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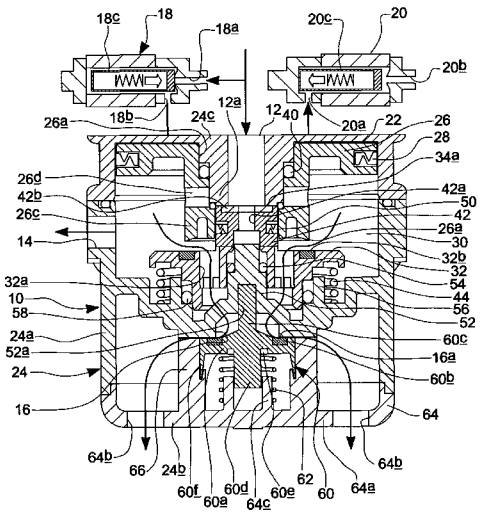
(54) **Title**: VALVE ASSEMBLY

FIG 1




(57) **Abstract**: A valve assembly (10) having a supply inlet (12) which is adapted to be connected to a source of pressurised fluid, a delivery port (14) which is adapted to be connected to a working volume, and a exhaust outlet (16) which vents to the atmosphere, wherein the exhaust outlet (16) is provided with a valve member (60, 60') which is movable between an open position in which flow of fluid through the exhaust outlet (16) is permitted, and a closed position in which the valve member (60, 60') substantially prevents flow of fluid through the exhaust outlet (16), characterised in that a resilient biasing means (62) is provided which biases the valve member (60, 60') into the closed position.

Title: Valve Assembly

Description of Invention

The present invention relates to a valve assembly, in particular a water exclusion device for a valve, particularly but not exclusively for use as a modulator in a braking system of a heavy goods vehicle.

The braking system of a vehicle, in particular a heavy goods vehicle, typically includes a modulator which converts a braking signal – which can be an electrical, pneumatic or hydraulic signal, to a fluid pressure brake actuating signal which is transmitted to a fluid pressure operated brake actuator. The modulator is configured to ensure that the magnitude of the brake actuating signal is such that the brake actuator causes the brake to apply a braking force which matches the level of braking demand set by the braking signal.

The modulator typically has an inlet port which is connected to a source of pressurised fluid, such as a compressed air reservoir, a control inlet which, in a conventional pneumatic or hydraulic braking system is connected to the source of the fluid pressure braking signal, and which in an electronic braking system (EBS) is also connected to the source of pressurised fluid, a delivery outlet which is connected to the brake actuator, and an exhaust outlet which vents to atmosphere, or any other low pressure region.

The or each modulator in a braking system is typically mounted on the underside of the vehicle, and, can therefore be subjected to spray from the road when the vehicle is travelling in wet conditions, and, if mounted low on the chassis, for example adjacent a wheel mounted actuator, may, in exceptional circumstances be temporarily submerged in water. A modulator typically comprises a series of pistons or diaphragms and solenoid operated valves, so it will be readily apparent that ingress of water into the modulator is undesirable, particularly if the water includes salt from grit spread on the road

in winter, as this is likely to cause corrosion and premature failure of parts within the modulator.

The exhaust outlet, of course, provides a conduit whereby water may enter the modulator, and it is known, therefore, to provide a device to close the exhaust outlet to prevent fluid outside the modulator from entering the exhaust outlet, whilst permitting free flow of exhaust fluids out of the modulator via the exhaust outlet. Such a device typically comprises a rubber flap which engages with the outside of the exhaust outlet to substantially close the exhaust outlet, and which is sufficiently flexible to move out of engagement with the exhaust outlet under the pressure of fluid in the modulator.

It has been found, however, that such devices have a limited lifespan, as, over time, the rubber relaxes and the sealing between the flap and the exhaust outlet deteriorates. Whilst this may be acceptable when the modulator is mounted relatively high on the vehicle chassis, and therefore subjected only to spray from the road, it is not when the modulator is lower, and is occasionally submerged.

According to the invention we provide a valve assembly having a supply inlet which is adapted to be connected to a source of pressurised fluid, a delivery port which is adapted to be connected to a working volume, and a exhaust outlet which vents to a low pressure volume, wherein the exhaust outlet is provided with a valve member which is movable between an open position in which flow of fluid through the exhaust outlet is permitted, and a closed position in which the valve member substantially prevents flow of fluid through the exhaust outlet, characterised in that a resilient biasing means is provided which biases the valve member into the closed position.

Advantageously, the valve member is made predominantly from a generally rigid material such as a metal or plastics material, but may be provided with a seat portion which is made from a flexible material such as rubber, the seat

portion engaging with the exhaust outlet to substantially close the exhaust outlet when the valve member is in the closed position.

Preferably the resilient biasing means is a helical spring, which may also be made from metal.

Preferably the valve assembly includes a control assembly which is movable between an exhaust position in which the delivery outlet is connected to the exhaust outlet, a build state in which the delivery outlet connected to the supply inlet and a hold state in which flow of fluid between any two of the delivery outlet, the supply inlet and the exhaust outlet is substantially prevented, the exhaust valve member being separate to the control assembly to the extent that, during normal operation of the valve assembly, movement of the exhaust valve member between the open position and the closed position is not effected by means of a mechanical connection between the control assembly and the exhaust valve member.

The control assembly may include a first movable element which is acted on by fluid pressure in a control chamber. In this case, the valve assembly may further include one or more electrically operable valves, by means of which flow of fluid into or out of the control chamber may be controlled. Preferably the control assembly also includes a second movable element, and the first and second movable element may be movable into engagement with one another, the engagement of the first movable element with the second movable element preventing flow of fluid between two of the supply inlet, the delivery port and the exhaust outlet. Further preferably, the engagement of the first movable element with the second movable element substantially prevents flow of fluid between the delivery port and the exhaust outlet. Furthermore, the second movable element may be movable into engagement with a valve seat which is secured relative to a housing of the modulator, engagement of the second movable element with the valve seat substantially preventing flow of fluid between the supply inlet and the delivery port.

The resilient biasing means is advantageously arranged such that if the fluid pressure at the exhaust outlet exceeds the fluid pressure in the low pressure volume by a pre-determined amount, the exhaust valve member moves from the closed position to the open position, whereas if the fluid pressure at the exhaust outlet is less than the pressure in the low pressure volume or exceeds the pressure in the low pressure volume by less than the pre-determined amount, the exhaust valve member remains in the closed position unless acted on by an external force sufficient to overcome the biasing force of the resilient biasing means.

The valve member is preferably provided with at least one damping element which engages with the exhaust outlet or a part which is fixed relative to the exhaust outlet to impede movement of the exhaust valve member between the open position and the closed position. Without the provision of such damping elements, it has been found that at certain airflows, the exhaust valve member oscillates, in particular as the final volume of fluid escapes through the exhaust outlet, which creates an undesirable noise. The damping elements ensure that hysteresis is present in the movement of the exhaust valve member between the open and closed positions, and this may assist in preventing unwanted oscillations of the exhaust valve member.

Preferably the or each damping element is integral with the exhaust valve member.

The engagement of the or each damping element with the exhaust outlet or a part fixed relative to the exhaust outlet advantageously causes elastic deformation of the or each damping element. In the case where the or each damping element is integral with the exhaust valve member, in order to achieve such elastic deformation, the or each damping elements may be substantially thinner than the remainder of the valve member.

The valve assembly preferably includes a sound attenuating device which is located between the exhaust outlet and the low pressure volume, and which includes a plurality of apertures through which fluid flowing from the exhaust outlet to atmosphere must pass.

The sound attenuating device is preferably provided between the exhaust valve member and the low pressure volume.

The sound attenuating device may comprise a tubular element in which is provided a plurality of longitudinal slots.

The valve assembly may be further provided with an exhaust cap, the sound attenuating device being provided between the exhaust cap and the exhaust outlet, and the exhaust cap including at least one aperture, the or each aperture in the exhaust cap being substantially larger than the apertures in the sound attenuating device. In this case, the sound attenuating device may be integral with the exhaust cap.

The sound attenuating device may engage with the exhaust valve member to restrict movement of the valve member relative to the exhaust outlet. In this case, the damping elements may engage with the sound attenuating device to impede movement of the valve member between the open position and the closed position.

An embodiment of the invention will now be described with reference to the following figures of which,

FIGURE 1 shows a cross-section through a valve assembly according to the invention,

FIGURE 2 shows a more detailed view of the exhaust outlet of the valve assembly shown in Figure 1,

FIGURE 3 shows a perspective view of the water exclusion valve member of the valve assembly illustrated in Figure 1,

FIGURE 4 shows a perspective view of the exhaust cap of the valve assembly illustrated in Figure 1,

FIGURE 5 shows a cross section of the exhaust outlet of a further embodiment of valve assembly according to the invention, and

FIGURE 6 shows a perspective view of the water exclusion valve member of the valve assembly illustrated in Figure 5.

Referring now to the Figure 1 there is provided a valve assembly 10 according to the invention, which in this example is a modulator suitable for use in a vehicle braking system. The valve assembly 10 includes a generally cylindrical housing 24 having a supply inlet 12 which is adapted to be connected to a compressed air reservoir (not shown), a delivery port 14 which is adapted to be connected to a brake actuator (not shown), and an exhaust outlet 16 which, in this example, vents to atmosphere, but could equally vent to any other low pressure volume.

There is also shown a hold valve 18 which has an inlet 18a which is connected to the supply inlet 12 of the modulator 10, and an outlet 18b which is connected to a control chamber 22 of the modulator 10, and an exhaust valve 20 which has an inlet 20a which is connected to the control chamber 22 and an outlet 20b which vents to the atmosphere. The hold valve 18 has a valve member 18c which is movable from an open position in which flow of fluid between the supply inlet 12 and the control chamber 22 is permitted, and a closed position in which flow of fluid between the control chamber 22 and the supply inlet 12 is substantially prevented. Similarly, the exhaust valve 20 has a valve member 20c which is movable between an open position in which venting of fluid from the control chamber 22 to the atmosphere is permitted, and a closed position in which flow of fluid from the control chamber 22 to

atmosphere is substantially prevented. Typically each of the valve members 18c, 20c is moved between the open and closed positions using an electrical actuator such as a solenoid or a piezoelectric element.

The control chamber 22 is located in the space between the modulator housing 24 and a first movable element, which could be a diaphragm but in this example is a piston 26, hereinafter referred to as the control piston 26, which is movable within the housing 24 to vary the volume of the control chamber 22. An O-ring 28 is provided in a circumferential grove in the first piston 26, and engages with the side wall of the housing 24 to provide a substantially fluid tight seal between the housing 24 and the piston 26. The space within the housing 24 on the opposite side of the control piston 26 to the control chamber 22 is hereinafter referred to as the main chamber 30.

The supply inlet 12, delivery port 14 and the exhaust outlet 16 all form apertures in the housing 24 which extend into the main chamber 30 of the modulator 10. Moreover, the delivery port 14 forms an aperture in the side wall 24a of the housing 24, whilst the exhaust outlet 16 is located in an end face 24b of the housing 24, the end face 24b extending generally perpendicular to the direction of travel of the control piston 26 and the main chamber 30 being located between the end face 24b and the control piston 26. The supply inlet 12 is located in a top face 24c of the housing 24, the top face 24c being opposite to the end face 24b so that the control chamber 22 is located between the top face 24c and the control piston 26.

Of course, if the supply inlet 12 were simply an aperture through the housing 24, being located in this top face 24c of the housing 24 would mean that it would communicate with the control chamber 22 rather than the main chamber 30. As such, a tubular extension 12a extends from around the aperture formed by the supply inlet 12 into the control chamber 22, through generally central aperture 26b provided in the control piston 26 and into the main chamber 30. An O-ring 40 is provided in the aperture 26b in the control piston

26 to provide a substantially fluid tight seal between the control piston 26 and the outer diameter of the tubular extension 12a. Thus, movement of the control piston 26 relative to the modulator housing 24 is permitted whilst maintaining separation of the fluid in the control chamber 22 from the fluid in the main chamber 30.

A second movable element, which could be a diaphragm, but in this example is a piston 32, hereinafter referred to as the main piston 32, is provided in the main chamber 30. The main piston 32 is also movable relative to the housing 24 to increase or decrease the separation between it and the control piston 26. A resilient biasing element, in this example a helical compression spring 44, is provided between the main piston 32 and the end face 24b of the housing 24, the spring 44 being compressed when there is movement of the main piston 32 from its equilibrium position closest to the control piston 26 towards the end face 24b of the housing 24 (i.e. away from the control piston 26).

The main piston 32 is provided with a central aperture 32a which extends through the main piston 32 from the side of the piston 32 adjacent the control piston 26 to the other, in the aperture 32a is mounted a tubular reservoir seat support 42. The reservoir seat support 42 has a smaller diameter than the aperture 32a, is supported in the aperture 32a by at least two support arms (not visible in the cross-section shown in the figures) and extends towards the control piston 26. At the end of the reservoir seat support 42 is provided a reservoir seat 42b which is a generally annular portion of the end surface of the reservoir seat support 42 which surrounds a central bore 42a extending axially through the seat support 42.

Into the central bore 42a of the reservoir seat support 42 extends a reduced diameter portion of a guide spigot 52 which is supported in the exhaust outlet 16 by a plurality of support arms (not shown in the cross-sectional view illustrated in the figures). The outer diameter of the reduced diameter portion of the guide spigot 52 is just slightly less than the diameter of the central bore

42a, and yet another O-ring 54 is provided to ensure that there is a generally fluid tight seal between the guide spigot 52 and the reservoir seat support 42. This means that any fluid entering the central bore 42a of the reservoir seat support 42 cannot escape and, in particular, cannot pass into the exhaust outlet 16.

As mentioned above, the main piston 32 is biased by the spring 44 towards the control piston 26 such that, when there are no other forces acting on the main piston 32, the reservoir seat 42b is urged into engagement with a generally circular ridge 34a provided at the end of the tubular extension 12a which extends into the main chamber 30. The ridge 34a surrounds the aperture of the supply inlet 12, so it will be appreciated that when the main piston 32 is in this position, fluid at the supply inlet 12 is substantially restricted to flowing into the central bore 42a of the reservoir seat support 42, where it is trapped by the guide spigot 52. As such, bringing the reservoir seat 42b into engagement with this ridge 34a amounts to closing of the supply inlet 12.

Typically the main piston 32 and reservoir seat support 42 are made from metal, and if this is the case, the reservoir seat 42b may constitute a rubber insert which may deform when engaged with the ridge 34a to improve the quality of the seal provided by the reservoir seat 42b.

The central bore 42a of the reservoir seat support 42 increases in diameter between the end on which the reservoir seat 42b is provided, and the portion engaged with the guide spigot 52, the diameter of the portion engaged with the guide spigot 52 having generally the same diameter as the internal diameter of the ridge 34a of the tubular extension 12a which engaged with the reservoir seat 42b. Configuring the central bore 42a this way, and allowing fluid at the supply inlet 12 to pass into the central bore 42a ensures that, when the reservoir seat 42b is closed, there is no net force exerted on the main piston 32 by the reservoir pressure. In other words, the reservoir pressure does not contribute to the energisation of the reservoir seat 42b.

The area around the central aperture 32a in the main piston 32 also provides a valve seat 32b, hereinafter referred to as the exhaust seat 32b. Again, the face of the control piston 26 which forms a boundary of the main chamber 30 is provided with a generally circular ridge 26a which has a larger diameter than the central aperture 32a in the main piston 32, and the control piston 26 is movable in the housing 24 until the ridge 26a engages with the exhaust valve seat 32b, thus preventing flow of fluid from around the main piston 32 into the central aperture 32a of the main piston 32.

The main piston 32 is typically made from metal and in this case the exhaust seat 32b may constitute a rubber insert which may deform when engaged with the ridge 26a to improve the seal provided by the exhaust seat 32b.

The ridge 26a is provided on a tubular extension portion 26c of the control piston 26 which extends from around the central aperture 26b towards the main piston 32. The reservoir seat support 42 extends into a central bore of the tubular extension portion 26c of the control piston 26, with an O-ring 50 being provided in a circumferential groove provided in the inner surface of the tubular extension portion 26c of the control piston 26 to provide a generally fluid tight seal between the tubular extension portion 26c and the reservoir support seat 42.

The tubular extension portion 26c of the control piston 26 is provided with a plurality of transverse apertures 26d which extend from the central bore to the exterior of the tubular extension portion 26c. Thus, when the main piston 32 is positioned such that the tubular extension 12a of the supply inlet 12 is spaced from the reservoir seat 42b, fluid can flow from the source of pressurised fluid, through the supply inlet 12 and the transverse apertures 26d of the control piston 26, into the main chamber 30, and on to the delivery port 14.

The central aperture 32a of the main piston 32 is aligned with and slightly larger in diameter than the exhaust outlet 16. A generally circular sealing

flange 56 extends from the end face 24b of the housing 24 from around the exhaust outlet 16, the main piston 32 being partially located within the sealing flange 56 so that the outer surface of the main piston 32 engages with the inner surface of the sealing flange 56. An O-ring 58 is located between the two parts to provide a substantially fluid tight seal, and, as a result, flow of fluid to the exhaust outlet 16 from the main chamber 30 of the modulator 10 can only occur via the central aperture 32a of the main piston 32. It will therefore be appreciated that, by virtue of this arrangement, bringing the exhaust seat 32b into engagement with the ridge 26a on the control piston 26 amounts to closing of the exhaust outlet 16.

At the exhaust outlet 16 is provided a water exclusion valve member 60 which is typically made from metal, but may equally be made from plastic or any other generally rigid material, and a resilient biasing means 62, which in this example is a helical spring, which biases the water exclusion valve member 60 into a closed position in which the water exclusion valve member 60 engages with the exhaust outlet 16 substantially to prevent flow of fluid through the exhaust outlet 16. The biasing force of the spring 62 is such that when the fluid pressure at the exhaust outlet 16 exceeds a predetermined, relatively low value, which in this example is around 50mbar, the water exclusion valve member 60 moves against the biasing force of the spring 62 into an open position, in which it is moved out of engagement with the exhaust outlet 16 so that flow of fluid through the exhaust outlet 16 is permitted. It has been found that setting the biasing force of the spring 62 to this level is advantageous as it prevents the water exclusion valve member 60 from opening when it experiences wheel vibrations resulting from a vehicle acceleration of up to 30G. As such, the water exclusion valve member 60 remains closed under normal circumstances, except when exhausting of pressurised fluid from the braking system is required. The water exclusion valve member 60 is shown in more detail in Figures 2 and 3.

The water exclusion valve member 60 comprises a body 60a in the shape of a generally circular disc, having a larger diameter than the aperture formed by the exhaust outlet 16, which is mounted outside the housing 24, the plane of the disc extending generally parallel to the end face 24b of the housing 24. A generally circular ridge 16a is provided in the outside of the housing 24 around the aperture formed by the exhaust outlet 16, and, when in the closed position, the body 60a of the valve member 60 provides a valve seat 60b which engages with the ridge 16a around the exhaust outlet 16 to substantially close the exhaust outlet 16. In this example, the valve seat 60b is formed by a generally circular rubber insert which is mounted in a groove provided in the valve body 60a. When the valve member 60 moves to the open position, the valve body 60a moves away from the ridge 16a so that fluid may flow through the exhaust outlet 16, between the ridge 16a and the valve body 60a to the atmosphere.

The spring 62 extends between the face of the body 60a of the valve member 60 which faces away from the housing 24 and an exhaust cap 64 which is secured to the end face 24b of the housing 24. The exhaust cap 64 comprises a support face 64a which is spaced from and generally parallel to the end face 24b of the housing 24 and is provided with a plurality of apertures 64b which ensure that the space between the exhaust cap 64 and the housing 24 is open to the atmosphere. The exhaust cap 64 is also provided with a generally cylindrical locating tube 64c which extends from the support face 64a towards the end face 24b of the housing 24. The spring 62 engages with the support face 24a of the exhaust cap 64 and extends around the locating tube 64c to the end face 24b of the housing 24.

The valve member 60 is also provided with a first locating stem 60c which comprises a generally cylindrical rod and which extends from the centre of the face of the valve body 60a directly adjacent the housing 24, through the exhaust outlet 16 into a bore 52a provided in the guide spigot 52. A second locating stem 60d, which in this example also comprises a generally cylindrical

rod, extends from the centre of the opposite face of the valve body 60a towards the exhaust cap 64 and into the locating tube 64c. The diameter of the bore 52a in the guide spigot 52 and the internal diameter of the locating tube 64c are just slightly larger than the diameters of the first locating stem 60c and second locating stem 60d respectively, so sliding movement of the stems 60c, 60d in the bore 52a and locating tube 64c is not impeded as the valve member 60 moves between its open position and its closed position, whilst the guide spigot 52 and locating tube 64c assist in locating the valve member 60 in its desired position relative to the ridge 16a by restricting lateral movement of the valve member 60.

A further circular rubber insert 60e is mounted in the valve body 60a around the second locating stem 60d. This further rubber insert 60e is provided to engage with the locating tube 24b when the valve member 60 is in the open position, to prevent any further movement of the valve member 60 away from the housing 24, and is made from rubber so as to minimise the noise made by the valve member 60 when it engages with the locating tube 24b having moved to the open position.

Finally, the valve member 60 is provided with damping elements 60f which engage with the exhaust cap 64 to impede movement of the valve member 60 between the open position and the closed position. In this example, the damping elements 60f comprise a plurality of feathers which extend from the outer edge of the face of the valve body 60a towards the exhaust cap 64. The cross-section of each feather 60f in the direction radial of the valve body 60a decreases from the portion of the feather 60f directly adjacent the valve body 60a to the free end of the feather, and is sufficiently thin that, despite being integral with the valve body 60a, and therefore made from the same material, the feathers 60f can be readily bent. The feathers 60f are arranged in a generally circular array around the valve body 60a, in this case there being six feathers 60f in the array, and the feathers 60f are inclined such that the

diameter of the circle formed by the free ends of the feathers 60f is slightly greater than the diameter of the valve body 60a.

The exhaust cap 64 is illustrated in more detail in Figure 4, and is provided with a generally cylindrical sound diffuser tube 66, which extends from the support face 64a to the end face 24b of the housing 24. The sound diffuser tube 66 is coaxial with and surrounds the locating tube 64c, and in this example includes a plurality of axially extending slots 66a which extend along substantially the entire length of the tube 66, in this example from the exhaust cap 64 to the housing 24. Fluid escaping through the exhaust outlet to atmosphere must therefore pass through the slots 66a in the sound diffuser tube 66 before exiting through the apertures 64b in the exhaust cap 64.

It will be appreciated, however, that the sound diffuser tube 66 need not be provided with slots - these may be replaced with a plurality of apertures. Moreover, whilst in this example, the apertures 64b in the exhaust cap 64 are substantially bigger than the apertures or slots in the sound diffuser tube (66) (and therefore do not contribute to any significant extent to attenuating the sound of the exhaust fluid), this need not be the case, and these apertures 64b may be as small as or smaller than those in the sound diffuser tube 66, and therefore may also have a sound attenuating effect.

The internal diameter of the sound diffuser tube 66 is just slightly greater than the diameter of the body 60a of the valve member 60, and therefore the feathers 60f must be bent slightly in order to fit in the sound diffuser tube. The free ends of the feathers 60f are therefore resiliently biased into engagement with the sound diffuser tube 66, and as a result of frictional forces between the feathers 60f and the sound diffuser tube 66, impede movement of the valve member 60 between the open position and the closed position. The degree to which this movement is impeded is dependant on various factors including the forces between the feathers 60f and the sound diffuser tube 66, and may be increased by increasing the degree of inclination of the feathers 66f, which, of

course, increases the extent to which they need to be bent to fit inside the sound diffuser tube 66.

The slots 66a in the sound diffuser tube 66 are shaped so as to attenuate the sound of fluid escaping through the exhaust outlet 16. The exhaust cap 64 therefore acts as a silencer for the modulator 10. In this example, the width of each of the slots 66a is greatest at the interior of the sound diffuser tube 66, decreases to up to a point generally mid-way between the interior and exterior of the tube 66, and remains generally constant from the mid-point to the exterior of the tube 66.

In this case, both the locating tube 24c and the sound diffuser tube 66 are integral with the exhaust cap 24, which is preferably moulded from a plastics material, but may be made from metal, preferably by casting and machining.

Flow of fluid between these apertures is controlled by movement of the control piston 26 and the main piston 32 as follows.

When there is no braking demand, the modulator 10 adopts the exhaust configuration. The hold valve 18 is in the closed position, and the exhaust valve 20 is in the open position. The control chamber 22 is therefore vented to atmosphere and the control piston is located such that the volume of the control chamber 22 is minimum. The reservoir seat 42b is engaged with the tubular extension 12a of the supply inlet 12 so that flow of fluid from the supply inlet 12 to the delivery port 14 is prevented, and the exhaust seat 32b is spaced from the control piston 26 so that flow of fluid from the delivery port 14 to the exhaust outlet 16 via the central aperture 32a in the main piston 32 is permitted. The water exclusion valve member 60 is in the closed position, any fluid pressure at the exhaust outlet 16 above around 50mbar having caused the valve member 60 to move to the open position, thus allowing the fluid at the exhaust outlet 16 to vent to atmosphere via the sound diffuser tube 66 and the apertures 64b in the exhaust cap 64. The delivery port 14, and hence the

brake actuator has therefore vented to atmosphere, and no pressure is being applied at the brake.

When a braking demand signal is received, the hold valve 18 is operated so that the valve member 18c moves to the open position, and the exhaust valve 20 is operated so that the valve member 20c moves to the closed position. The control chamber 22 is therefore no longer venting to atmosphere, and flow of fluid from the reservoir into the control chamber 22 causes fluid pressure in the control chamber 22 to increase. The control piston 26 is acted on by this increasing pressure and moves towards the main piston 32 to increase the volume of the control chamber 22. As the control piston 26 moves, it comes into engagement with the exhaust seat 32b on the main piston 32. At this point, the delivery port 14 is no longer connected to the exhaust outlet 16.

As the fluid pressure in the control chamber 22 continues to increase, when it reaches a certain point, the force of the fluid pressure in the control chamber 22 acting on the control piston 26 is sufficiently large that the control piston 26 carries on moving to increase the volume of the control chamber 22 and therefore pushes the main piston 32 against the biasing force of the spring 44 so that the reservoir seat 42b moves out of engagement with the tubular extension 12a of the supply inlet 12. At this point, the supply inlet 12 can communicate with the delivery port 14, and flow of fluid from the reservoir to the brake actuator commences. The modulator 10 is said to be in the “build configuration”.

When the pressure in the brake actuator reaches the required level (this is typically determined using a pressure transducer which measures the delivery pressure in the brake actuator), and it is desired to hold that pressure, the hold valve 18 is operated to move the valve member 18c to the closed position. The control chamber 22 is therefore closed. As fluid continues to flow from the reservoir and into the modulator 10 via the supply inlet 12, fluid pressure in the main chamber 30 increases, and acts on main piston 32 and the control piston

26 against the pressure in the control chamber 22 to cause the pistons 26, 32 to move back to reduce the volume of the control chamber 22 until the reservoir seat 42b comes into engagement with the tubular extension 12a of the supply inlet 12. At this point, flow of fluid from the reservoir to the brake actuator is prevented whilst the exhaust outlet 16 remains closed, and the modulator 10 reaches an equilibrium at which the fluid pressure in all parts of the modulator 10 remains constant. The modulator 10 is then said to be in the “hold configuration” or "lapped configuration".

To release the brake pressure, the exhaust solenoid 20 is operated to move the valve member 20c to the open position. The fluid in the control chamber 22 is vented to atmosphere, and the fluid pressure in the main chamber 30 of the modulator 10 acts on the control piston 26, pushing it out of engagement with the exhaust seat 32b. Fluid may then flow from the brake actuator into the delivery port 14, through the central aperture 32a of the main piston 32 to the exhaust outlet 16 where it pushes the water exclusion valve member 60 against the biasing force of the spring 62 into the open position, passes through the slots 66a in the sound diffuser tube 66, and out of the apertures 64b in the exhaust cap 64 to atmosphere. The modulator 10 thus returns to the “exhaust configuration”.

The impedance of the movement of the valve member 60 relative to the exhaust outlet 16 provided by the feathers 60f ensures that there is hysteresis in the movement of the water exclusion valve member 60 between the closed position and the open position, which may assist in preventing the oscillations of the valve member 60 which can occur with an undamped valve member 60 at particular through-flow rates.

It will be appreciated that the above description relates to one embodiment of the invention only, and various modifications may be made without departing from the scope of the invention.

The essential feature of the modulator 10 is that it is includes a control assembly which is moveable to control flow of fluid between a source of pressurised fluid and a working volume, and is configured such that one of three control states can be selected – an exhaust state in which the working volume is connected to the atmosphere or other low pressure region, a build state in which the working volume is connected to the source of pressurised fluid and a hold state in which flow of fluid between any two of the working volume, the supply of pressurised fluid and the low pressure region is substantially prevented. This functionality may be achieved in a variety of ways – other possible configurations being described in UK patent application numbers 0902989.3 and GB2407131, or WO03/031855, for example, and the water exclusion and sound attenuation arrangement described above could equally be applied to exhaust ports of other configurations of modulator or other valve.

The water exclusion arrangement also need not be exactly as described above. An alternative configuration of water exclusion valve member 60' is, for example, illustrated in Figures 5 and 6. In this version, the second locating stem 60d' provides the means for impeding movement of the valve member 60' relative to the exhaust outlet 16 to prevent the unwanted oscillations of the valve member 60'. In this case, the second locating stem 60d' is a generally cylindrical tube which is split longitudinally into four feathers. The four feathers are slightly splayed so that the external diameter of the stem 60d' increases slightly from the valve body 60a' to the free end of the stem 60d'. As in the first embodiment of the invention, the feathers are sufficiently pliable that they are elastically deformable to a sufficient extent that they may be bent inwardly to enable the locating stem 60d' to fit inside the location tube 64c. As such, in this case, it is the frictional forces between the feathers of the second locating stem 60d' and the locating tube 64c which providence the required damping of the valve member 60'.

It should also be appreciated that movement of the water exclusion valve member 60 between the open and closed position may be impeded without the use of such feathers. For example, the tolerances between one or both of the first and/or second locating stems 60c, 60d and the bore 52a in the guide spigot 52 or the internal diameter of the locating tube 64c may be such that, whilst the sliding movement of the parts required to permit the valve member 60 to move between the open position and the closed position is possible, frictional forces between these parts provide the required damping to prevent unwanted oscillations of the valve member 60.

On the other hand, where feathers 66f are provided, these may be used to locate the valve body 60a relative to the exhaust outlet 16, and one or both of the locating stems 60c, 60d may be omitted.

When used in this specification and claims, the terms "comprises" and "comprising" and variations thereof mean that the specified features, steps or integers are included. The terms are not to be interpreted to exclude the presence of other features, steps or components.

The features disclosed in the foregoing description, or the following claims, or the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for attaining the disclosed result, as appropriate, may, separately, or in any combination of such features, be utilised for realising the invention in diverse forms thereof.

CLAIMS

1. A valve assembly having a supply inlet which is adapted to be connected to a source of pressurised fluid, a delivery outlet which is adapted to be connected to a working volume, and a exhaust outlet which vents to a low pressure volume, wherein the exhaust outlet is provided with an exhaust valve member which is movable between an open position in which flow of fluid through the exhaust outlet is permitted, and a closed position in which the exhaust valve member substantially prevents flow of fluid through the exhaust outlet, characterised in that a resilient biasing means is provided which biases the exhaust valve member into the closed position.

2. A valve assembly according to claim 1 wherein the valve assembly includes a control assembly which is movable between an exhaust position in which the delivery outlet is connected to the exhaust outlet, a build state in which the delivery outlet connected to the supply inlet and a hold state in which flow of fluid between any two of the delivery outlet, the supply inlet and the exhaust outlet is substantially prevented, the exhaust valve member being separate to the control assembly to the extent that, during normal operation of the valve assembly, movement of the exhaust valve member between the open position and the closed position is not effected by means of a mechanical connection between the control assembly and the exhaust valve member.

3. A valve assembly according to claim 2 wherein the control assembly includes a first movable element which is acted on by fluid pressure in a control chamber.

4. A valve assembly according to claim 3 wherein the valve assembly further includes one or more electrically operable valves, by means of which flow of fluid into or out of the control chamber may be controlled.

5. A valve assembly according to claim 3 wherein the control assembly also includes a second movable element, and the first and second movable element are movable into engagement with one another, engagement of the first movable element with the second movable element preventing flow of fluid between two of the supply inlet, the delivery port and the exhaust outlet.

6. A valve assembly according to claim 5 wherein the engagement of the first movable element with the second movable element substantially prevents flow of fluid between the delivery port and the exhaust outlet.

7. A valve assembly according to claim 5 or 6 wherein the second movable element is movable into engagement with a valve seat which is secured relative to a housing of the modulator, engagement of the second movable element with the valve seat substantially preventing flow of fluid between the supply inlet and the delivery port.

8. A valve assembly according to any preceding claim wherein the resilient biasing means is arranged such that if the fluid pressure at the exhaust outlet exceeds the fluid pressure in the low pressure volume by a pre-determined amount, the exhaust valve member moves from the closed position to the open position, whereas if the fluid pressure at the exhaust outlet is less than the pressure in the low pressure volume or exceeds the pressure in the low pressure volume by less than the pre-determined amount, the exhaust valve member remains in the closed position unless acted on by an external force sufficient to overcome the biasing force of the resilient biasing means.

9. A valve assembly according to any preceding claim wherein the valve member is provided with at least one damping element which engages with the exhaust outlet or a part which is fixed relative to the exhaust outlet to impede movement of the exhaust valve member between the open position and the closed position.

10. A valve assembly according to claim 9 wherein the engagement of the or each damping element with the exhaust outlet or a part fixed relative to the exhaust outlet advantageously causes elastic deformation of the or each damping element.

11. A valve assembly according to any preceding claim wherein the valve assembly includes a sound attenuating device which is located between the exhaust outlet and the low pressure volume, and which includes a plurality of apertures through which fluid flowing from the exhaust outlet to atmosphere must pass.

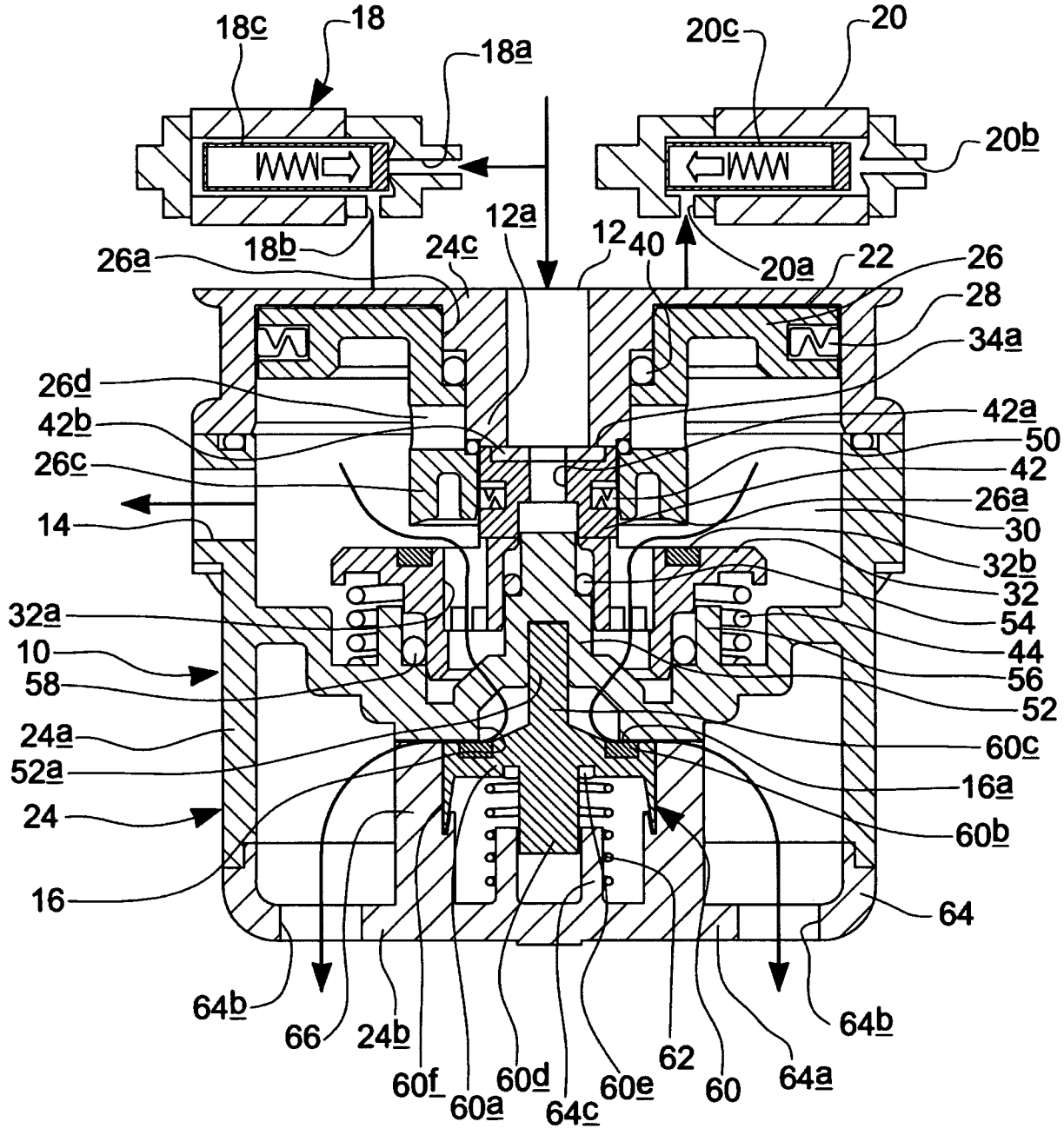
12. A valve assembly according to claim 10 wherein the sound attenuating device is provided between the exhaust valve member and the low pressure volume.

13. A valve assembly according to claim 11 or 12 wherein the valve assembly is further provided with an exhaust cap, the sound attenuating device being provided between the exhaust cap and the exhaust outlet, and the exhaust cap including at least one aperture, the or each aperture in the exhaust cap being substantially larger than the apertures in the sound attenuating device.

14. A valve assembly according to any one of claims 11 to 13 wherein the sound attenuating device engages with the exhaust valve member to restrict movement of the exhaust valve member relative to the exhaust outlet.

15. A valve assembly according to claim 15 wherein the damping elements engage with the sound attenuating device to impede movement of the exhaust valve member between the open position and the closed position.

16. A valve assembly substantially as hereinbefore described with reference to and as shown in the accompanying drawings.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18a
20c
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20b
12a
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18b
24c
26a
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42b
26c
14
42a
50
42
26a
30
32b
32
54
44
56
52
60c
16a
60b
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32a
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58
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60d
64c
60e
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60
64a
64b

FIG 1

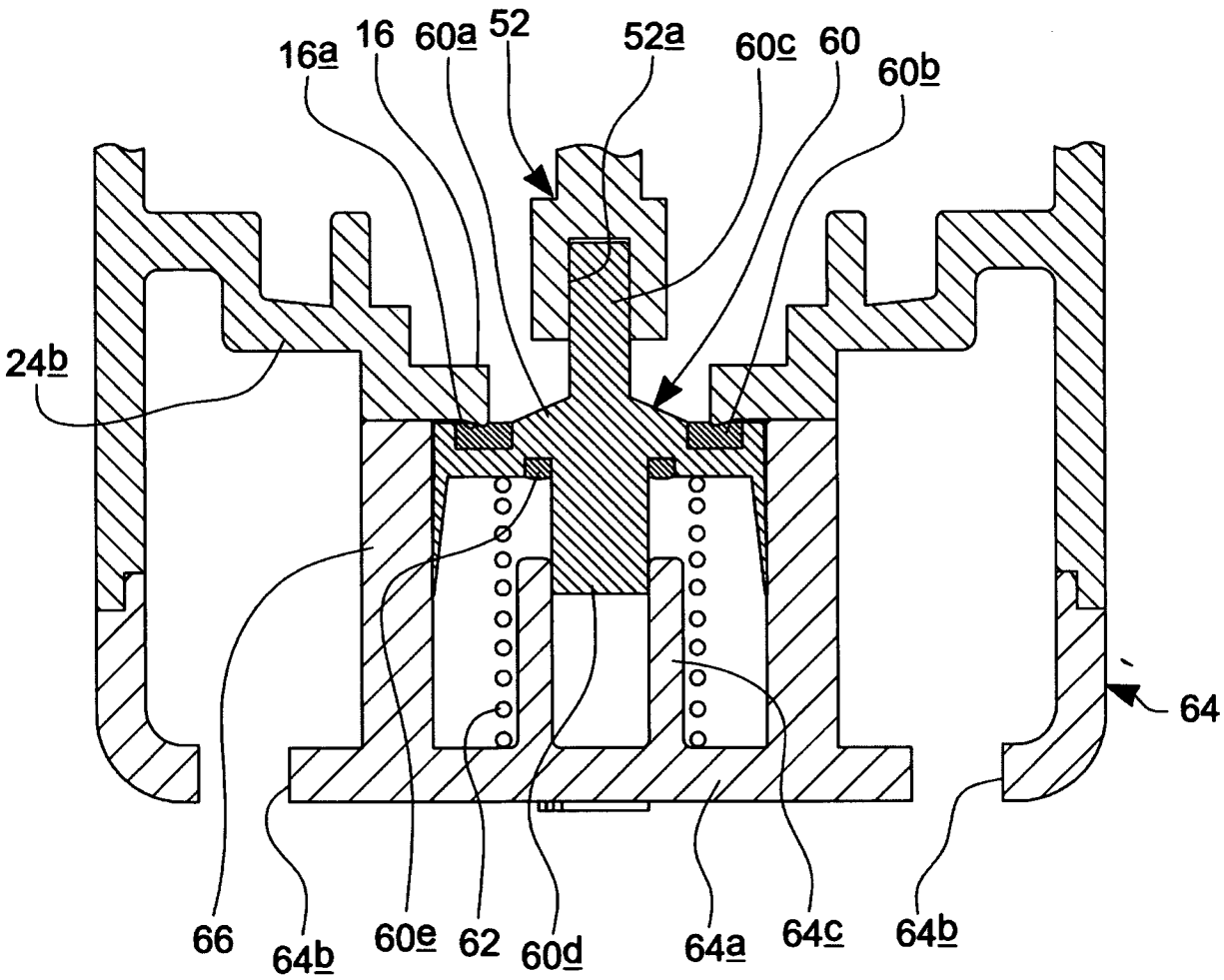


FIG 2

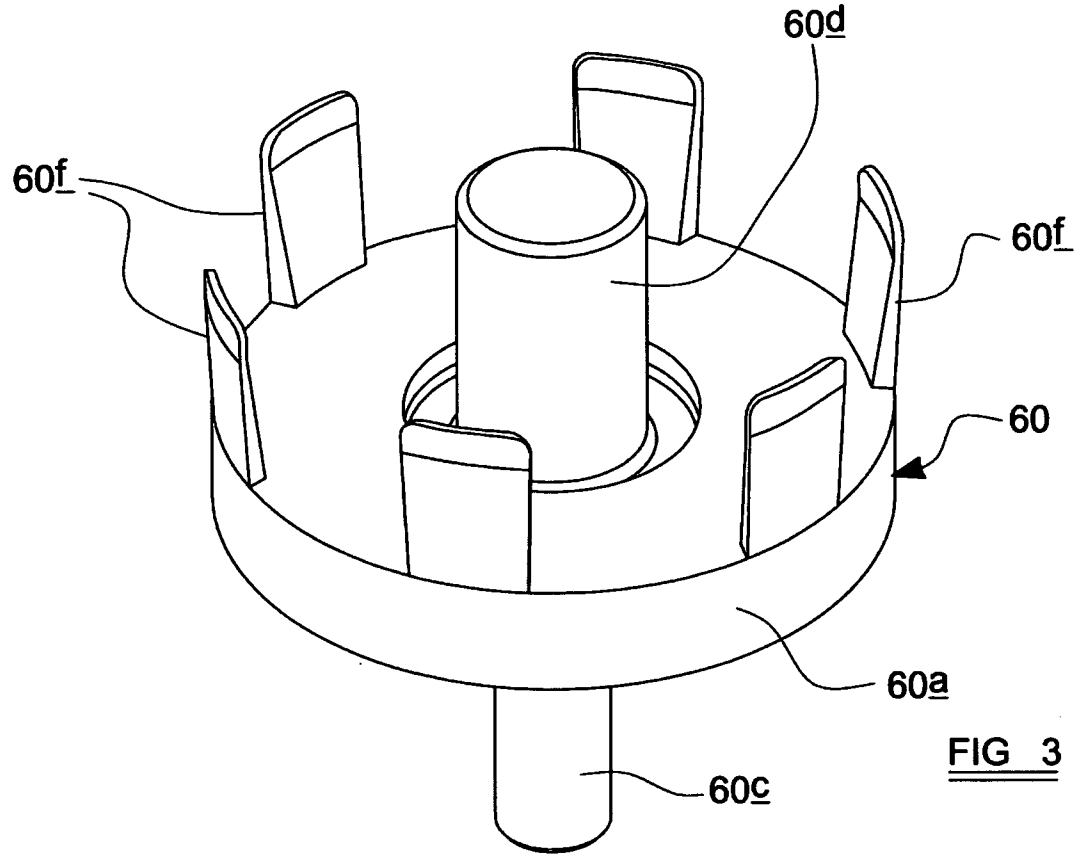


FIG 3

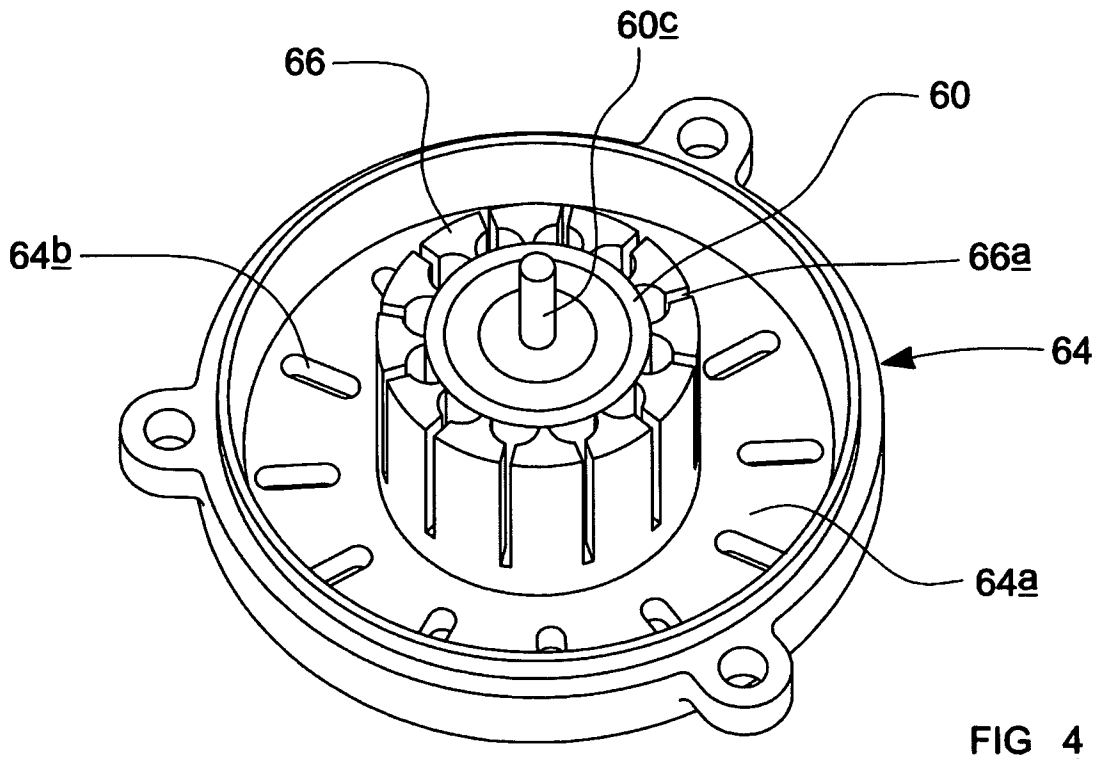


FIG 4

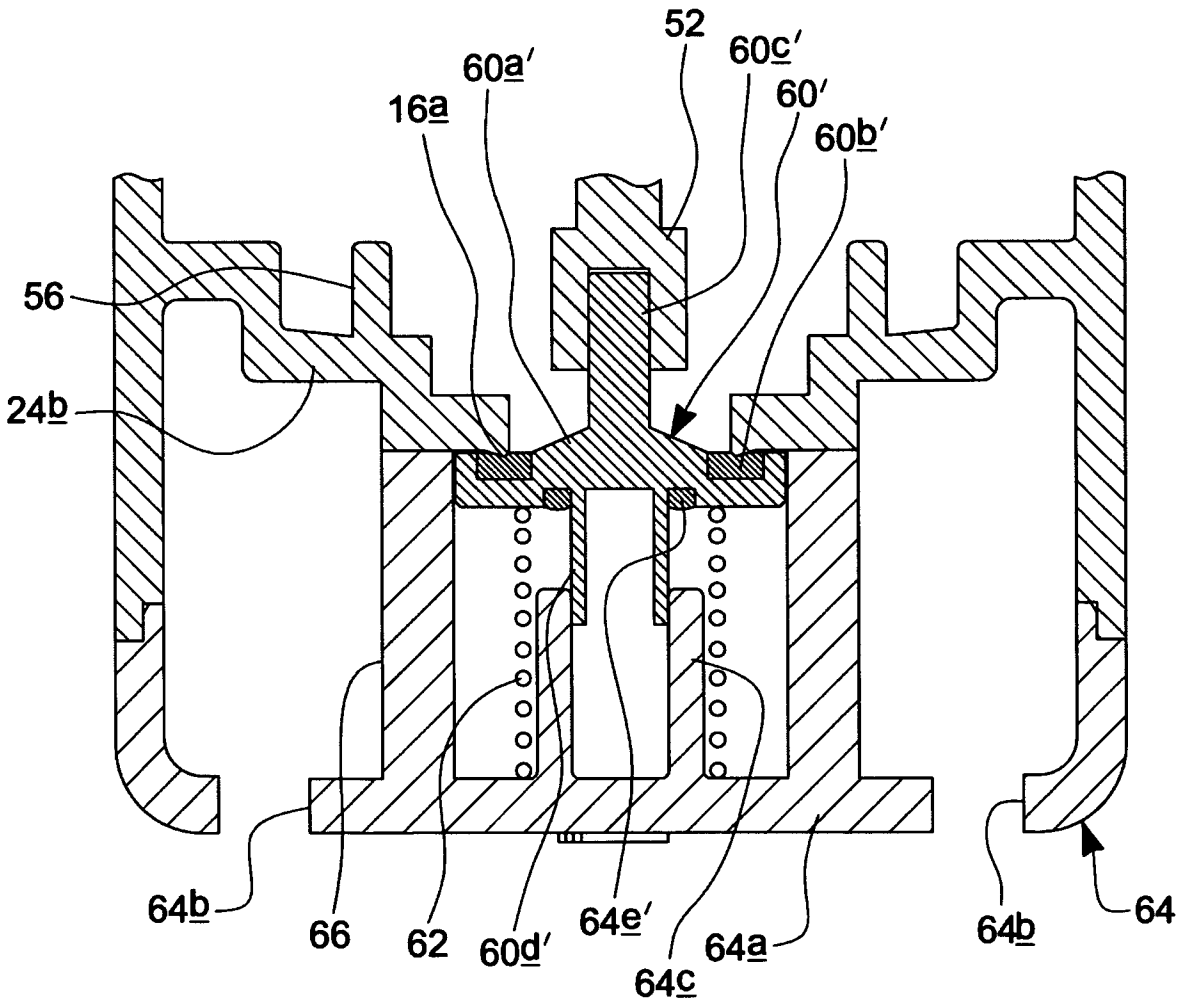


FIG 5

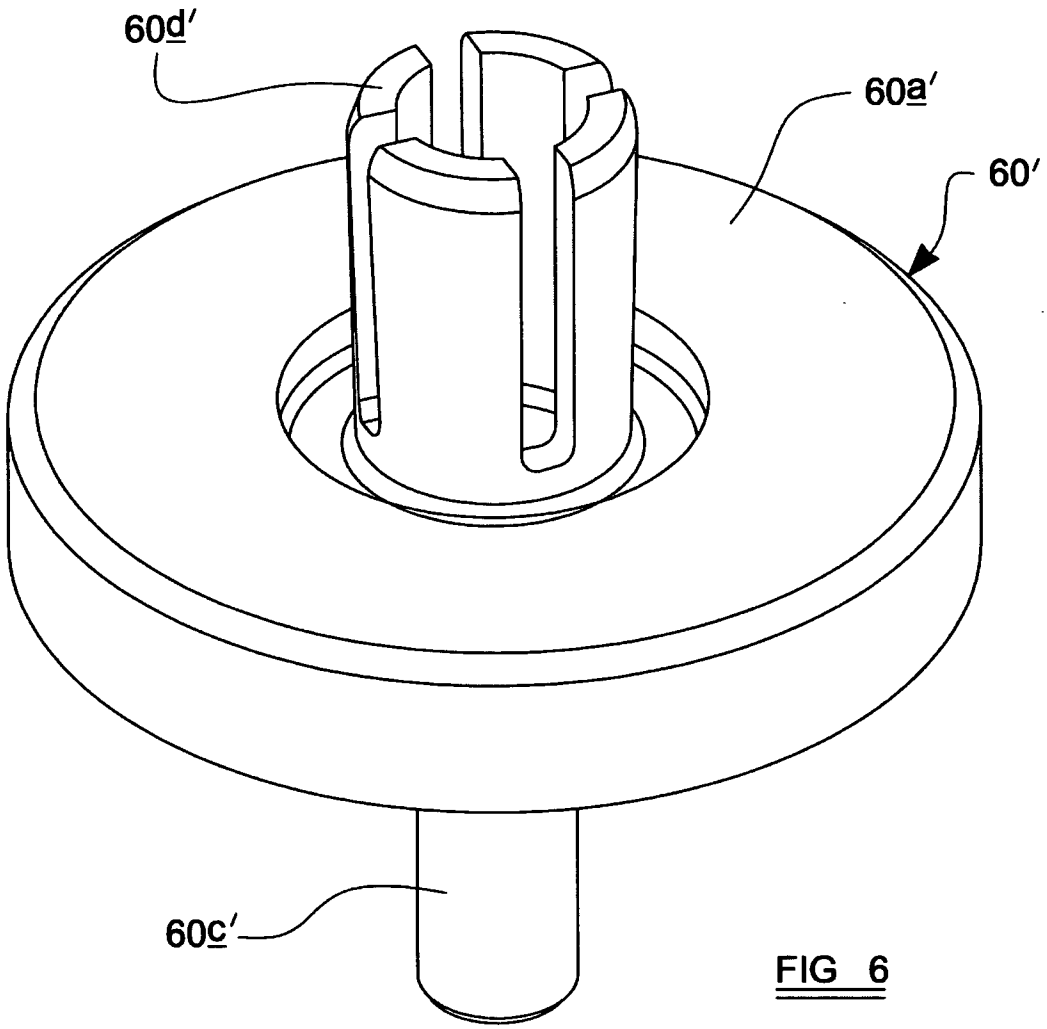


FIG 6

# INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2010/050263

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. B60T17/00
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)
B60T

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 practical, search terms used)
EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"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

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 20 May 2010 | 28/05/2010 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Meijs, Paul |

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International application No
PCT/GB2010/050263

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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