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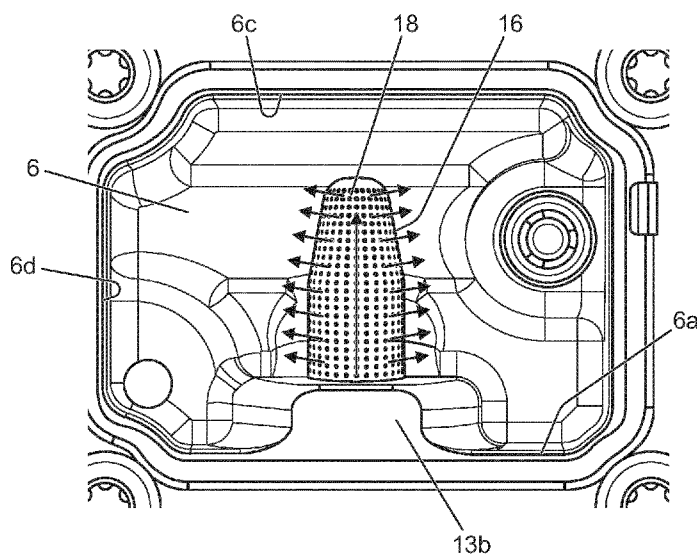


Figure 5

(57) Abstract: The present invention provides a variable valve lift system (3) for an automotive internal combustion engine (2), the variable valve lift system comprising: a high pressure chamber (4, 5) configured to receive a fluid for controlling the operation of at least one valve (7) of the engine; a medium pressure chamber (6) configured to be selectively fluidically coupled to the high pressure chamber to control the pressure of fluid within the high pressure chamber; a valve assembly (1 3) for controlling the flow of fluid between the high pressure chamber and the medium pressure chamber; and a diffusing system (16, 19, 20, 21) configured to diffuse pressure waves entering the medium pressure chamber in use. A method of operating a variable valve lift system of an automotive internal combustion engine is also provided.



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VARIABLE VALVE LIFT SYSTEM

TECHNICAL FIELD

- 5 The present disclosure relates to hydraulically actuated variable valve lift systems for automotive internal combustion engines. Aspects of the invention relate to a variable valve lift system, to an automotive internal combustion engine, and to a method of operating a variable valve lift system.

10 BACKGROUND

- It is well established that the ability to vary the timing, duration and lift of valves in an internal combustion engine offers advantages in terms of engine performance and efficiency. For example, it may be desirable to implement a higher valve lift when the
15 engine is running at a relatively high speed in order to maximise performance, while lowering the valve lift at lower engine speeds so as to improve efficiency. It may also be desirable to close an intake valve early during some modes of operation in order to control the quantity of air entering an engine cylinder.

- 20 Mechanical variable valve lift systems are known, in which a pair of cam sets is provided to drive the intake valves; one cam set optimised for providing low valve lift at low engine speeds, and the other for providing higher valve lift at higher engine speeds. The vehicle switches between cam sets when an engine speed threshold is passed. This type of arrangement is often referred to as 'cam profile switching'. A
25 drawback with such arrangements is that the switching creates a step change in engine output, resulting in reduced refinement. Even if the switch is timed to coincide with a crossing point for respective torque curves of each of the cam sets, there can be a momentary loss of performance during the switch.

- 30 For this reason, various continuously variable valve lift (CVVL) systems have been proposed, and some are in use in modern vehicles. These systems are able to control valve lift to any desired level within the operational range of the valve. This means that valve lift can be optimised throughout the engine speed range, thereby enabling true optimisation of engine performance.

One such arrangement employs a hydraulic system for controlling valve lift, including one or more high pressure chambers each filled with a working fluid for controlling the operation of at least one valve and one or more medium pressure chambers arranged
5 to be selectively fluidically coupled to the high pressure chambers to control the pressure of the fluid within the high pressure chambers. However, engines fitted with variable valve lift systems of this type can suffer from additional noise, vibrations and harshness (NVH) issues.

10 It is an aim of the present invention to address disadvantages associated with the prior art.

SUMMARY OF THE INVENTION

15 According to an aspect of the present invention there is provided a variable valve lift system for an automotive internal combustion engine, the variable valve lift system comprising:

- a high pressure chamber configured to receive a fluid for controlling the operation of at least one valve of the engine;
- 20 a medium pressure chamber configured to be selectively fluidically coupled to the high pressure chamber to control the pressure of fluid within the high pressure chamber;
- a valve assembly for controlling the flow of fluid between the high pressure chamber and the medium pressure chamber; and
- 25 a diffusing system configured to diffuse pressure waves entering the medium pressure chamber in use.

The diffusing system acts during use of the variable valve lift system to diffuse pressure waves passing towards and/or through the medium pressure chamber,
30 especially when the valve assembly is opened to reduce pressure in the high pressure chamber, for example during early intake valve closing (EIVC) modes of operation. The diffusing system therefore enables a reduction in noise, vibration and harshness (NVH) issues caused by the introduction of the variable valve lift system. The diffusion of pressure waves may, for example, include the attenuation or breaking up of

pressure waves before impact with a rear wall of the medium pressure chamber and/or the deflection of pressure waves before impact with the rear wall of the medium pressure chamber to thereby reduce NVH issues.

- 5 The diffusion of pressure waves may occur in the medium pressure chamber and/or within a passage extending between the valve assembly and the medium pressure chamber, depending on the design and location of the diffusing system, as described in more detail below.
- 10 The variable valve lift system may be for controlling the operation of at least one intake valve and/or at least one exhaust valve. The variable valve lift system may comprise multiple high pressure chambers each configured for use in controlling at least one valve, and may comprise multiple medium pressure chambers each configured for controlling the pressure of fluid within at least one of the high pressure chambers.
- 15 Each of the medium pressure chambers may be provided with a respective diffusing system. The variable valve lift system may be a continuously variable valve lift system.

- It will be appreciated that the variable valve lift system does not require the presence
- 20 of any particular fluid within the high pressure chamber or the medium pressure chamber, and that the working fluid may be introduced into the high pressure chamber and the medium pressure chamber once the system has been installed and is ready for use. Therefore the variable valve lift system may be supplied without any particular working fluid being present in the high pressure chamber and the medium pressure
 - 25 chamber.

It will be appreciated that the terms “high pressure” and “medium pressure” refer only to the pressures typically experienced in one of the chambers relative to the other.

- 30 The diffusing system may comprise at least one diffusing element configured to allow fluid passing through or travelling towards the medium pressure chamber to pass therethrough. The diffusing element may act to attenuate and/or break up pressure waves passing therethrough in use. By arranging the diffusing element to attenuate and/or break up pressure waves before impact against the rear wall of the medium

pressure chamber it is possible to minimise NVH issues caused by the introduction of the variable valve lift system.

5 The diffusing element may comprise a wall having a plurality of apertures extending therethrough, the apertures being configured to allow fluid passing through or travelling towards the medium pressure chamber to pass therethrough. The apertures may be at least substantially circular in shape, although other shapes are also possible. The apertures may have small diameters, for example less than 2mm or less than 1mm or less than 0.5mm or less than 0.25mm, although other diameters are also possible.

10

The wall may include a large number of apertures, for example at least 100 apertures, or at least 200 apertures, or at least 400 apertures. Other numbers are also possible.

15 The diffusing element may be in the form of a sleeve. The sleeve may take the form of an elongate cylinder, although other shapes are also possible. The sleeve may be substantially hollow. The sleeve may be configured to allow fluid entering or travelling towards the medium pressure chamber to pass through its interior, for example along its length. The sleeve may optionally be at least partially filled with a porous material for diffusing pressure waves passing through the sleeve, such as a sponge type material or a metal wool type material.

20 Other forms are also possible, such as a plate, optionally a planar plate, including apertures. Such a plate may, for example, be located in the medium pressure chamber between an inlet of the medium pressure chamber (via which fluid enters the medium pressure chamber in use) and a rear wall of the medium pressure chamber (that is the wall opposing the inlet), or in a passage extending between the valve assembly and the medium pressure chamber.

25 The apertures may decrease in size towards a distal end of the sleeve. The decrease in the size of the apertures may be progressive, or alternatively may occur in one more steps.

The sleeve may have a substantially closed distal end. However, the distal end of the sleeve may still be provided with apertures, as described above.

The sleeve may taper inwardly towards its distal end. The sleeve may taper along only a portion of its length, and may comprise at least one section of substantially constant cross-section in addition to a tapered section.

5

The sleeve may be located at least partially within the medium pressure chamber. The sleeve may be located substantially or even entirely within the medium pressure chamber. Alternatively the sleeve may be located at least partially within a passage extending between the valve assembly and the medium pressure chamber.

10

The sleeve may be mounted to the valve assembly. For example, a portion of the sleeve such as a mounting flange may be retained between a valve and a housing of the valve assembly. Other mounting arrangements are also possible.

15 The diffusing element may comprise a porous material configured to allow the passage of fluid therethrough.

The porous material may comprise a sponge type material or a metal wool type material, for example steel wool.

20

The porous material may be provided in the medium pressure chamber and/or in a passage extending between the valve assembly and the medium pressure chamber. Where the diffusing system comprises both a diffusing element in the form of a sleeve and a porous material configured to allow the passage of fluid therethrough, the
25 porous material may be located either inside the sleeve or outside the sleeve.

30

The diffusing system may comprise a diffusing element that is configured to deflect pressure waves before impact against a rear wall of the medium pressure chamber (that is the wall opposing the inlet via which fluid enters the medium pressure chamber in use). By arranging the diffusing element to deflect pressure waves before impact against the rear wall of the medium pressure chamber it is possible to prevent pressure waves from impacting the rear wall of the medium pressure chamber perpendicularly, thereby reducing NVH issues caused by the introduction of the variable valve lift system.

The diffusing element may be located between the rear wall of the medium pressure chamber and the inlet via which fluid enters the medium pressure chamber in use. The diffusing element may be located at least substantially directly in front of the inlet,
5 or alternatively may be offset from the inlet.

The diffusing element may extend outwardly from the rear wall of the medium pressure chamber in a direction towards the inlet.

10 The diffusing element may be integrally formed with the rear wall of the medium pressure chamber.

The diffusing element may be in the form of a protrusion. The diffusing system may comprise only one protrusion or alternatively a plurality of the protrusions. The
15 protrusion(s) may be provided either alone or in combination with one more recesses.

In addition to diffusing pressure waves, the protrusion may be configured to reinforce at least a portion of the medium pressure chamber. By reinforcing at least a portion of the medium pressure chamber, the protrusion may further reduce NVH issues
20 generated during operation of the variable valve lift system.

The protrusion may be configured to split pressure waves before impact against the rear wall of the medium pressure chamber.

25 The protrusion may be in the form of an elongate rib. Other shapes are also possible, for example an axisymmetric protrusion.

The rib may have a leading edge that is substantially perpendicular to a direction towards the inlet, or that is angled with respect to a direction towards the inlet.
30

The protrusion may extend outwardly from the wall by at least 3mm, preferably by at least 5mm. Other dimensions are also possible.

The protrusion may taper inwardly in a direction away from the rear wall of the medium pressure chamber (and towards the inlet).

5 The protrusion may have a rounded or pointed tip. The rounded tip may have a radius of at least 2mm or at least 4mm.

10 The protrusion may be blended into the rear wall with a radius of curvature of at least 3mm, preferably at least 5mm. The protrusion may be blended into the rear wall with a radius of curvature that is as large as permitted by the available package area. Other dimensions are also possible. The protrusion may be blended into the rear wall with a smaller radius of curvature, for example 1mm. However, blending the protrusion into the rear wall with a larger radius of curvature may enable the protrusion to deflect pressure waves and thereby minimise NVH issues more effectively.

15 The diffusing element may comprise a side wall of the medium pressure chamber located adjacent to the rear wall of the medium pressure chamber that is configured to deflect pressure waves before impact against the rear wall of the medium pressure chamber.

20 The deflecting side wall may have a curved shape. The curved deflecting side wall may be blended into the rear wall of the medium pressure chamber.

The inlet via which fluid enters the medium pressure chamber in use may be located adjacent to the deflecting side wall.

25

It will be appreciated that a single diffusing system may include any combination of the various types of diffusing elements described above.

30 A further aspect of the present invention provides an automotive internal combustion engine comprising a variable valve lift system as described above.

A further aspect of the present invention provides a vehicle comprising an automotive internal combustion engine as described above. The vehicle may be a car.

A further aspect of the present invention provides a method of operating a variable valve lift system of an automotive internal combustion engine, the method comprising using fluid pressure within a high pressure chamber to control the operation of at least one valve of the engine; opening a valve assembly to fluidically connect the high pressure chamber to a medium pressure chamber to thereby reduce the fluid pressure
5 within the high pressure chamber; and using a diffusing system to diffuse a pressure wave entering the medium pressure chamber in response to the opening of the valve assembly.

10 The method may be used in operating a variable valve lift system as described above, and may include any steps associated with the normal operation of a variable valve lift system including any of the above-described features.

The step of using the diffusing system to diffuse the pressure wave may comprise
15 using the diffusing system to attenuate and/or break up and/or deflect the pressure wave before impact against a rear wall of the medium pressure chamber.

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
20 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
25 amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

BRIEF DESCRIPTION OF THE DRAWINGS

30 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 illustrates a vehicle;

Figures 2 and 3 schematically illustrate a portion of a continuously variable valve lift (CVVL) system according to an embodiment of the present invention;

Figures 4 and 5 schematically illustrate the medium pressure chamber of the CVVL
5 system of Figures 2 and 3;

Figures 6 to 8 schematically illustrate the medium pressure chamber of a CVVL system according to a further embodiment of the present invention;

10 Figures 9 and 10 schematically illustrate the medium pressure chambers of CVVL systems according to still further embodiments of the present invention.

DETAILED DESCRIPTION

15 Figure 1 illustrates a car 1. The car comprises an engine 2 having a plurality of combustion cylinders (not shown), each provided with a pair of intake valves. The intake valves are controlled by a continuously variable valve lift (CVVL) system 3 according to an embodiment of the present invention, as described below. The CVVL system 3 comprises a camshaft and a plurality of hydraulic systems that are each
20 configured to be driven by the cam shaft and to control the operation of the intake valves of a respective one of the combustion cylinders. For simplicity the following description refers only to a single hydraulic system for controlling the intake valves of a single combustion cylinder, although it will be appreciated that the CVVL system also comprises further similarly arranged hydraulic systems for controlling the operation of
25 the intake valves of the remaining combustion cylinders.

Figures 2 and 3 schematically illustrate a portion of the CVVL system 3 for controlling the intake valves of one of the combustion cylinders of the engine 2. The CVVL system 3 comprises a master cylinder 4, a slave cylinder 5, and a control chamber or
30 medium pressure chamber 6, each of which is filled with a working fluid, for example engine oil, in use. The master cylinder 4 and the slave cylinder 5 together form a high pressure chamber. In use, the CVVL system 3 controls the operation of the intake valves 7 of the combustion cylinder by controlling the oil pressure within the high pressure chamber 4, 5. The medium pressure chamber 6 is configured to be

selectively fluidically coupled to the high pressure chamber 4, 5 to control the pressure of the oil within the high pressure chamber, as described in more detail below.

5 The master cylinder 4 is provided with a master piston 8 that is configured to be driven by a cam lobe 9 of the camshaft 10. The master piston 8 is biased outwardly from the master cylinder 4 by a spring (not shown). The master piston 8 may be driven by the cam lobe 9 via a finger follower or other mechanical coupling arrangement, although Figures 2 and 3 illustrate the cam lobe 9 acting directly on the master piston 8 for simplicity. The master piston 8 is configured to be moved inwardly into the master
10 cylinder 4 by the cam lobe 9 to thereby increase the pressure of the oil within the high pressure chamber 4, 5 (including both the master cylinder and the slave cylinder).

The slave cylinder 5 is provided with a slave piston 11 that is configured to be driven by the pressure of the oil within the high pressure chamber 4, 5, and to thereby control
15 the position of the intake valves 7. The intake valves 7 may be driven by the slave piston 11 via a mechanical or hydraulic coupling arrangement, although Figures 2 and 3 illustrate the slave piston 11 acting directly on a single intake valve 7 for simplicity. The slave piston 11 is biased inwardly into the slave cylinder 5 by a slave piston spring 12. During operation of the engine 2, as the cam lobe 9 pushes the master piston 8
20 into the master cylinder 4 thereby increasing the oil pressure within the high pressure chamber 4, 5, the increased oil pressure causes the slave piston 11 to move outwardly from the slave cylinder 5 to thereby move the intake valves 7 into their open positions. Later during the rotation cycle of the camshaft 10, as the cam lobe 9 allows the master piston 8 to move outwardly from the master piston 4, the oil pressure within the high
25 pressure chamber 4, 5 decreases, thereby allowing the slave piston 11 to move inwardly back into the slave cylinder 5 and the intake valves 7 to return to their closed positions. In this way the CVVL system 3 may be operated to open and close the intake valves 7 in accordance with the profile of the cam lobe 9.

30 The medium pressure chamber 6 is coupled to the high pressure chamber by a passage extending between the high pressure chamber 4, 5 and the medium pressure chamber 6. The CVVL system 3 further comprises a valve assembly 13 including a solenoid valve 13a and a valve housing 13b. (The valve assembly 13 is only illustrated schematically in Figures 2 and 3, but the solenoid valve 13a and the valve

housing 13b are illustrated in more detail in Figure 4.) The solenoid valve 13a is configured to be controlled electrically, and may be selectively moved between an open position in which the passage between the high pressure chamber 4, 5 and the medium pressure chamber 6 is opened and the medium pressure chamber 6 is fluidically coupled to the high pressure chamber 4, 5, and a closed position in which the valve assembly 13 acts to close the passage between the high pressure chamber 4, 5 and the medium pressure chamber 6 such that the medium pressure chamber 6 is isolated from the high pressure chamber 4, 5. The medium pressure chamber 6 is provided with a control plunger 14 for controlling the pressure of oil within the medium pressure chamber 6. The control plunger 14 is biased inwardly towards the medium pressure chamber 6 by a control plunger spring 15. The control plunger spring 15 is less stiff than the slave piston spring 12.

The medium pressure chamber 6 is generally cuboidal in shape, and comprises a front wall 6a including an inlet 6b via which oil enters the medium pressure chamber from the high pressure chamber 4, 5 when the solenoid valve 13a is opened in use. The medium pressure chamber further comprises a rear wall 6c (that is the wall opposite to and facing towards the inlet 6b), and side walls 6d extending between the front wall 6a and the rear wall 6c. It will be appreciated that other shapes are also possible for the medium pressure chamber 6.

During operation of the engine 2, the solenoid valve 13a may be maintained in its closed position (as schematically illustrated in Figure 2) to thereby isolate the medium pressure chamber 6 from the high pressure chamber 4, 5. In this mode of operation the CVVL system 3 does not vary the timing, lift or duration of the intake valves 7, and the intake valves 7 are instead opened and closed in accordance with the basic profile of the cam lobe 9.

However, it is additionally possible to operate the solenoid valve 13a during operation of the engine 2 (as schematically illustrated in Figure 3) to selectively fluidically couple the medium pressure chamber 6 to the high pressure chamber 4, 5 to thereby control the oil pressure within the high pressure chamber 4, 5 and therefore the opening and closing of the intake valves 7. For example, it is possible to move the solenoid valve 13a into its open position while the intake valve 7 is open (either at a position of

maximum opening or during intake valve opening) to thereby open the passage between the high pressure chamber 4, 5 and the medium pressure chamber 6 and fluidically couple the medium pressure chamber 6 to the high pressure chamber 4, 5. When the medium pressure chamber 6 is fluidically coupled to the high pressure chamber 4, 5, the oil pressure in the high pressure chamber 4, 5 rapidly reduces, and the oil pressure in the medium pressure chamber increases 6. When this happens, the control plunger 14 is forced outwardly away from the medium pressure chamber 6 by the increased oil pressure in the medium pressure chamber 6, thereby increasing the volume of the medium pressure chamber 6, and oil is allowed to flow from the high pressure chamber 4, 5 towards and into the medium pressure chamber 6. The reduction in oil pressure in the high pressure chamber 4, 5 allows the slave piston 11 to move inwardly back into the slave cylinder 5 under the action of the slave piston spring 12, thereby allowing the intake valves 7 to return to their closed positions earlier than if the solenoid valve 13a had not been opened. In this way, it is possible to operate the CVVL system 3 to close the intake valves 7 early to achieve an early intake valve close (EIVC) mode of operation.

The skilled person will understand that the CVVL system 3 may also be operated in other ways to achieve other modes of operation besides EIVC. For example, the solenoid valve may be maintained in its open position prior to intake valve opening and then moved into its closed position after the cam lobe 9 has started to move the master piston 8 inwardly into the master cylinder 4 to achieve a late intake valve open (LIVO) mode of operation. Other modes of operation of a hydraulic CVVL system 3 are known to the skilled person and will not be described in detail.

25

The CVVL system 3 further comprises a diffusing element 16 in the form of a hollow, elongate, cylindrical sleeve, as illustrated in Figures 4 and 5. The sleeve 16 is located substantially within the medium pressure chamber 6 and is mounted to the valve assembly 13 by a mounting flange 17 that is retained between the solenoid valve 13a and the valve housing 13b. The sleeve 16 includes a proximal portion with a constant cross-section, and a distal portion which tapers inwardly towards the distal end of the sleeve 16. The sleeve is formed by a wall, and includes a large number of small circular apertures 18, for example approximately 400 apertures. Each aperture has a diameter of approximately 0.4mm. The apertures 18 are configured to allow oil

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entering the medium pressure chamber 6 to pass therethrough. The apertures illustrated in Figures 3 and 4 are substantially identical, but in other embodiments the diameters of the apertures may generally decrease towards the distal end of the sleeve. The sleeve 16 has a substantially closed distal end, but the closed distal end
5 may optionally still be provided with one or more apertures. The sleeve may optionally be at least partially filled with a porous material, for example a sponge type material or a metal wool type material.

During operation of the CVVL system 3, the oil pressures experienced in the high
10 pressure chamber 4, 5 may reach 90 to 120 bar or more while the medium pressure chamber 6 is isolated from the high pressure chamber 4, 5. In contrast, the medium pressure chamber 6 is generally maintained at a far lower pressure, for example at oil feed pressure. When the solenoid valve 13a is opened to fluidically couple the medium pressure chamber 6 to the high pressure chamber 4, 5, especially during
15 EIVC modes of operation, a strong pressure wave passes from the valve assembly 13 towards and into the medium pressure chamber 6. This may lead to noise, vibrations and harshness (NVH) issues. However, as the pressure wave enters the medium pressure chamber 6, the pressure wave is diffused by the sleeve 16, which acts to break up the pressure wave before it can impact the rear wall 6c of the medium
20 pressure chamber (that is the wall opposite to the inlet via which oil enters the medium pressure chamber in use). The sleeve 16 therefore acts as a diffusing system and reduces NVH issues caused by the introduction of the hydraulic CVVL system 3.

Figures 6, 7 and 8 illustrate a medium pressure chamber 6 of a CVVL system 3
25 according to another embodiment of the present invention. The CVVL system 3 illustrated in part in Figures 6, 7 and 8 is generally similar to the CVVL system described above, and so the same reference numbers have been used for equivalent elements of the system and only differences compared to the CVVL system illustrated in part in Figures 4 and 5 will be described.

30

The medium pressure chamber 6 illustrated in Figures 6, 7 and 8 is generally similar in design to the medium pressure chamber illustrated in Figures 4 and 5. However, instead of a diffusing element in the form of a sleeve, the medium pressure chamber 6 illustrated in Figures 6, 7 and 8 instead includes a diffusing element 19 in the form of

an elongate, rib-shaped protrusion located between the rear wall 6c of the medium pressure chamber 6 and the inlet 6b via which oil enters the medium pressure chamber in use. The rib 19 is integrally formed with the rear wall 6c of the medium pressure chamber 6 and extends outwardly from the rear wall 6c of the medium pressure chamber 6 towards the inlet 6b by approximately 6mm. The rib 19 generally
5 tapers inwardly towards the inlet 6b, and has a rounded tip with a radius of approximately 5mm. The rib 19 is blended into the rear wall 6c of the medium pressure chamber 6 with a radius of curvature of approximately 6mm. The rib 19 has a leading edge that is angled with respect to the direction towards the inlet 6b, as
10 shown most clearly in Figure 7.

Figures 6 and 7 also illustrate an adjacent medium pressure chamber 6' (corresponding to another cylinder of the engine) that does not include a diffusing rib for comparison.

15

As pressure waves enter the medium pressure chamber 6 during use of the CVVL system 3, the rib 19 acts to split the pressure waves before impact against the rear wall 6c of the medium pressure chamber 6, as illustrated in Figure 8. In addition, the rib 19 also acts to divert the pressure waves before impact against the rear wall 6c of
20 the medium pressure chamber 6, thereby preventing the pressure waves from impacting the rear wall 6c of the medium pressure chamber in a direction perpendicular to the rear wall 6c, as also illustrated in Figure 8. In this way the rib 19 diffuses pressure waves entering the medium pressure chamber 6, thereby reducing NVH issues caused by the introduction of the hydraulic CVVL system 3. The
25 attenuation of pressure waves is improved by arranging the rib 19 to split the pressure waves and by blending the rib 19 into the rear wall 6c of the medium pressure chamber 6 with a large radius.

The rib 19 illustrated in Figures 6, 7 and 8 also provides the advantage of stiffening the
30 medium pressure chamber 6, thereby further reducing NVH issues caused by the introduction of the hydraulic CVVL system 3. By forming the rib 19 integrally with a wall 6c of the medium pressure chamber 6 it is also not necessary to introduce any additional components (such as a sleeve as illustrated in Figures 4 and 5) in order to diffuse pressure waves entering the medium pressure chamber 6.

It will be appreciated that the protrusion 16 is not required to be a single elongate rib as illustrated in Figures 6, 7 and 8, but may instead take the form of one or more protrusions of any shape(s) that are adapted to diffuse pressure waves to thereby
5 reduce NVH issues, for example an axisymmetric protrusion.

Figure 9 illustrates a medium pressure chamber 6 of a CVVL system 3 according to another embodiment of the present invention. The CVVL system 3 illustrated in part in
10 Figure 9 is generally similar to the CVVL systems described above, and so the same reference numbers have been used for equivalent elements of the system and only differences compared to the CVVL systems illustrated in part in Figures 4 to 8 will be described.

The medium pressure chamber illustrated in Figure 9 is generally similar in design to
15 the medium pressure chambers illustrated in Figures 4 to 8. However, instead of a diffusing element in the form of a sleeve or a rib, the medium pressure chamber 6 illustrated in Figure 9 instead includes a diffusing element 20 in the form of a sponge type or metal wool type porous material provided in the medium pressure chamber 6. The porous material 20 is provided as a block that occupies a portion of the medium
20 pressure chamber 6, and may, in some embodiments, at least substantially full the medium pressure chamber. The porous material 20 is configured to allow the passage of oil therethrough, but to diffuse pressure waves entering the medium pressure 6 chamber during use of the CVVL system 3 before impact with the rear wall 6c of the medium pressure chamber 6, thereby reducing NVH issues caused by the introduction
25 of the hydraulic CVVL system. In other embodiments, a porous material (for example a sponge type or metal wool type material) may equally be used to diffuse pressure waves in a CVVL system also comprising a further diffusing element, for example a rib 19 (in which case the porous material may optionally surround the rib and/or be located in front of the rib) or a sleeve 16 (in which case the porous material may
30 optionally be located within the sleeve).

Figure 10 illustrates a medium pressure chamber 6 of a CVVL system 3 according to another embodiment of the present invention. The CVVL system 3 illustrated in part in Figure 10 is generally similar to the CVVL systems described above, and so the same

reference numbers have been used for equivalent elements of the system and only differences compared to the CVVL systems illustrated in part in Figures 4 to 9 will be described.

- 5 The medium pressure chamber 6 illustrated in Figure 10 is generally similar in design to the medium pressure chambers illustrated in Figures 4 to 9 (although Figure 10 only provides a simplified schematic representation of the medium pressure chamber). However, in the embodiment of Figure 10, the inlet 6b via which oil enters the medium pressure chamber 6 in use is located adjacent to a side wall 6d of the medium pressure chamber 6 instead of in the centre of the front wall 6a. In this embodiment the side wall 6d, 21 adjacent to which the inlet 6b is located has a curved shape 21 and blends into the rear wall 6c of the medium pressure chamber 6 (that is the wall opposite to the inlet 6b). In this embodiment, when pressure waves enter the medium pressure chamber 6, for example in response to opening of the solenoid valve 13a, the curved side wall 21 of the medium pressure chamber acts as a diffusing element by deflecting the pressure waves before impact against the rear wall 6c of the medium pressure chamber 6, thereby preventing the pressure waves from impacting the rear wall 6c of the medium pressure chamber 6 in a direction perpendicular to the rear wall 6c (as illustrated in Figure 10) and reducing NVH issues caused by the introduction of the hydraulic CVVL system 3.

The master cylinder, the slave cylinder, the medium pressure chamber, the passage connecting the master cylinder to the slave cylinder, the passage connecting the high pressure chamber to the medium pressure chamber, and the valve housing may all be provided by a single integrally formed component, for example a cast head of the engine. However, it will be appreciated that in other embodiments one or more of the master cylinder, the slave cylinder, the medium pressure chamber, the passage connecting the master cylinder to the slave cylinder, the passage connecting the high pressure chamber to the medium pressure chamber, and the valve housing may be provided separately by one or more separate components.

In addition, the skilled person will understand that although Figures 2 and 3 schematically illustrate the master cylinder, the slave cylinder and the medium pressure chamber as simple cylinders arranged in a perpendicular "T" shaped

arrangement for simplicity, many shapes and relative arrangements are possible each portion of the CVVL system.

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

CLAIMS

1. A variable valve lift system for an automotive internal combustion engine, the variable valve lift system comprising:
 - 5 a high pressure chamber configured to receive a fluid for controlling the operation of at least one valve of the engine;
 - a medium pressure chamber configured to be selectively fluidically coupled to the high pressure chamber to control the pressure of fluid within the high pressure chamber;
 - 10 a valve assembly for controlling the flow of fluid between the high pressure chamber and the medium pressure chamber; and
 - a diffusing system configured to diffuse pressure waves entering the medium pressure chamber in use.
- 15 2. A variable valve lift system according to claim 1, wherein the diffusing system comprises at least one diffusing element configured to allow fluid passing through or travelling towards the medium pressure chamber to pass therethrough.
- 20 3. A variable valve lift system according to claim 2, wherein the diffusing element comprises a wall having a plurality of apertures extending therethrough, the apertures being configured to allow fluid passing through or travelling towards the medium pressure chamber to pass therethrough.
- 25 4. A variable valve lift system according to claim 2 or claim 3, wherein the diffusing element is in the form of a sleeve.
5. A variable valve lift system according to claim 4, wherein the sleeve has a substantially closed distal end.
- 30 6. A variable valve lift system according to claim 4 or claim 5, wherein the sleeve tapers inwardly towards its distal end.
7. A variable valve lift system according to any of claims 4 to 6, wherein the sleeve is located at least partially within the medium pressure chamber.
- 35

8. A variable valve lift system according to claim 2, wherein the diffusing element comprises a porous material configured to allow the passage of fluid therethrough.
- 5 9. A variable valve lift system according to claim 8, wherein the porous material comprises a sponge type material or a metal wool type material.
- 10 10. A variable valve lift system according to claim 8 or claim 9, wherein the porous material is provided in the medium pressure chamber and/or in a passage extending between the valve assembly and the medium pressure chamber.
- 15 11. A variable valve lift system according to claim 1, wherein the diffusing system comprises a diffusing element that is configured to deflect pressure waves before impact against a rear wall of the medium pressure chamber.
- 20 12. A variable valve lift system according to claim 11, wherein the diffusing element is located between the rear wall of the medium pressure chamber and an inlet via which fluid enters the medium pressure chamber in use.
- 25 13. A variable valve lift system according to claim 11 or claim 12, wherein the diffusing element is integrally formed with the rear wall of the medium pressure chamber.
- 30 14. A variable valve lift system according to any of claims 11 to 13, wherein the diffusing element is in the form of a protrusion.
15. A variable valve lift system according to claim 14, wherein the protrusion is configured to split pressure waves before impact against the rear wall of the medium pressure chamber.
- 35 16. A variable valve lift system according to claim 14 or claim 15, wherein the protrusion is in the form of an elongate rib.
17. A variable valve lift system according to any of claims 14 to 16, wherein the protrusion extends outwardly from the wall by at least 3mm, preferably by at least 5mm.

18. A variable valve lift system according to any of claims 14 to 17, wherein the protrusion tapers inwardly in a direction away from the rear wall of the medium pressure chamber.
- 5 19. A variable valve lift system according to any of claims 14 to 18, wherein the protrusion is blended into the rear wall with a radius of curvature of at least 3mm, preferably at least 5mm.
- 10 20. A variable valve lift system according to any of claims 11 to 13, wherein the diffusing element comprises a side wall of the medium pressure chamber located adjacent to the rear wall of the medium pressure chamber that is configured to deflect pressure waves before impact against the rear wall of the medium pressure chamber.
- 15 21. An automotive internal combustion engine comprising a variable valve lift system according to any preceding claim.
- 20 22. A vehicle comprising an automotive internal combustion engine according to claim 21.
- 25 23. A method of operating a variable valve lift system of an automotive internal combustion engine, the method comprising using fluid pressure within a high pressure chamber to control the operation of at least one valve of the engine; opening a valve assembly to fluidically connect the high pressure chamber to a medium pressure chamber to thereby reduce the fluid pressure within the high pressure chamber; and using a diffusing system to diffuse a pressure wave entering the medium pressure chamber in response to the opening of the valve assembly.
- 30 24. A method according to claim 23, wherein the step of using the diffusing system to diffuse the pressure wave comprises using the diffusing system to attenuate and/or break up and/or deflect the pressure wave before impact against a rear wall of the medium pressure chamber.
- 35

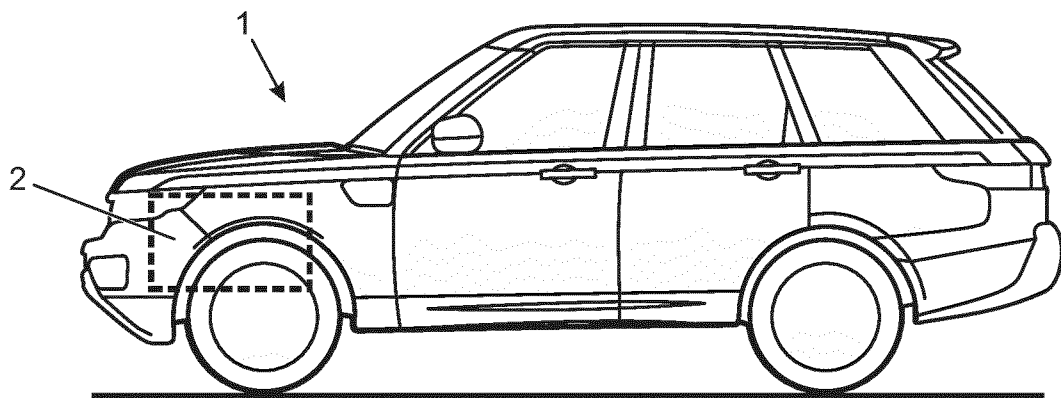


Figure 1

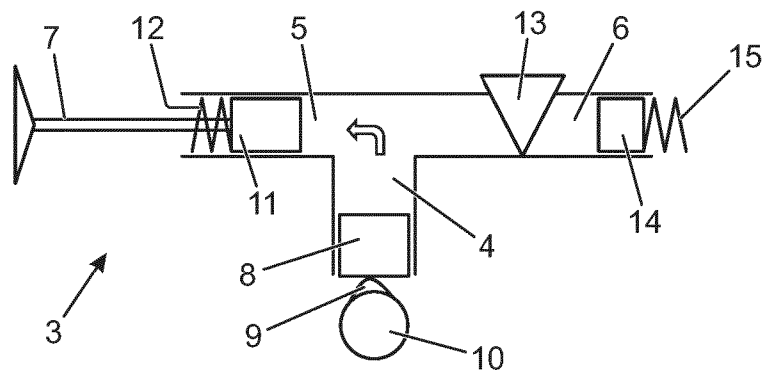


Figure 2

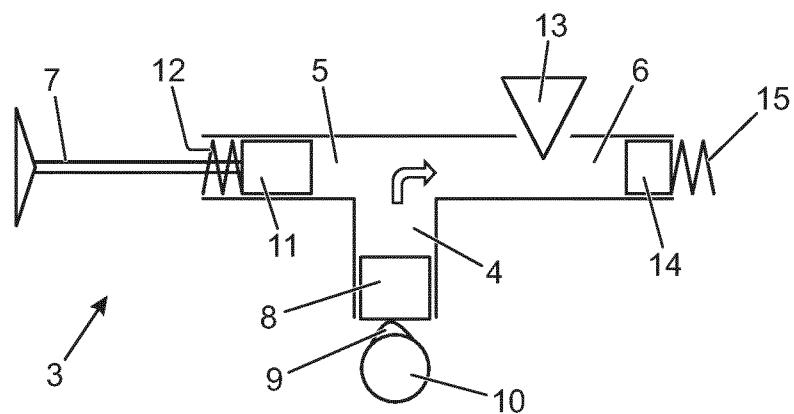


Figure 3

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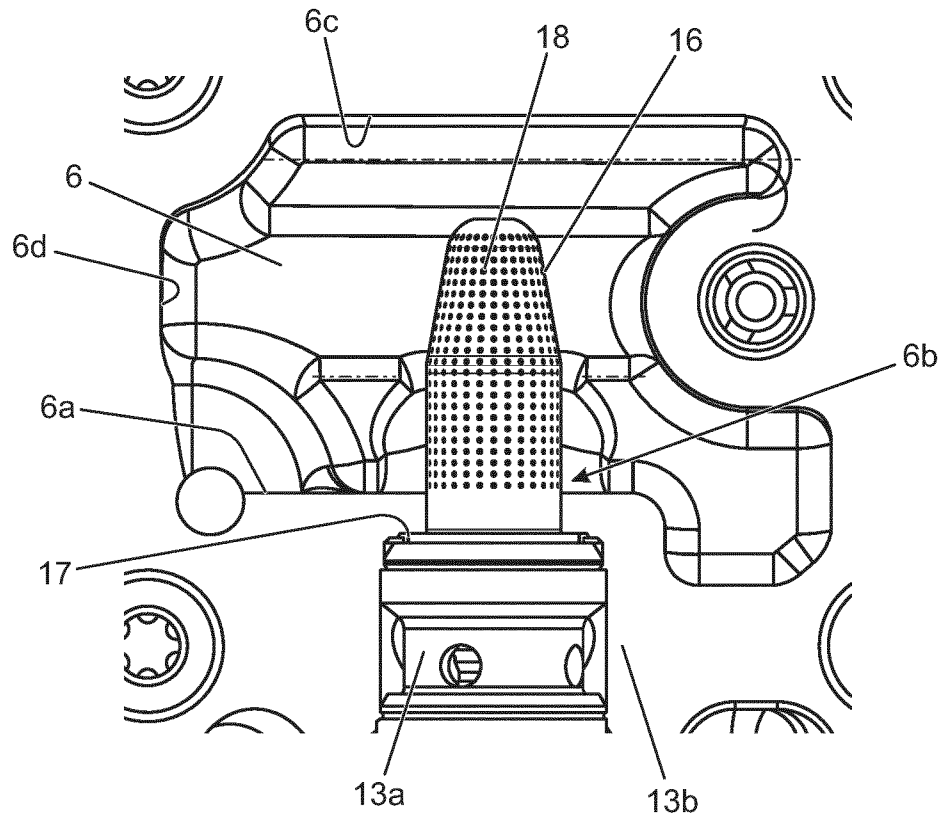


Figure 4

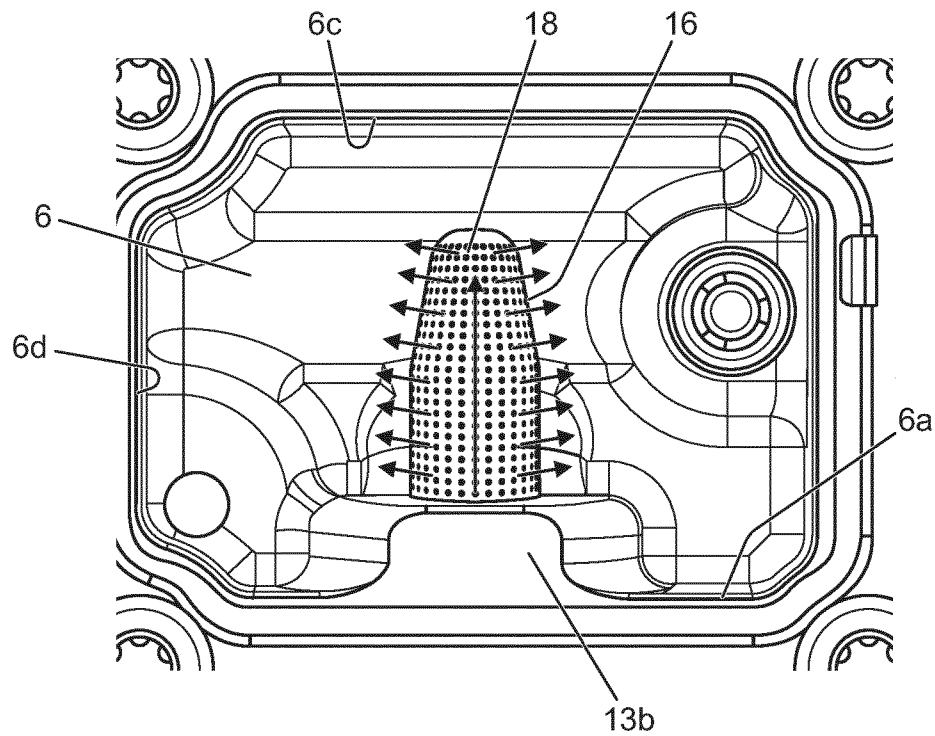


Figure 5

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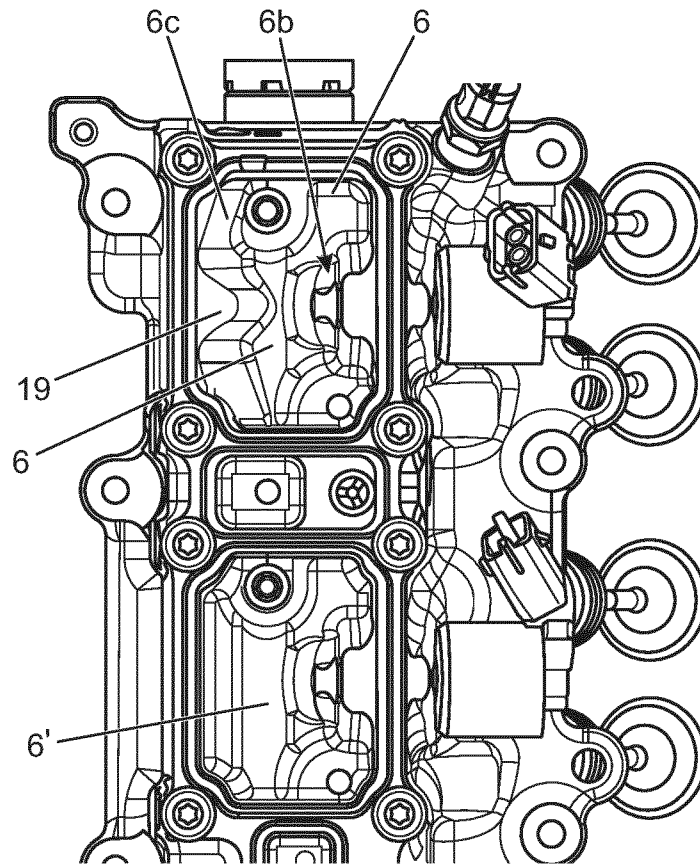


Figure 6

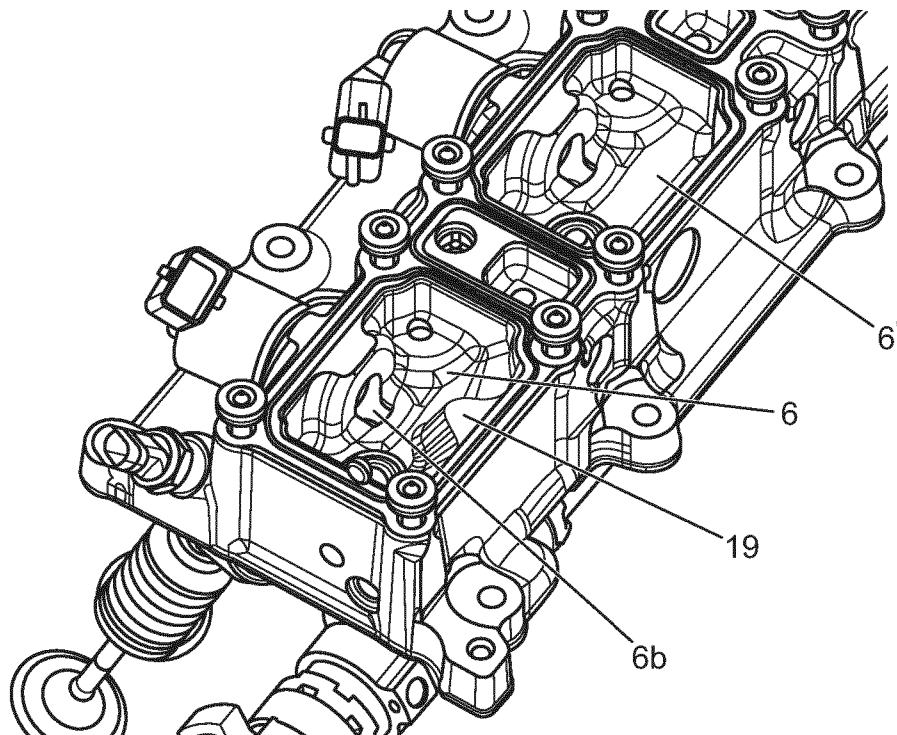


Figure 7

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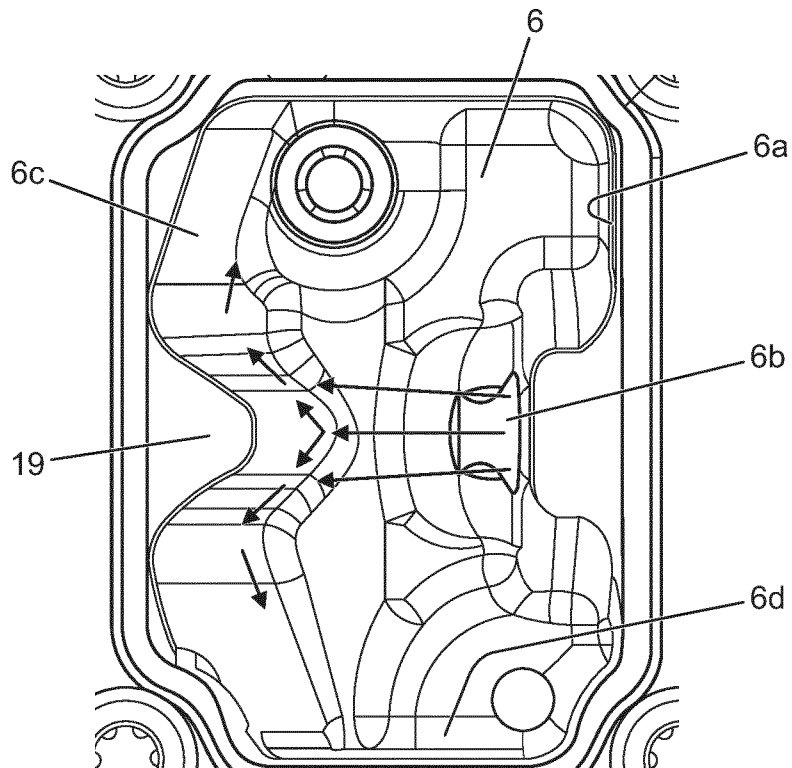


Figure 8

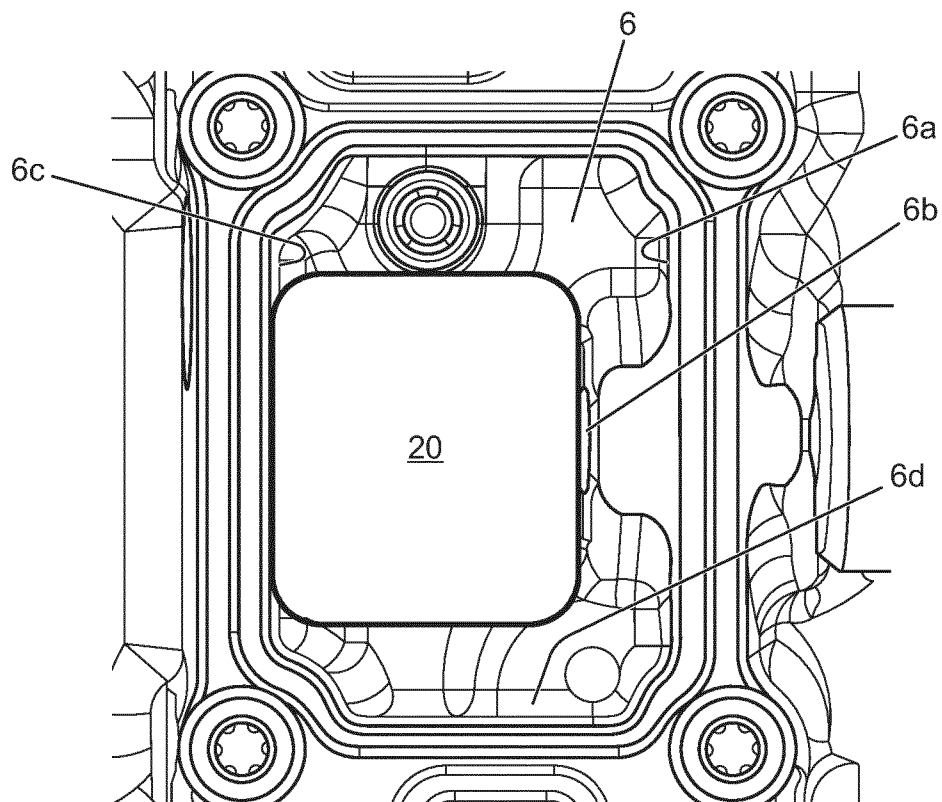


Figure 9

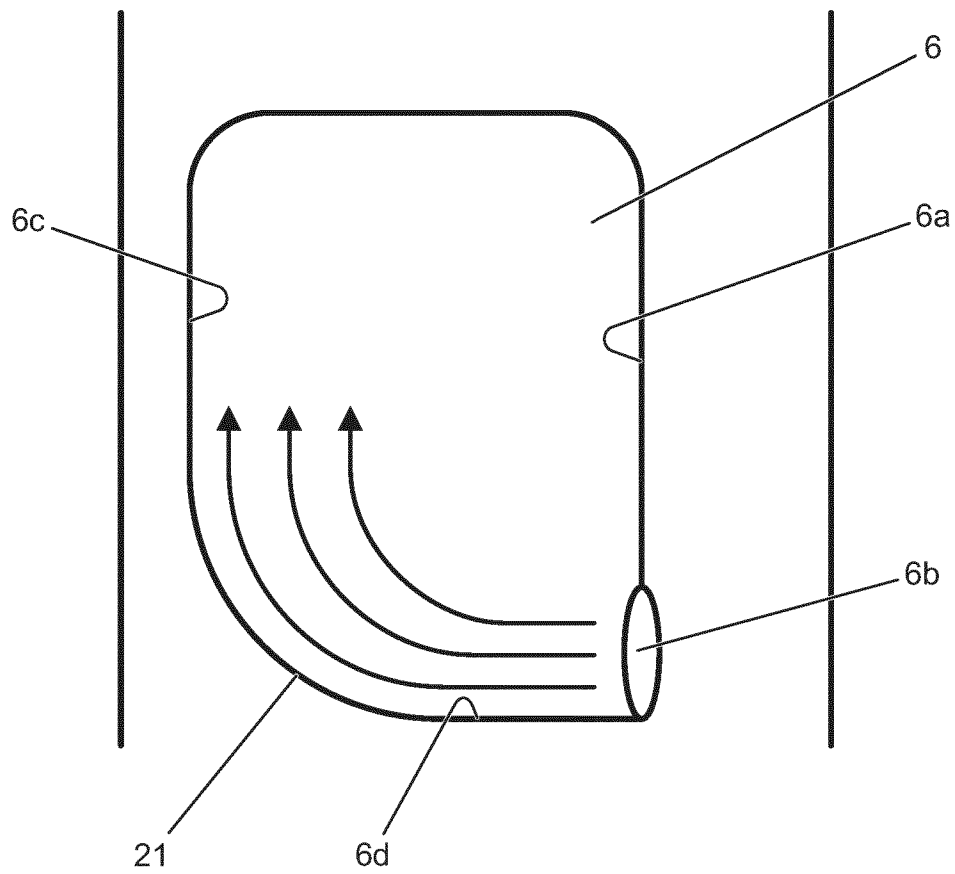


Figure 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/061192

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01L9/02
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)
F01L

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)

EP0-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 2010/224152 A1 (KUHL MARIO [DE] ET AL) 9 September 2010 (2010-09-09) the whole document -----	1,2,4-7, 11,12, 21-24
X	US 2011/259288 A1 (RINNERT ANDREAS [DE]) 27 October 2011 (2011-10-27) the whole document -----	1,23
X	US 8 020 526 B2 (RAUCH MARTIN [DE] ET AL) 20 September 2011 (2011-09-20) the whole document -----	1,23
A	GB 2 528 087 A (JAGUAR LAND ROVER LTD [GB]) 13 January 2016 (2016-01-13) the whole document -----	1



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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

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"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

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Date of the actual completion of the international search

6 July 2017

Date of mailing of the international search report

13/07/2017

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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