housing 74 may be a value in the range 20 mm to 40 mm. Further spacers (not shown) are disposed longitudinally at regular intervals between the outer surface 98 of the conduit assembly 52 and the inner surface 100 of the housing 74 to ensure that the distance between

the outer surface 98 of the conduit assembly 52 and the inner surface 100 of the housing 74 is longitudinally constant. In this way, a concentric cross-section is maintained along the length of the conduit 14.

- 5 The spacers 96 are fixed in place by welding each spacer 96 to the outer surface 98 of the conduit assembly and the inner surface 100 of the housing. In an alternative embodiment, the spacers 96 may be attached to the outer surface 98 of the conduit assembly and/or the inner surface 100 of the housing by an adhesive. Other methods of attachment may be used.

10

The conduit 14 attenuates noise carried by gas travelling through the conduit 14 by the mechanism of destructive interference.

- 15 Noise propagating through the vehicle exhaust system 30 originates in the engine 12, as a by-product of the combustion cycle. Noise generated by an internal combustion engine is broadband noise. Broadband noise comprises a plurality of sound waves, wherein individual waves, or each component wave, of the plurality have different frequencies.

- 20 Each aperture 58a, 58b, 58c, 58d in the conduit assembly has a resonant frequency at which the magnitude of vibration of gas inside the aperture 58a, 58b, 58c, 58d is greatest when excited at the resonant frequency. It will be appreciated that the size of an aperture is generally inversely proportional to the frequency of noise which it attenuates.

25

- As the plurality of sound waves propagates along the conduit assembly 52, gas within each aperture 58a, 58b, 58c, 58d is excited, causing the gas to vibrate at the corresponding resonant frequency of each aperture. When gas within an aperture vibrates at its resonant frequency the aperture 58a, 58b, 58c, 58d behaves as a
30 Helmholtz resonator. The vibration of the gas in the aperture generates a resonant sound wave at the resonant frequency of the aperture.

The resonant sound wave generated by vibration of gas within the aperture is out of phase with its corresponding component wave of the broadband noise. When the

resonant sound wave interferes with its corresponding component wave, the waves cancel due to their phase difference. The effect of this destructive interference is a reduction in the amplitude of the component wave.

- 5 The size of each aperture 58a, 58b, 58c, 58d is configured to attenuate sound waves of a particular frequency propagating through gas conveyed by the conduit assembly 52 having been produced by the engine 12.

10 By including apertures 58a, 58b, 58c, 58d with a wide spread of diameters, the broadband noise that propagates through the exhaust system 30 can be attenuated by the conduit assembly 52. The diameter of an aperture 58a, 58b, 58c, 58d is inversely proportional to the frequency of the component that is specifically targeted and attenuated by that aperture 58a, 58b, 58c, 58d.

- 15 The apertures 82a, 82b, 82c in aperture zones 86a, 86b, 86c of the housing 74 attenuate noise generated by the conduit or conduit assembly. Common issues of this type are resonances caused by the conduit assembly 52, resonances caused by the apertures 58a, 58b, 58c, 58d of the conduit assembly 52, or noise generated by vibration of the conduit 14 in use. In the same manner as the attenuation of noise by
20 the apertures of the conduit assembly 52, the apertures 82a, 82b, 82c of the housing 74 attenuate noise by the mechanism of destructive interference. The apertures 82a, 82b, 82c in aperture zones 86a, 86b, 86c of the housing 74 also act to attenuate any noise that may leak through the apertures 58a, 58b, 58c, 58d of the conduit assembly 52.

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The aperture zones 86a, 86b, 86c are located at specific points along the length of the housing 74 to reduce noise generated by the conduit 14 while minimising new noise sources. Similarly, the dimensions of the intermediate volume 94 and the thickness of the inner walls and outer wall are chosen to minimise resonances.

30

Figure 2 illustrates a portion of the conduit 14. The apertures 58a, 58b, 58c, 58d, 82a, 82b, 82c of the conduit assembly and/or housing 52, 74 extend along the entire length of the conduit 14. In an alternative embodiment, the apertures may be restricted to small clusters of regions and or zones of apertures.

The apertures 58a, 58b, 58c, 58d in the conduit assembly 52 of Figure 2 constitute only one possible configuration that may be implemented. Other configurations may be employed in alternative embodiments. For example, regions containing sets of
5 apertures may be positioned at regular intervals, grouped together at specific points, grouped randomly or may increase or decrease in area with distance from the inlet 44. Alternatively, the regions may be arranged such that the diameters of the apertures within each region are larger than the previous region or vice versa.

10 The number, diameter and shape of the apertures of the conduit assembly 52 may be calibrated to achieve an intended result. For example, high attenuation of the noise within the exhaust system 32 would require a large number of apertures having a large, equal distribution of diameters, whereas to attenuate engine noise that has a low frequency spike, an increased number of large diameter apertures are necessary.
15 Apertures may be shaped to have a square or elongated profile to achieve an intended result.

The pattern of the apertures in a set will also have an influence on the resulting noise profile. For example, by varying the positioning and density of apertures, and
20 concentrating apertures at potential anti-node positions along the conduit assembly 52, a greater level of noise reduction may be achieved by the assembly 52 and the apertures.

The zones 86a, 86b, 86c shown in the housing 74 in Figure 2 are small and occupy a
25 small surface area on the housing 74, although, depending upon the intended use and the required attenuation, each zone may be any reasonable size. Additionally, each zone may incorporate apertures of a diameter that differs from the diameters of the other apertures or many different sized apertures.

30 In alternative embodiments of the invention, apertures may be arranged in alternative configurations than that shown in the figures and described above. For example, identical apertures may be distributed throughout the conduit assembly and/or housing, and dispersed with apertures of dissimilar diameters.

The apertures 58a, 58b, 58c, 58d within the regions shown in Figure 2 are evenly distributed across each region. In other configurations, regions may have apertures grouped in clusters within the region or spaced randomly within the region. The region may also be restricted to a small area of the conduit assembly 52 surface, with more
5 regions disposed around the circumference of the conduit assembly 52.

Figure 4 is a perspective view of an end cap 102 for connecting the conduit assembly 52 and the housing 74 at an outlet (not shown) of the second portion 34.

10 The end cap 102 aids in maintaining the width of the intermediate volume 94 by securing the outlets of the conduit assembly 52 and housing 74 relative to one another. Additionally, the end cap 102 secures the conduit assembly 52 and housing 74 so that there is no longitudinal movement of one relative to the other. This is achieved by the end cap 102 sliding between the inner surface 100 of the housing 74
15 and the outer surface 98 of the conduit assembly 52 and fixing the housing 74 and conduit assembly 52 in place.

In an embodiment of the invention, the end cap 102 may optionally have holes drilled through its surfaces to provide lower resistance to exhaust gas flow out of the
20 intermediate volume 94.

It is envisaged that in an alternative embodiment, an end cap will not be used, and the conduit assembly 52 will be joined directly to the housing 74. In a further embodiment, the conduit assembly 52 and housing 74 may be manufactured as a single component.
25 This may allow the removal and necessity of the spacers 96 along the length of the conduit 14 and would fix the conduit assembly 52 and housing 74 relative to one another.

Alternative embodiments of the invention include apertures in a conduit assembly in a
30 variety of patterns, shapes and sizes. For example, in one configuration of apertures, 10 sets of apertures, each set having apertures of a different size, and wherein the sizes of the apertures are at 0.5 mm intervals from 0.5 mm to 5 mm inclusive. Each set of apertures is therefore tuned to attenuate a particular frequency of sound waves propagating through the gas. The aperture sets are arranged such that the density of

apertures of a particular size is constant along the length of the conduit assembly. As will be clear to the skilled person, many other different configurations exist.

5 In an embodiment of the invention, sound absorbing material may be incorporated into the conduit 14 to increase the attenuation of the noise. The sound absorbing material is placed in the intermediate volume 94, or at specific, strategic points along the length of the conduit 14. Gauze may be incorporated between the conduit assembly 52 and the housing 74 to restrict movement of the absorbing material within the intermediate volume 94. For example, a mineral wool may be used for its sound absorbing
10 properties. Due to the dense nature of mineral wool, it is unlikely to pass through the apertures 58a, 58b, 58c, 58d in either the conduit assembly 52 or the housing 74, and so will remain in position during use.

15 In an alternative embodiment, the apertures 82a, 82b, 82c in the housing 74 may be positioned close to the end cap 102 or outlet of the conduit 14. In this case, the conduit 14 may incorporate sound absorbing material as above to achieve a similar effect along its length.

20 In another embodiment of the invention, the housing 74 comprises a taut micro-perforated foil or textured sheet rather than an outer pipe 80. Micro-perforated foils have good absorptive properties and provide the advantage of a significant weight reduction without significant loss of noise attenuation properties.

25 In an alternative embodiment, the apertures of the conduit assembly exist within a gauze or micro-perforated foil installed in an opening in the wall of the conduit assembly.

30 It is possible that alternative conduit configurations may be incorporated without departing from the scope of the invention. For example, the cross-section of the conduit 14 may be an oval shape to enable a flatter profile.

In alternative system configurations, the second portion 34 may further comprise at least one traditional exhaust pipe section that connects to the conduit 14. Alternatively, a plurality of conduits 14 may be attached to a plurality of pipe sections. For example,

pipe sections may form the inlet and outlet of the second portion 34, a conduit 14 being disposed between the pipe sections. It is possible to combine one or more conduits 14 and one or more pipe sections to form the second portion 34. A variety of junctions and pipe bends may also be incorporated as well as traditional silencer units and other after-treatment devices. In these configurations, the length of each conduit 14 may be of any appropriate length depending upon its positioning and usage. For example, it is envisaged that the range of lengths of the conduit 14 will be between 1 m and 2.5 m.

One possible technique for implementing the invention is shown in Figure 5. In particular, windows (cut outs) are defined in a conduit 200 – in the present case 3 windows 210a, 210b, 210c. Within each of windows 210a, 210b, 210c, a thin sheet of material 220a, 220b, 220c respectively such as metal foil is provided. These may be fixed to the conduit around the respective window, either on the inside or the outside of the conduit, using an adhesive for example. Each of the sheets 220a, 220b, 220c is perforated with apertures. The apertures may be formed in the sheets 220a, 220b, 220c either before or after the sheet is fitted to the respective window. The apertures in respect of each window may be of the same size, or may vary in size along the length of the window. The apertures in respect of one of the windows may differ in size compared with the apertures in respect of another of the windows. For example, the apertures in the sheet 220a of the window 210a may be larger than the apertures in the sheet 220b of the window 210b, which in turn may be larger than the apertures in the sheet 220c of the window 210c. The use of the thin sheet material makes it easier to provide apertures having a smaller pitch, since the direct formation in the walls of the conduit of apertures having a small pitch is difficult, and such small apertures may tend to become blocked due to the relatively large length of the hole (through the wall of the conduit) compared with its size/pitch.

Many modifications may be made to the above examples without departing from the scope of the present invention as defined in the accompanying claims.

CLAIMS

1. A conduit for reducing noise associated with gas conveyed by the conduit, the conduit comprising:
 - 5 a conduit assembly which defines at least two sets of apertures, wherein each set of apertures is configured to attenuate sound waves propagating through the gas; and
 - a housing which surrounds the conduit assembly, wherein the housing which surrounds the conduit assembly defines a first volume, and the conduit
10 assembly defines a second volume, the first volume being no more than twice the size of the second volume.
2. The conduit of Claim 1, wherein the sets of apertures are configured to attenuate sound waves of a particular frequency propagating through the gas.
- 15 3. The conduit of Claim 1, wherein each set of apertures is configured to attenuate sound waves of a particular frequency propagating through the gas.
4. The conduit of any preceding claim, wherein the at least two sets of apertures
20 includes four sets of apertures.
5. The conduit of any preceding claim, wherein the apertures within each set have a uniform size.
- 25 6. The conduit of Claim 5, wherein the size of the apertures in each set is different to the sizes of the apertures in one or more of the other sets.
7. The conduit of any preceding claim, wherein the apertures of the at least two sets of apertures have a uniform shape.
- 30 8. The conduit of Claim 7, wherein the shape of the apertures of one set of the at least two sets of apertures is different to the shape of the apertures within at least one of the other sets of apertures.

9. The conduit of any preceding claim, wherein the conduit assembly defines a hollow member.
- 5 10. The conduit of any preceding claim, wherein the conduit assembly comprises a wall.
11. The conduit of Claim 10, wherein at least one set of the at least two sets of apertures extends through the wall.
- 10 12. The conduit of any preceding claim, wherein the housing has a longitudinal axis, and the longitudinal portion of the housing which surrounds the conduit assembly defines the first volume.
- 15 13. The conduit of any preceding claim, wherein the housing defines at least one set of apertures configured to attenuate sound waves.
14. The conduit of Claim 13, wherein the at least one set of apertures extend through the housing.
- 20 15. The conduit of any preceding claim, wherein the housing comprises a wall.
16. The conduit of any preceding claim, wherein the housing comprises foil.
- 25 17. The conduit of any preceding claim, wherein an annular intermediate volume is defined between the conduit assembly and the housing.
18. The conduit of Claim 17, wherein a sound absorptive material is disposed within the intermediate volume.
- 30 19. The conduit of Claims 17 or 18, wherein the conduit further comprises a plurality of spacers positioned within the intermediate volume so as to maintain the position of the conduit assembly relative to the housing.

20. The conduit of any preceding claim, wherein the conduit comprises an inlet for gas ingress into the conduit and an outlet for gas egress from the conduit.
- 5 21. The conduit of Claim 20, wherein the conduit assembly extends between the inlet and the outlet.
22. The conduit of Claims 20 or 21, wherein the housing extends between the inlet and the outlet.
- 10 23. The conduit of any preceding claim, further comprising an end cap to maintain the position of the conduit assembly relative to the housing.
24. The conduit of any preceding claim, wherein each set of apertures comprises apertures of a size in the range 0.1 mm to 5 mm.
- 15 25. The conduit of any preceding claim, wherein the length of the conduit is greater than 1 m (one metre).
26. The conduit of any preceding claim, wherein the diameter of the conduit is not greater than 90 mm.
- 20 27. The conduit of any preceding claim, wherein the size of the apertures varies continuously along the length of the conduit.
- 25 28. The conduit of any preceding claim, comprising one or more windows in the wall of the conduit, each window being fitted with a sheet of material having apertures through it.
- 30 29. A vehicle exhaust system comprising a conduit according to any preceding claim.
- 35 30. The vehicle exhaust system of Claim 29 comprising a first portion connected to a second portion, the first portion comprising an exhaust manifold and/or at least one after-treatment device, and wherein the second portion is entirely comprised of the conduit.

31. A vehicle comprising the conduit of any one of Claims 1 to 28 or the vehicle exhaust system of Claim 29 or 30.

5

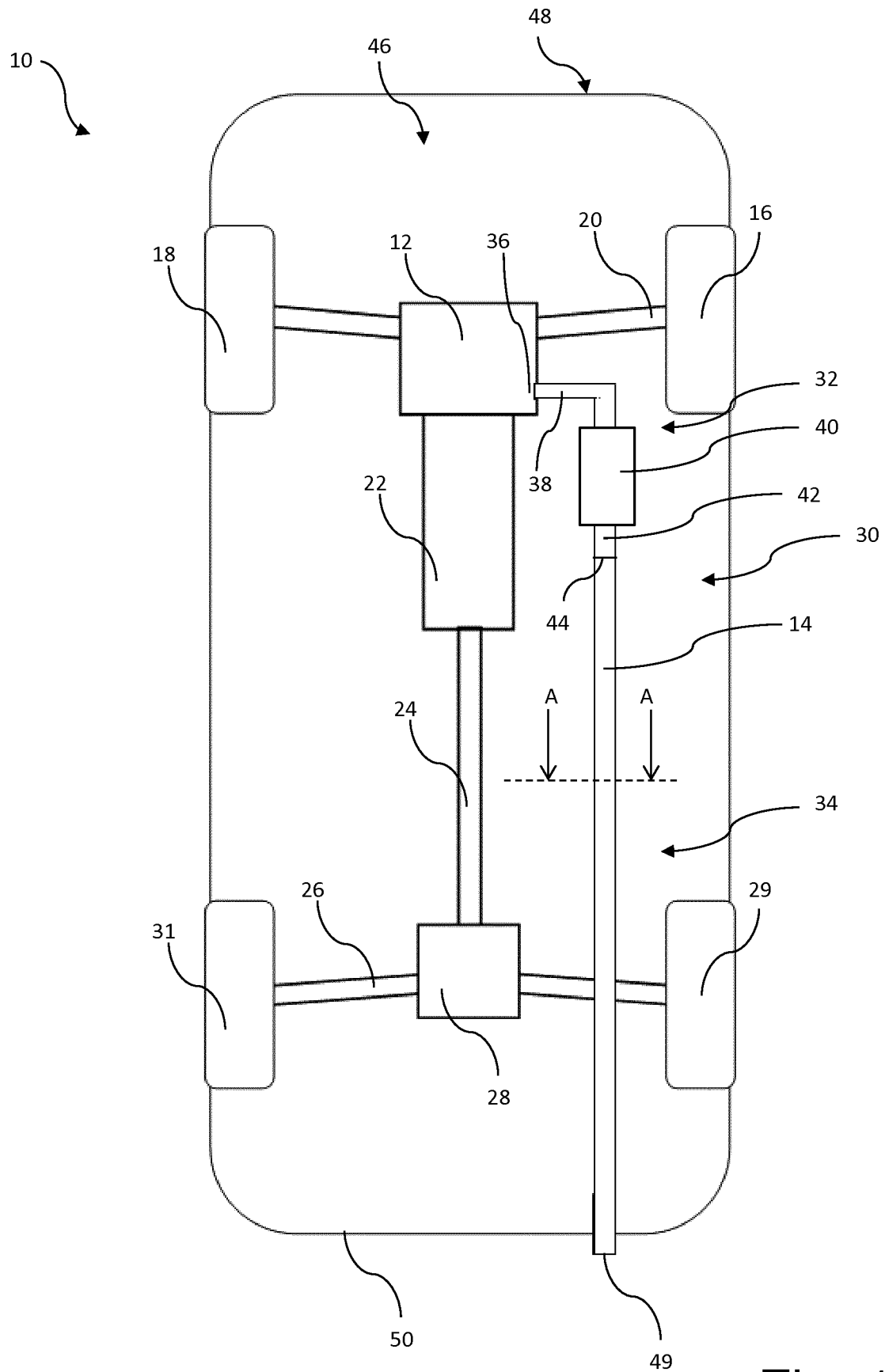


Fig. 1

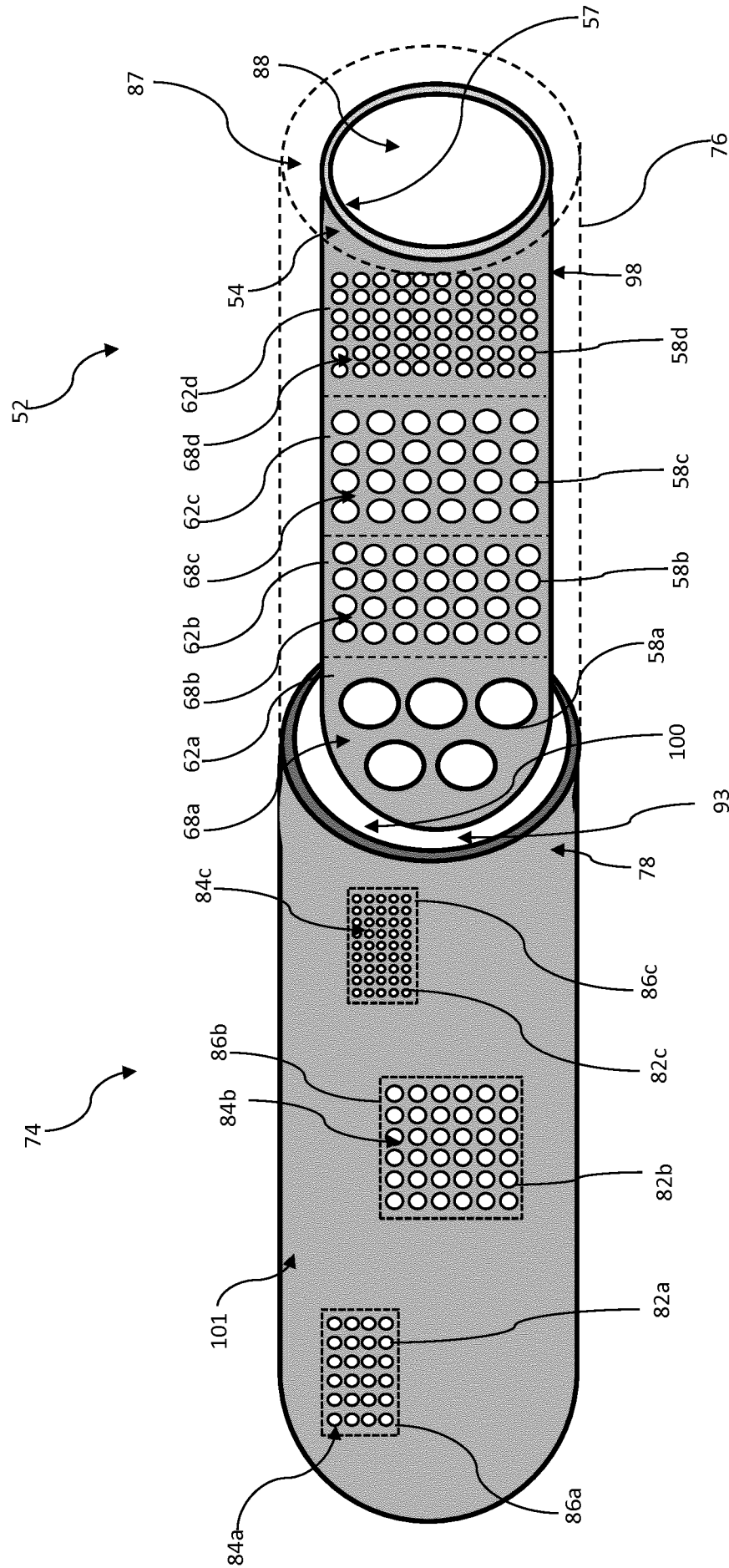


Fig. 2

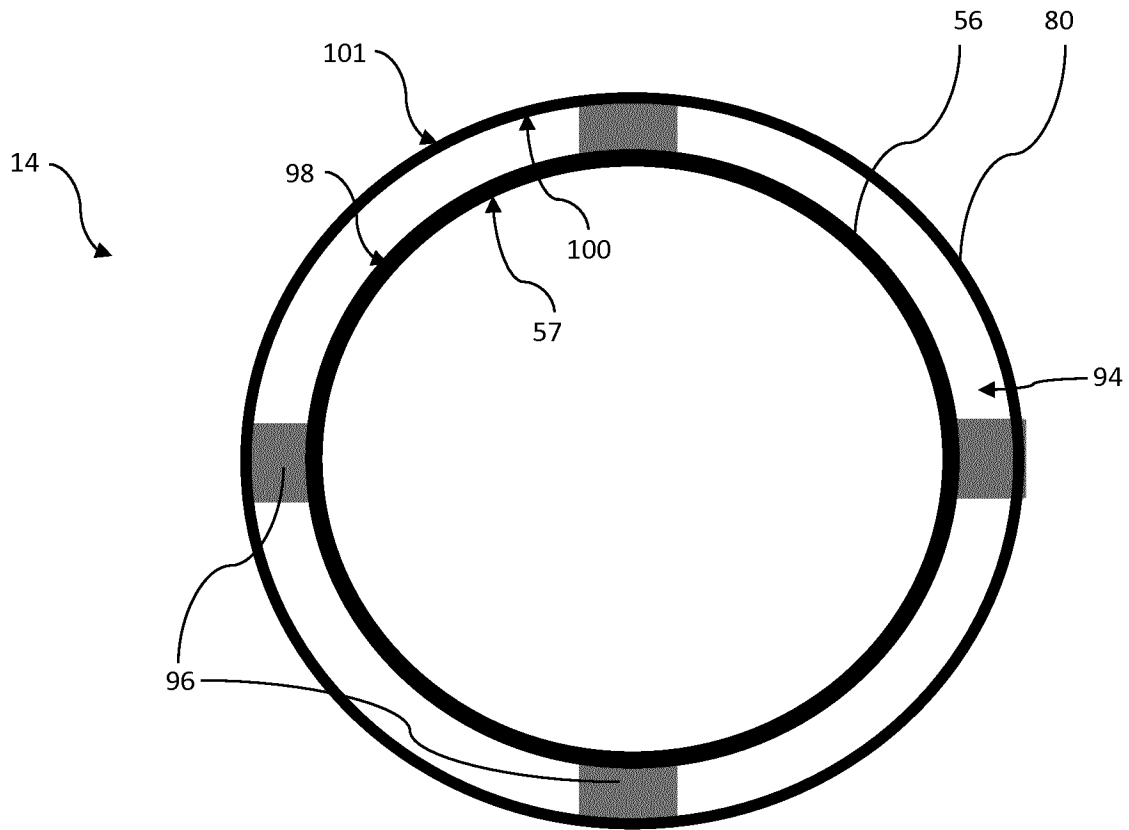


Fig. 3

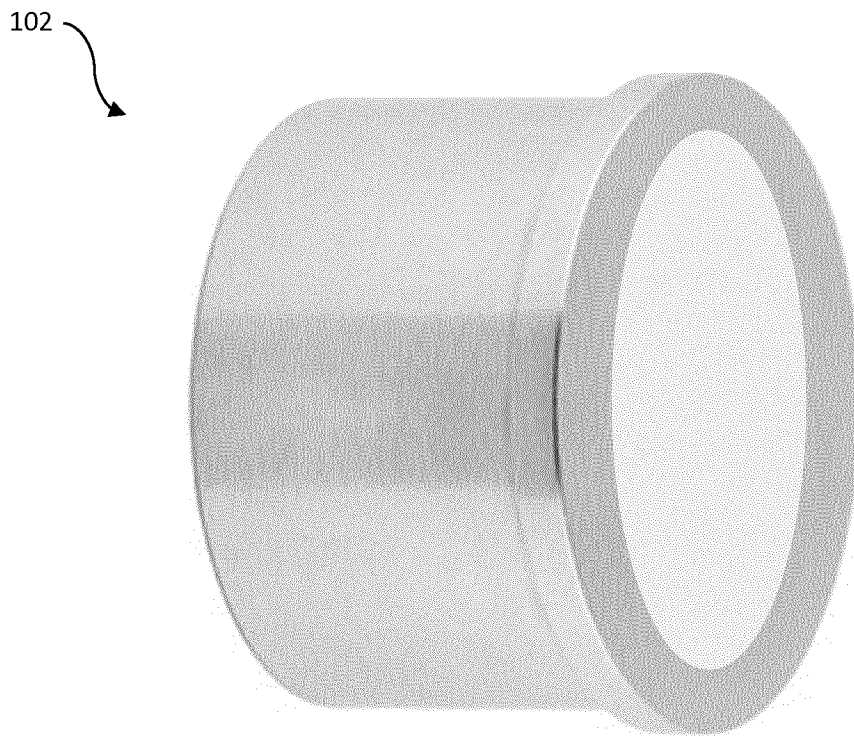


Fig. 4

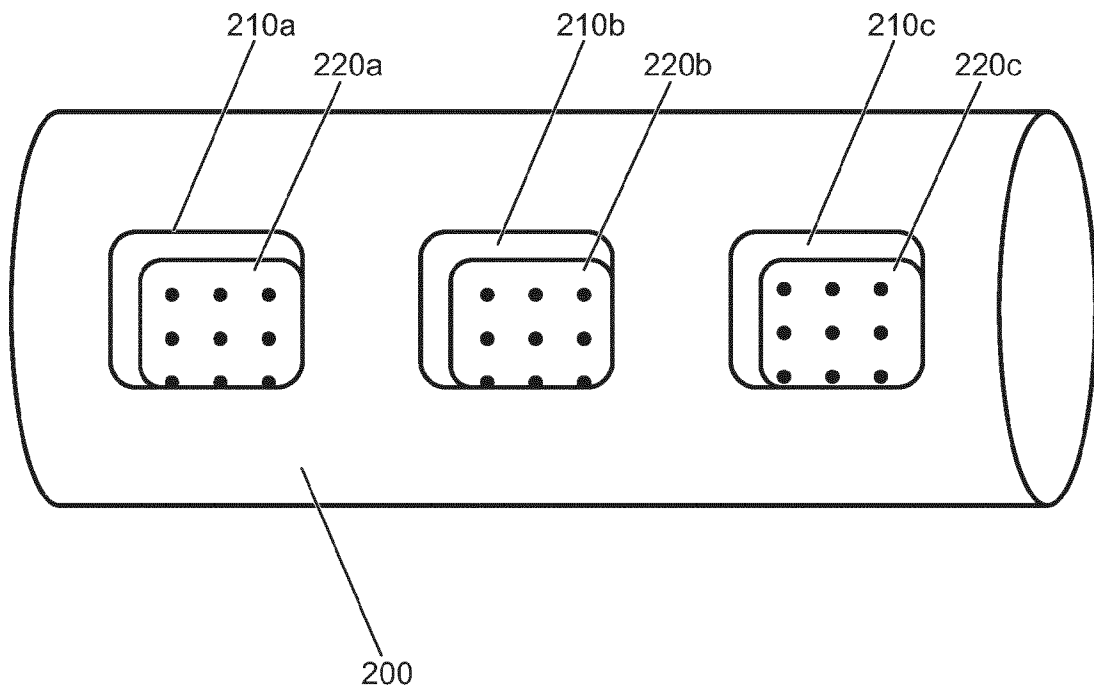


Figure 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/065280

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01N1/02 F01N1/00 F01N1/24
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/126034 A1 (SIERRA BALJIT [CA]) 23 May 2013 (2013-05-23) figures 1-4,6,10,11 page 2, paragraphs 33,36,37,39 page 3, paragraph 56 - page 4, paragraph 56	1-26, 28-31
X	EP 1 375 848 A1 (BENTELER AUTOMOBILTECHNIK GMBH [DE]; BAYERISCHE MOTOREN WERKE AG [DE]) 2 January 2004 (2004-01-02) figure 1 ----- -/--	1-3, 5-12, 15-17, 20-22, 27,29,31



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

26 September 2017

Date of mailing of the international search report

17/10/2017

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Harf, Julien

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/065280

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 371 331 A (WALL ALAN T [US]) 6 December 1994 (1994-12-06) cited in the application figure 3 -----	1-3, 5-12, 15-23, 29,31
X	US 2 191 620 A (MULLER LLOYD E) 27 February 1940 (1940-02-27) figure 1 -----	1-3, 5-12, 15-17, 19-23, 29,31
A	FR 2 865 766 A1 (HUTCHINSON [FR]) 5 August 2005 (2005-08-05) figures 2,3 -----	1-31
A	US 5 350 888 A (SAGER JR ROBERT L [US] ET AL) 27 September 1994 (1994-09-27) figures 1,2 -----	1-31
A	US 4 706 454 A (SMITH JR JOHNNY M [US]) 17 November 1987 (1987-11-17) figures 1,2 -----	28

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/065280

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013126034	A1	23-05-2013	CA 2806707 A1 29-09-2011
			EP 2556228 A1 13-02-2013
			US 2013126034 A1 23-05-2013
			WO 2011116447 A1 29-09-2011
EP 1375848	A1	02-01-2004	AT 286202 T 15-01-2005
			EP 1375848 A1 02-01-2004
US 5371331	A	06-12-1994	NONE
US 2191620	A	27-02-1940	NONE
FR 2865766	A1	05-08-2005	EP 1559877 A1 03-08-2005
			FR 2865766 A1 05-08-2005
			JP 2005214209 A 11-08-2005
			US 2005167192 A1 04-08-2005
US 5350888	A	27-09-1994	NONE
US 4706454	A	17-11-1987	NONE