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(54) **DOUBLE ACTING CYLINDER ASSEMBLY**

(57) A double acting cylinder assembly (10) comprises a rod cylinder (100) which extends from a first end (12) to a second end (14) along a longitudinal axis (16). The rod cylinder (100) is hollow and defines a chamber (110). A rod cylinder piston (200) is located in, and operable to move along, the rod cylinder chamber (110). A first rod cylinder sub-chamber region (112) is defined on one side of the rod cylinder piston (200) and a second rod cylinder sub-chamber region (114) is defined on the other side of the rod cylinder piston (200). A floating piston (700) is also located in, and operable to slide along, the rod cylinder chamber (110). The rod cylinder piston (200) and floating piston (700) are configured to have a **coupled state** in which the rod cylinder piston (200) and floating piston (700) are coupled to one another such that the floating piston (700) is moveable with the rod cylinder piston (200) along the rod cylinder chamber (110). The rod cylinder piston (200) and floating piston (700) are also configured to have a **de-coupled state** in which the rod cylinder piston (200) and floating piston (700) are spaced apart from one another to define a first floating piston sub-volume (118) of the rod cylinder chamber (110) between the rod cylinder piston (200) and floating piston (700).

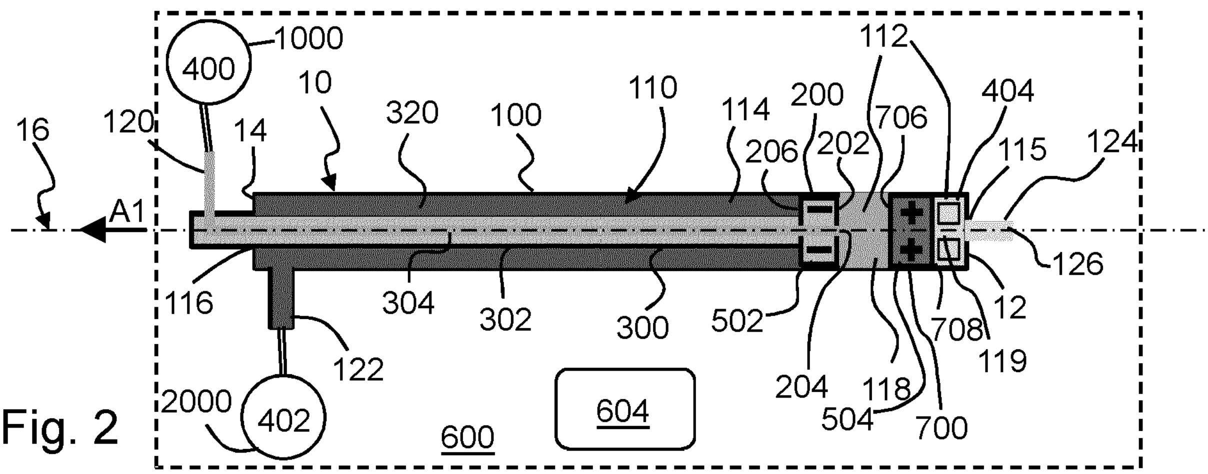

Fig. 2

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Description

FIELD

[0001] The present disclosure relates to a double acting cylinder assembly.

BACKGROUND

[0002] In hydraulic systems it is common for double acting cylinders to be used. Double acting cylinders can be retracted and extended by control of flow of hydraulic fluid to either side of a piston within the cylinder. Additionally double acting cylinders may be configured to provide damping when extended and retracted.

[0003] In certain applications (for example as part of a suspension system of a vehicle, or part of a recoil mitigation system for ordnance) the double acting cylinder having been extended or retracted to have a given length may then be subjected to loading that further extends or compresses the cylinder. Depending on the exact arrangement, the relative movement of the piston and cylinder may induce an increase in volume of the cylinder's hydraulic fluid, which may cause cavitation. For example, with reference to figure 1, during extension of the piston in response to a shock load, fluid is fed into a bore 4 through a bore port 3 and fluid is ejected from an annulus 5 via an annulus port 2. If port 3 is closed, cavitation may occur in the bore 4.

[0004] Cavitation may result in unpredictable damping performance as well as damage to the piston and/or cylinder. Hence a double acting cylinder that can mitigate or avoid cavitation is highly desirable.

SUMMARY

[0005] According to the present disclosure there is provided an apparatus and system as set forth in the appended claims. Other features of the invention will be apparent from the dependent claims, and the description which follows.

[0006] Accordingly there may be provided a double acting cylinder assembly (10, 20, 30, 40) comprising a rod cylinder (100) which extends from a first end (12) to a second end (14) along a longitudinal axis (16), the rod cylinder (100) being hollow and defining a chamber (110). The double acting cylinder assembly (10, 20, 30, 40) may further comprise a rod cylinder piston (200) located in, and operable to move along, the rod cylinder chamber (110) to define a first rod cylinder sub-chamber region (112) on one side of the rod cylinder piston (200) and a second rod cylinder sub-chamber region (114) on the other side of the rod cylinder piston (200). The double acting cylinder assembly (10, 20, 30, 40) may further comprise a floating piston (700) located in, and operable to slide along, the rod cylinder chamber (110).

[0007] The rod cylinder piston (200) and floating piston (700) may be configured to have a **coupled state** in which the rod cylinder piston (200) and floating piston (700) are coupled to one another such that the floating piston (700) is moveable with the rod cylinder piston (200) along the rod cylinder chamber (110).

[0008] The rod cylinder piston (200) and floating piston (700) may be configured to have a **de-coupled state** in which the rod cylinder piston (200) and floating piston (700) are spaced apart from one another to define a first floating piston sub-volume (118) of the rod cylinder chamber (110) between the rod cylinder piston (200) and floating piston (700).

[0009] The rod cylinder piston (200) and floating piston (700) may comprise a coupling apparatus wherein coupling engagement provided by the coupling apparatus between the rod cylinder piston (200) and floating piston (700) is configured to be sufficient to: hold the rod cylinder piston (200) and floating piston (700) together in the **coupled state;** and allow the rod cylinder piston (200) and floating piston (700) to provide the **de-coupled state.**

[0010] The rod cylinder piston (200) and floating piston (700) may comprise magnetic material and at least one of the rod cylinder piston (200) and floating piston (700) may comprise a magnet. The force of attraction between the rod cylinder piston (200) and floating piston (700) may be configured to be sufficient to hold the rod cylinder piston (200) and floating piston (700) together in the **coupled state.** The force of attraction between the rod cylinder piston (200) and floating piston (700) may be configured to be sufficient to allow the rod cylinder piston (200) and floating piston (700) to provide the **de-coupled state.** The force of attraction between the rod cylinder piston (200) and floating piston (700) may be configured to be sufficient to urge the floating piston (700) from the **de-coupled state** to the **coupled state.**

[0011] The double acting cylinder assembly (10, 20, 30, 40) may further comprise a suspension rod (300) which extends from the rod cylinder piston (200) inside the second rod cylinder sub-chamber region (114), through an aperture (116) at the second end (14) of the rod cylinder (100). An annulus (320) may be defined between the suspension rod (300) and the rod cylinder (100).

[0012] The floating piston (700) may be located in, and operable to slide along, the first rod cylinder sub-chamber region (112) between a stop (702) located between the first end (12) and the rod cylinder piston (200) such that:

in the **coupled state** the floating piston (700) is moveable with the rod cylinder piston (200) and in the **coupled state** the floating piston 700 is moveable along the first rod cylinder sub-chamber region (112); and

in the **de-coupled state** the first floating piston sub-volume (118) is a sub-volume of the first rod cylinder sub-chamber region (112).

[0013] A second floating piston sub-volume (119) may be defined between the floating piston (700) and the first end (12) of the rod cylinder (100).

[0014] The second floating piston sub-volume (119) of the first rod cylinder sub-chamber region (112) may be in fluid communication with a breather port (124).

[0015] The first floating piston sub-volume (118) may be configured to be in fluid communication with a first working fluid circuit (1000) via a first flow port (120). The second rod cylinder sub-chamber region (114) may be configured to be in fluid communication with a second working fluid circuit (2000) via a second flow port (122).

[0016] The double acting cylinder assembly (10, 20) may be configured such that when the first flow port (120) and the second flow port (122) are controlled to be open, flow of first working fluid (400) into the first floating piston sub-volume (118) from the first working fluid circuit (1000) through the first flow port (120) causes relative movement between the rod cylinder piston (200) and the floating piston (700).

[0017] The double acting cylinder assembly (10, 20) may be configured such that when the floating piston (700) is in engagement with the stop (702) the flow of first working fluid (400) into the first floating piston sub-volume (118) causes the distance between the rod cylinder piston (200) and the first end (12) of the double acting cylinder assembly (10, 20) to **increase,** causing the second working fluid (402) to flow from the second rod cylinder sub-chamber region (114) to the second working fluid circuit (2000) through the second flow port (122).

[0018] The floating piston (700) may be located in, and operable to slide along, the second rod cylinder sub-chamber region (114), between a stop (704) located between the second end (14) and the rod cylinder piston (200) such that:

in the **coupled state** the floating piston (700) is moveable with the rod cylinder piston (200) in the second rod cylinder sub-chamber region (114); and

in the **de-coupled state** the first floating piston sub-volume (118) is a sub-volume of the second rod cylinder sub-chamber region (114).

[0019] A second floating piston sub-volume (119) may be defined between the floating piston (700) and the second end (14) of the rod cylinder (100).

[0020] The second rod cylinder sub-chamber region (114) may be in fluid communication with a breather port (124).

[0021] The first rod cylinder sub-chamber region (112) may be configured to be in fluid communication with a second working fluid circuit (2000) via a second flow port (122). The first floating piston sub-volume (118) may be configured to be in fluid communication with a first working fluid circuit (1000) via a first flow port (120).

[0022] The double acting cylinder assembly (30, 40) may be configured such that when the first flow port (120) and the second flow port (122) are controlled to be open flow of first working fluid (400) into the first floating piston sub-volume (118) from the first working fluid circuit (1000) through the first flow port (120) causes relative movement between the rod cylinder piston (200) and the floating piston (700) to cause the floating piston (700) to be urged towards the stop (704) to cause the second working fluid (402) to flow from the first rod cylinder sub-chamber region (112) to the second working fluid circuit (2000) through the second flow port (122) and to **reduce** the distance between the rod cylinder piston (200) and the first end (12) of the double acting cylinder assembly (30, 40).

[0023] The suspension rod (300) may define a first flow passage (304) which extends between the first flow port (120) and an opening (204) defined by the rod cylinder piston (200) configured to deliver the first working fluid (400) to the first floating piston sub-volume (118) between the rod cylinder piston (200) and the floating piston (700).

[0024] The double acting cylinder assembly (20, 40) may further comprise a bore feed tube (800) which extends through the first end (12) of the rod cylinder piston (200), and through the floating piston (700) to deliver the first working fluid (400) to the first floating piston sub-volume (118) between the rod cylinder piston (200) and the floating piston (700).

[0025] The rod cylinder piston (200) and floating piston (700) may be configured to seal against the rod cylinder chamber (110).

[0026] There may also be provided a shock absorbing system (600) comprising a first double acting cylinder assembly (10, 20, 30, 40) according the present disclosure.

[0027] Hence there is provided a double acting cylinder that can mitigate or avoid cavitation.

[0028] This is achieved by the rod cylinder piston and floating piston being configured to have a coupled state and an uncoupled state. This allows for the rod cylinder piston and floating piston to separate during a shock/impulse load so that any volume change in the fluid constrained by the floating piston is prevented or minimised, thereby minimising the likelihood of cavitation occurring.

BRIEF DESCRIPTION OF THE FIGURES

[0029] Embodiments of the invention will now be described by way of example only with reference to the figures, in which:

Figure 1 shows an example of a conventional double acting cylinder;

Figure 2 shows a first example of a double acting cylinder according to the present disclosure;

Figures 3 to 5 shows stages of operation of the first example of a double acting cylinder according to the present disclosure;

Figure 6 shows a second example of a double acting cylinder according to the present disclosure;

Figures 7 to 9 shows stages of operation of the second example of a double acting cylinder according to the present disclosure;

Figure 10 shows a third example of a double acting cylinder according to the present disclosure;

Figures 11 to 14 show shows stages of operation of the third example of a double acting cylinder according to the present disclosure;

Figure 15 shows a fourth example of a double acting cylinder, according to the present disclosure; and

Figure 16 to 19 show stages of operation of the fourth example of a double acting cylinder according to the present disclosure.

DETAILED DESCRIPTION

[0030] The present disclosure relates to a double acting cylinder assembly 10, 20, 30, 40.

[0031] The double acting cylinder assembly 10, 20, 30, 40 may provide a required spring force and load damping while also being operable to be increased and decreased in length.

[0032] Hence the double acting cylinder assembly 10, 20, 30, 40 may form part of a shock absorbing system 600. The shock absorbing system 600 is shown generically as a dashed box around the examples of figures 2, 6, 10 and 15.

[0033] The double acting cylinder assembly 10, 20, 30, 40 may form part of a suspension system for a vehicle. The shock absorbing system 600 may form part of a suspension strut assembly for a vehicle.

[0034] The double acting cylinder assembly 10, 20, 30, 40 may form part of an artillery weapon. For example the double acting cylinder may 10, 20, 30, 40 form part of a recoil mitigation system for an ordnance. That is to say, the shock absorbing system 600 may form part of a recoil mitigation system of an artillery weapon. For example, the double acting cylinder 10, 20, 30, 40 may be coupled to a barrel of an ordnance operable to travel between an in-battery position and an out-of-battery position in response to a projectile being fired from the barrel. *"In-battery"* defines a forward position of the ordnance before (and ready for) firing. *"Out-of-battery"* defines a position of the ordnance when fully recoiled.

[0035] Several examples of a double acting cylinder 10, 20, 30, 40 according to the present disclosure are shown. A first example is shown in figures 2 to 5. A second example is shown in figures 6 to 9. A third example is shown in figures 10 to 14. A fourth example is shown in figures 15 to 19.

[0036] In all examples, the double acting cylinder assembly 10, 20, 30, 40 may comprise a rod cylinder 100. As shown in figures 2, 6, 10 and 15 the rod cylinder 100 may extend from a first end 12 to a second end 14 along a longitudinal axis 16. The rod cylinder 100 may be hollow and define a chamber 110.

[0037] There may also be provided a rod cylinder piston 200 located in, and operable to move along, the rod cylinder chamber 110 to define a first rod cylinder sub-chamber region 112 on one side of the rod cylinder piston 200 and a second rod cylinder sub-chamber region 114 on the other side of the rod cylinder piston 200.

[0038] The rod cylinder piston 200 may comprise a first surface 202 and a second surface 206 spaced apart from one another along the length of the rod cylinder piston 200. The rod cylinder piston 200 may be configured such that the first surface 202 is closest to (i.e. faces) the first end 12 rod cylinder 100 and the second surface 206 is closest to (i.e. faces) the second end 14 of the rod cylinder 100.

[0039] The double acting cylinder assembly 10, 20, 30, 40 may also comprise a floating piston 700 located in, and operable to slide along, the rod cylinder chamber 110.

[0040] The floating piston 700 may comprise a first surface 708 and a second surface 706 spaced apart from one another along the length of the floating cylinder piston 700. The first surface 708 may be closest to the first end 12 rod cylinder 100 and the second surface 706 may be closest to the second end 14 rod cylinder 100. The floating cylinder piston 700 may be located in, and operable to slide along, the rod cylinder chamber 110.

[0041] The rod cylinder piston 200 and floating piston 700 may be configured to have a **coupled state** in which the rod cylinder piston 200 and floating piston 700 are coupled to one another such that the floating piston 700 is moveable with the rod cylinder piston 200 along the rod cylinder chamber 110 (for example, as shown in figures 3, 4; figures 7, 8; figures 11, 14 and figures 16, 19).

[0042] The rod cylinder piston 200 and floating piston 700 may also be configured to have a **de-coupled state** in which the rod cylinder piston 200 and floating piston 700 are spaced apart from one another to define a first floating piston sub-volume 118 of the rod cylinder chamber 110 between the rod cylinder piston 200 and the floating piston 700 (for example, as shown in figures 2, 5; figures 6, 9; figures 10, 12, 13 and figures 15, 17, 18).

[0043] The rod cylinder piston 200 and floating piston 700 may be coupled by a coupling apparatus 500 (i.e. a device / means, which may comprise parts 502, 504) operable to releasably couple the pistons 200, 700 such that they may be repeatedly (and reliably) coupled and uncoupled.

[0044] Hence the coupling engagement provided by the coupling apparatus between the rod cylinder piston 200 and floating piston 700 may be configured to be sufficient to hold the rod cylinder piston 200 and floating piston 700 together in the **coupled state.**

[0045] The coupling engagement provided by the coupling apparatus between the rod cylinder piston 200 and floating piston 700 may be configured to allow the rod cylinder piston 200 and floating piston 700 to provide the **de-coupled state.** That is to say, the engagement provided by the coupling apparatus between the rod cylinder piston 200 and floating piston 700 may be configured to be sufficient to allow the rod cylinder piston 200 and floating piston 700 to separate and become spaced apart from one another along the rod cylinder chamber 110.

[0046] In one example, as shown in the figures, the coupling apparatus 500 may comprise a magnetic coupling arrangement/system (denoted by + and - signs in the drawings). For example the rod cylinder piston 200 and floating piston 700 may comprise magnetic material (e.g., a ferrous material). At least one of the rod cylinder piston 200 and floating piston 700 may comprise a magnet. Hence the rod cylinder piston 200 may comprise a first part 502 of the magnetic coupling arrangement and the floating piston 700 may comprise a second part 504 of the magnetic coupling arrangement. In examples in which the rod cylinder piston 200 and floating piston 700 comprise magnets, poles (e.g. + and -) of the/each magnet in the rod cylinder piston 200 may be arranged to face opposite poles of the/each magnet in the floating piston 700 (i.e., so that they are attracted towards one another). The rod cylinder 100 may comprise a non-magnetic material.

[0047] The force of attraction between the rod cylinder piston 200 and floating piston 700 may be configured to be sufficient to hold the rod cylinder piston 200 and floating piston 700 together in the **coupled state.**

[0048] The force of attraction between the rod cylinder piston 200 and floating piston 700 may be configured to be sufficient to allow the rod cylinder piston 200 and floating piston 700 to provide the **de-coupled state.** That is to say, the force of attraction between the rod cylinder piston 200 and floating piston 700 may be configured to be sufficient to allow the rod cylinder piston 200 and floating piston 700 to separate and become spaced apart from one another along the rod cylinder chamber 110.

[0049] The force of attraction between the rod cylinder piston 200 and floating piston 700 may be configured to be sufficient to urge the floating piston 700 from the **de-coupled state** to the **coupled state.** That is to say, the force of attraction between the rod cylinder piston 200 and floating piston 700 may be configured to be sufficient to urge the floating piston 700 towards, and to couple to, the rod cylinder piston 200.

[0050] In another example (not shown) the coupling apparatus 500 may comprise a mechanical latch (for example a ball spring plunger arrangement). For example the rod cylinder piston 200 may comprise a first engagement feature 502 and the floating piston 700 may comprise a second engagement feature 504, wherein the first engagement feature 502 and second engagement feature 504 are configured to engage to couple the cylinder piston 200 and floating piston 700 together and configured to disengage to allow the cylinder piston 200 and floating piston 700 to decouple.

[0051] The engagement between the first engagement feature and second engagement feature may be configured to be sufficient to hold the rod cylinder piston 200 and floating piston 700 together in the **coupled state.**

[0052] The engagement between the rod cylinder piston 200 and floating piston 700 may be configured to be sufficient to allow the rod cylinder piston 200 and floating piston 700 to provide the **de-coupled state.** That is to say, the force required to separate the first engagement feature and second engagement feature may be set to be sufficient to allow the rod cylinder piston 200 and floating piston 700 to separate and become spaced apart from one another along the rod cylinder chamber 110.

[0053] For example the first engagement feature may comprise a first part of a latch mechanism, and the second engagement feature may comprise a second part of a latch mechanism, wherein the first and second part of the latch mechanism are operable to engage to thereby couple/hold the rod cylinder piston 200 and floating piston 700 together in the **coupled state.**

[0054] The first and second part of the latch mechanism are operable to decouple to allow the rod cylinder piston 200 and floating piston 700 to provide the **de-coupled state.** That is to say, the engagement between the first part and second part of the latch mechanism may be configured to be sufficient to allow the rod cylinder piston 200 and floating piston 700 to separate and become spaced apart from one another along the rod cylinder chamber 110. Put another way, the first part and second part of the latch mechanism may be configured such that a force above a predetermined value will cause the first part and second part of the latch mechanism to separate/disengage and become spaced apart from one another along the rod cylinder chamber 110.

[0055] In the examples shown, the double acting cylinder assembly 10, 20, 30, 40 may comprise a suspension rod 300 which extends from the second surface 206 of the rod cylinder piston 200 inside the second rod cylinder sub-chamber region 114, through an aperture 116 at the second end 14 of the rod cylinder 100. An annulus 320 may be defined between an outer surface 302 of the suspension rod 300 and the rod cylinder 100. That is to say, there may be a clearance provided between the suspension rod 300 and the rod cylinder 100, wherein the clearance defines the annulus 320.

[0056] The rod cylinder piston 200 and floating piston 700 may be configured to seal against the rod cylinder chamber 110. A seal may be provided between the rod cylinder piston 200 and rod cylinder chamber 110. A seal may be provided between the floating piston 700 and rod cylinder chamber 110.

[0057] There may also be provided an external/auxiliary hydraulic system in fluid communication with a first working fluid circuit 1000 and a second working fluid circuit 2000. The external/auxiliary hydraulic system may comprise or define a reservoir for working fluid (i.e., a source of working fluid). The first working fluid circuit 1000 and the second working fluid circuit 2000 may be in fluid communication with one another via the external/auxiliary hydraulic system isolated from one another insofar as they receive and deliver working fluid from the same source. In another example the first working fluid circuit 1000 and the second working fluid circuit 2000 may be fluidly isolated from one another - for example the first working fluid circuit 1000 and the second working fluid circuit 2000 may be in fluid communication with different hydraulic system reservoirs.

[0058] The first working fluid circuit 1000 and second working fluid circuit 2000 are configured to deliver working fluid to and receive working fluid from the external/auxiliary hydraulic system. The external/auxiliary hydraulic system, first working fluid circuit 1000 and second working fluid circuit 2000 may be provided as part of the shock absorbing system 600, vehicle and/or artillery weapon.

[0059] The first working fluid circuit 1000 supplies a first working fluid 400 to the double acting cylinder assembly 10, 20, 30, 40. The second working fluid circuit 2000 supplies a second working fluid 402 to the double acting cylinder assembly 10, 20, 30, 40.

[0060] In the examples of figures 2 to 5 and figures 6 to 9, the floating piston 700 is located in, and operable to slide along, the first rod cylinder sub-chamber region 112 between a stop 702 and the first surface 202 of the rod cylinder piston 200. The stop 702 is provided in the first rod cylinder sub-chamber region 112. The stop 702, floating piston 700 and rod cylinder piston 200 are provided in series along the longitudinal axis 16. The stop 702 may be located between the first end 12 of the rod cylinder 100 and the rod cylinder piston 200. The stop 702 may be located at the first end 12 of the rod cylinder 100. The stop 702 may be defined by the first end 12 of the rod cylinder 100. The stop 702 may extend from the first end 12 of the rod cylinder 100. The stop may be spaced apart from the first end 12 of the rod cylinder 100.

[0061] In the **coupled state** the floating piston 700 is moveable with the rod cylinder piston 200 in the rod cylinder chamber 100 along the longitudinal axis 16. Hence in the **coupled state** the floating piston 700 is moveable with the rod cylinder piston 200 and in the **coupled state** the floating piston 700 moves along the first rod cylinder sub chamber region 112. In the **de-coupled state** the first floating piston sub-volume 118 is a sub-volume of the first rod cylinder sub-chamber region 112. A second floating piston sub-volume 119 is defined between the floating piston 700 and the first end 12 of the rod cylinder 100. Hence the second floating piston sub-volume 119 is also a sub-volume of the first rod cylinder sub-chamber region 112 since it is defined between the floating piston 700 and the first end 12 of the rod cylinder 100.

[0062] Also, in the examples of figures 2 to 5 and figures 6 to 9, the second floating piston sub-volume 119 of the first rod cylinder sub-chamber region 112 may be in fluid communication with a breather port 124. The breather port 124 may be open to atmosphere or a large reservoir.

[0063] The first floating piston sub-volume 118 between the rod cylinder piston 200 and the floating piston 700 may be configured to be in fluid communication with the first working fluid circuit 1000 via a first flow port 120.

[0064] The second rod cylinder sub-chamber region 114 may be configured to be in fluid communication with the second working fluid circuit 2000 via a second flow port 122.

[0065] There may be provided a control system 604, the control system 604 operable to control the first flow port 120 and second flow port 122.

[0066] In the examples of figures 10 to 14 and figures 15 to 19, the floating piston 700 may be located in, and operable to slide along, the second rod cylinder sub-chamber region 114, between a stop 704 and the rod cylinder piston 200.

[0067] It follows that, in the examples of figures 10 to 14 and figures 15 to 19 the first rod cylinder sub-chamber region 112 is on the opposite side of the rod cylinder piston 200 to the second rod cylinder sub-chamber region 114. That is, the first rod cylinder sub-chamber region 112 extends from the first end 12 of the rod cylinder 12.

[0068] The stop 704 is provided in the second rod cylinder sub-chamber region 114. The stop 704, floating piston 700 and rod cylinder piston 200 are provided in series along the longitudinal axis 16. The stop 704 may be located between the second end 14 and the rod cylinder piston 200. The stop 704 may be located at the second end 14. The stop 704 may be defined by the second end 14. The stop 704 may extend from the second end 14. The stop 702 may be spaced apart from the second end 14.

[0069] In the **coupled state** the floating piston 700 is moveable with the rod cylinder piston 200 in the second rod cylinder sub-chamber region 114 along the longitudinal axis 16. In the **de-coupled state** the first floating piston sub-volume 118 is a sub-volume of the second rod cylinder sub-chamber region 114. A second floating piston sub-volume 119 may be defined between the floating piston 700 and the second end 14 of the rod cylinder 100. The second floating piston sub-volume 119 is also a sub-volume of the first rod cylinder sub-chamber region 112. The second floating piston sub-volume 119 may be defined between the floating piston 700 and the second end 14 of the rod cylinder 100.

[0070] Also, in the examples of figures 10 to 14 and figures 15 to 19, the second rod cylinder sub-chamber region 114 may be in fluid communication with a breather port 124. The breather port 124 may be open to atmosphere or a large reservoir.

[0071] In the examples of figures 10 to 14 and figures 15 to 19, the first rod cylinder sub-chamber region 112 may be configured to be in fluid communication with the second working fluid circuit 2000 via a second flow port 122. The first floating piston sub-volume 118 between the rod cylinder piston 200 and the floating piston 700 may be configured to be in fluid communication with the first working fluid circuit 1000 via a first flow port 120.

[0072] In the examples of figures 2 to 5 and figures 10 to 14 the suspension rod 300 may define a first flow passage 304. The first flow passage 304 may extend between the first flow port 120 and an opening 204.

[0073] The first flow passage 304 may be configured to deliver the first working fluid 400 to between the rod cylinder piston 200 and the floating piston 700. That is to say the first flow passage 304 may be configured to deliver the first working fluid 400 to a region, volume and/or space defined between the rod cylinder piston 200 and the floating piston 700. Put another way, the first flow passage 304 may be configured to deliver the first working fluid 400 to the first floating piston sub-volume 118, between the rod cylinder piston 200 and the floating piston 700 via the opening 204.

[0074] In the example of figures 2 to 5 the opening 204 may be defined by the rod cylinder piston 200. The first flow passage 304 may extend from the suspension rod 300, through the second surface 206 of the rod cylinder piston 200 and through the rod cylinder piston 200 to the opening 204 on the first surface 202. In other words, the opening 204 may be in flow communication with the first flow passage 304 and open onto the first surface 202 of the rod cylinder piston 200.

[0075] In the example of figures 10 to 14 the opening 204 may be defined by the suspension rod 300. For example, the opening 204 may be in flow communication with the first flow passage 304 and open into the annulus 320 onto the outer surface 302 of the suspension rod 300. The opening 204 may be provided in the suspension rod 300. The opening 204 may be located proximate to the second surface 206 of the rod cylinder piston 200. The opening may be (at least in part) defined by the second surface 206 of the rod cylinder piston 200. The opening 204 may extend from the second surface 206 of the rod cylinder piston 200. The opening 204 may be spaced apart from the rod cylinder piston 200 along the outer surface 302 of the outer surface 302 of the suspension rod 300.

[0076] The first flow passage 304 may also be configured to remove the first working fluid 400 from the first floating piston sub-volume 118 between the rod cylinder piston 200 and the floating piston 700 when they are in the **de-coupled state.** For example the first working fluid 400 may be pumped/forced out of the first floating piston sub-volume 118 via the first flow passage 304.

[0077] In one example the first working fluid 400 may be removed from the first floating piston sub-volume 118 by drawing/sucking/pumping the first working fluid 400 from the first floating piston sub-volume 118, for example by the action of a pump in fluid communication with the first flow passage 304.

[0078] In an alternative example, with reference to figures 2 to 5 the first working fluid 400 may be removed from the first floating piston sub-volume 118 by pumping the second working fluid 402 into the second rod cylinder sub-chamber region 114 to move the rod cylinder piston 200 along the rod cylinder 100 towards the first end 12, which forces the first working fluid 400 and floating piston 700 along the rod cylinder 100 towards the first end 12 of the rod cylinder 100 until the floating piston 700 rests against the stop 702. If the second working fluid 402 continues to be pumped into the second rod cylinder sub-chamber region 114, the rod cylinder piston 200 continues to move along the rod cylinder 100 towards the first end 12 of the cylinder 100. With the floating piston 700 resting against the stop 702, the first working fluid 400 is forced out of the first floating piston sub-volume 118 via the first flow passage 304 until the rod cylinder piston 200 and the floating piston 700 make contact and achieve the **coupled state.**

[0079] In an alternative example, with reference to figures 10 to 14 the first working fluid 400 may be removed from the first floating piston sub-volume 118 by pumping the second working fluid 402 into the first rod cylinder sub-chamber region 112 to move the rod cylinder piston 200 along the rod cylinder towards the second end 14, which forces the first working fluid 400 and floating piston 700 along the rod cylinder 100 towards the second end 14 of the rod cylinder 100 until the floating piston 700 rests against the stop 704. If the second working fluid 402 continues to be pumped into the first rod cylinder sub-chamber region 112, the rod cylinder piston 200 continues to move along the rod cylinder 100 towards the second end 14 of the cylinder 100. With the floating piston 700 resting against the stop 704, the first working fluid 400 is forced out of the first floating piston sub-volume 118 the first flow passage 304 until the rod cylinder piston 200 and the floating piston 700 make contact and achieve the **coupled state.**

[0080] In the examples of figures 6 to 9 and figures 15 to 19 the double acting cylinder assembly 20, 40 comprises a bore feed tube 800 which may extend between the first flow port 120 and an opening 802. The bore feed tube 800 may extend through an aperture 115 at the first end 12 of the rod cylinder 100 to deliver the first working fluid 400 to between the rod cylinder piston 200 and the floating piston 700. That is to say, the bore feed tube 800 may be configured to deliver the first working fluid 400 to a region, volume and/or space defined between the rod cylinder piston 200 and the floating piston 700. Put another way, the bore feed tube 800 may be configured to deliver the first working fluid 400 to the first floating piston sub-volume 118, between the rod cylinder piston 200 and the floating piston 700 via the opening 802.

[0081] In the example of figures 6 to 9 the opening 802 may be defined by the floating cylinder piston 700. The bore feed tube 800 may extend through the floating cylinder piston 700 to the opening 802, where the opening 802 is provided on the second surface 706 of the floating cylinder piston 700. In other words, the opening 802 may be in fluid communication with the bore feed tube 800 and open onto the second surface 706 of the floating cylinder piston 700.

[0082] In the examples of figures 15 to 19 the opening 802 may be defined by the suspension rod 300. For example, the opening 802 may be in flow communication with the bore feed tube 800 and open into the annulus 320. The opening may be provided on the outer surface 302 of the suspension rod 300. The opening 802 may be located proximate to the second surface 206 of the rod cylinder piston 200. The opening 802 may be defined by the second surface 206 of the rod cylinder piston 200. The opening 802 may extend from the second surface 206 of the rod cylinder piston 200. The opening 802 may be spaced apart from the rod cylinder piston 200 along the suspension rod 300.

[0083] The bore feed tube 800 may also be configured to remove the first working fluid 400 from the first floating piston sub-volume 118 between the rod cylinder piston 200 and the floating piston 700 when they are in the **decoupled state.** For example the first working fluid 400 may be pumped/forced out of the first floating piston sub-volume 118 via the bore feed tube 800.

[0084] In one example the first working fluid 400 may be removed from the first floating piston sub-volume 118 by drawing/sucking/pumping the first working fluid 400 from the first floating piston sub-volume 118, for example by the action of a pump in fluid communication with the bore feed tube 800.

[0085] In an alternative example, with reference to figures 6 to 9 the first working fluid 400 may be removed from the first floating piston sub-volume 118 by pumping the second working fluid 402 into the second rod cylinder sub-chamber region 114 to move the rod cylinder piston 200 along the rod cylinder 100 towards the first end 12, which forces the first working fluid 400 and floating piston 700 along the rod cylinder 100 towards the first end 12 of the rod cylinder 100 until the floating piston 700 rests against the stop 702. If the second working fluid 402 continues to be pumped into the second rod cylinder sub-chamber region 114, the rod cylinder piston 200 continues to move along the rod cylinder 100 towards the first end 12 of the cylinder 100. With the floating piston 700 resting against the stop 702, the first working fluid 400 is forced out of the first floating piston sub-volume 118 via the bore tub 800 until the rod cylinder piston 200 and the floating piston 700 make contact and achieves the **coupled state.**

[0086] In an alternative example, with reference to figures 15 to 19 the first working fluid 400 may be removed from the first floating piston sub-volume 118 by pumping the second working fluid 402 into the first rod cylinder sub-chamber region 112 to move the rod cylinder piston 200 along the rod cylinder towards the second end 14, which forces the first working fluid 400 and floating piston 700 along the rod cylinder 100 towards the second end 14 of the rod cylinder 100 until the floating piston 700 rests against the stop 704. If the second working fluid 402 continues to be pumped into the first rod cylinder sub-chamber region 112, the rod cylinder piston 200 continues to move along the rod cylinder 100 towards the second end 14 of the cylinder 100. With the floating piston 700 resting against the stop 704, the first working fluid 400 is forced out of the first floating piston sub-volume 118 via the bore tub 800 until the rod cylinder piston 200 and the floating piston 700 make contact and achieve the **coupled state.**

[0087] In all examples, the breather port 124 may comprise a breather valve 126. The breather valve 126 may be operable to open to allow flow of a third working fluid 404 into and/or out of the second floating piston sub-volume 119 to allow free movement of the rod cylinder piston 200 and floating piston 700. The breather valve 126 may be operable to close to prevent flow of the third working fluid 404 into and/or out of the second floating piston sub-volume 119 to maintain the third working fluid 404 at a controllable and predictable pressure range in the second floating piston sub-volume 119. Air trapped in this volume, for example by diffusion or outgassing, can be vented through the breather valve 126.

[0088] The first working fluid 400 may be incompressible.

[0089] The second working fluid 402 may be incompressible.

[0090] The third working fluid 404 may be compressible.

[0091] In the examples of figures 2 to 5 and figures 6 to 9, the double acting cylinder assembly 10, 20 is operable to vary the position of the rod cylinder piston 200 between the first end 12 and the second end 14 of the rod cylinder 100 by the first flow port 120 being operable to control the flow of the first working fluid 400 between the first working fluid circuit 1000 and the first floating piston sub-volume 118 between the rod cylinder piston 200 and the floating piston 700 and by the second flow port 122 being operable to control the flow of the second working fluid 402 between the second working fluid circuit 2000 and the second rod cylinder sub-chamber region 114.

[0092] In the examples of figures 2 to 5 and figures 6 to 9, the double acting cylinder assembly 10, 20 may be configured so that when the first flow port 120 and the second flow port 122 are controlled to be open, the flow of first working fluid 400 into the first floating piston sub-volume 118 between the rod cylinder piston 200 and the floating piston 700 from the first working fluid circuit 1000 through the first flow port 120 causes them to decouple and causes relative movement between the rod cylinder piston 200 and the floating piston 700. This causes the floating piston 700 to be moved towards the stop 702. Hence this may result in the floating piston 700 being urged towards the stop 702.

[0093] Additionally, the flow of first working fluid 400 into the first floating piston sub-volume 118 between the rod cylinder piston 200 and the floating piston 700 causes the rod cylinder piston 200 to move in a direction away from the stop 702 towards the second end 14 of the rod cylinder 100 (i.e., to **increase** the distance between the rod cylinder piston 200 and the first end 12 of the double acting cylinder assembly 10, 20). At the same time the second working fluid 402 flows from the second rod cylinder sub-chamber region 114 to the second working fluid circuit 2000 through the second flow port 122. For example, the second working fluid 402 may be caused to flow from the second rod cylinder sub-chamber region 114 because of the force induced on the rod cylinder piston

200 by the flow of first working fluid 400 into the first floating piston sub-volume 118 between the rod cylinder piston 200 and the floating piston 700. Additionally, or alternatively, the second working fluid 402 may be drawn into the second working fluid circuit 2000 from the second rod cylinder sub-chamber region 114.

[0094] In the example of figures 2 to 5, figure 3 shows the double acting cylinder assembly 10 when fully compressed.

[0095] In the example of figures 6 to 9, figure 7 shows the double acting cylinder assembly 20 when fully compressed.

[0096] An external force applied to the rod 300 (indicated by the arrow A2, B2 in figures 3, 7), causes the cylinder assembly 10 to extend to the configuration shown in figures 4, 8. During this forced extension, the second working fluid 402 is allowed to egress from the annulus 320 through the second flow port 122.

[0097] If the rod cylinder piston 200 and floating piston 700 are in the **coupled state** (as shown in figures 3, 7) the floating piston 700 will travel with the rod cylinder piston 200 (for example to the position shown in figure 4, 8). In examples in which the breather port 124 is open to atmosphere, the changing volume of the second floating piston sub-volume 119 will not impede the movement of the rod cylinder piston 200 and floating piston 700.

[0098] The rod cylinder piston 200 can also be driven to extend from the configuration shown in figures 3, 7 by means of controlling the flow of first working fluid 400 into the first floating piston sub-volume 118 between the rod cylinder piston 200 and the floating piston 700 from the first working fluid circuit 1000 through the first flow port 120 (thereby causing the rod cylinder piston 200 and floating piston 700 to **de-couple**) and allowing egress of the second working fluid 402 from the annulus 320 through the second flow port 122 as shown in figures 5, 9.

[0099] In the example of figures 2 to 5 the first working fluid 400 is supplied to the first floating piston sub-volume 118 between the rod cylinder piston 200 and the floating piston 700 via the first flow passage 304 in the suspension rod 300.

[0100] In the example of figures 6 to 9 the first working fluid 400 is supplied to the first floating piston sub-volume 118 between the rod cylinder piston 200 and the floating piston 700 via the bore feed tube 800.

[0101] In both cases the introduction of a pressurised second working fluid 402 pushes the floating piston 700 towards the first end 12 of the rod cylinder 100 and causes the rod cylinder piston 200 and the floating piston 700 to **de-couple** and thus supply enough force to overcome the features of the coupling apparatus which hold them together (for example overcome the magnetic force between them where magnets are employed, or supply enough force to disengage the engagement features / latch parts where mechanical engagement features are employed.

[0102] In the configuration of figures 5, 9, should a force as indicated by arrows A3, B3, be applied to the suspension rod 300 in the direction shown in figures 5, 9 (i.e. away from the first end 12), the floating piston 700 will tend to follow the rod cylinder piston 200 (albeit being in the **de-coupled state** and hence being spaced apart from it) and cavitation will not occur, as no pressure drop will be needed to pull the floating piston 700 and no volume change in the first working fluid 400 of the first floating piston sub-volume 118 will occur, and hence no cavitation will occur.

[0103] The rate of fluid flow out of port 122 may be controlled to provide damping to the movement of the rod cylinder piston 200.

[0104] In the examples of figures 10 to 14 and figures 15 to 19 the double acting cylinder assembly 30, 40 is operable to vary the position of the rod cylinder piston 200 between the first end 12 and the second end 14 of the rod cylinder 100 by the first flow port 120 being operable to control the flow of the first working fluid 400 between the first working fluid circuit 1000 and the first floating piston sub-volume 118, and by the second flow port 122 being operable to control the flow of the second working fluid 402 between the second working fluid circuit 2000 and the first rod cylinder sub-chamber region 112.

[0105] In the examples of figures 10 to 14 and figures 15 to 19 the double acting cylinder assembly 30, 40 may be configured such that when the first flow port 120 and the second flow port 122 are controlled to be open the flow of the first working fluid 400 into the first floating piston sub-volume 118 from the first working fluid circuit 1000 through the first flow port 120 causes relative movement between the rod cylinder piston 200 and the floating piston 700. This causes the floating piston 700 to be moved towards the stop 704. Hence this may result in the floating piston 700 being urged towards the stop 704. This may result in the floating piston 700 being urged into engagement with the stop 704.

[0106] In turn this may cause the second working fluid 402 to flow from the first rod cylinder sub-chamber region 112 to the second working fluid circuit 2000 through the second flow port 122 to **reduce** the distance between the rod cylinder piston 200 and the first end 12 of the double acting cylinder assembly 30, 40.

[0107] The flow of the first working fluid 400 into the first floating piston sub-volume 118 causes the rod cylinder piston 200 to move in a direction away from the stop 704 towards the first end 12 (i.e. to **increase** the distance between the rod cylinder piston 200 and the second end 14 of the double acting cylinder assembly 30, 40). At the same time the second working fluid 402 flows from the first rod cylinder sub-chamber region 112 to the second working fluid circuit 2000 through the second flow port 122. For example, the second working fluid 402 may be caused to flow from the first rod cylinder sub-chamber region 112 because of the force induced on the rod cylinder piston 200 by the flow of first working fluid 400 into the first floating piston sub-volume 118. Additionally, or alternatively, the second working fluid 402 may be drawn into the second working fluid circuit 2000 from first rod cylinder sub-chamber region 112.

[0108] In the example of figures 10 to 14, figure 11 shows the double acting cylinder assembly 30 when fully extended.

[0109] In the example of figures 15 to 19, figure 16 shows the double acting cylinder assembly 40 when fully extended.

[0110] An external force applied to the rod 300 (indicated by the arrows C1, D1 in figures 11, 16), would cause the cylinder assembly 10 to retract.

[0111] If the rod cylinder piston 200 and floating piston 700 are in the **coupled state** (as shown in figures 11, 16) the floating piston 700 will travel with the rod cylinder piston 200. In examples in which the breather port 124 is open to atmosphere, the changing volume of the second floating piston sub-volume 119 will not impede the movement of the rod cylinder piston 200 and floating piston 700.

[0112] The rod cylinder piston 200 can also be driven to retract from the configuration shown in figures 11,16 by means of controlling the flow of first working fluid 400 into the first floating piston sub-volume 118 between the rod cylinder piston 200 and the floating piston 700 from the first working fluid circuit 1000 through the first flow port 120 (thereby causing the rod cylinder piston 200 and floating piston 700 to **de-couple**), and allowing egress of the second working fluid 402 from the first rod cylinder sub-chamber region 112 through the second flow port 122, as shown in figures 12, 17.

[0113] In the example of figures 10 to 14 the first working fluid 400 is supplied to the first floating piston sub-volume 118 between the rod cylinder piston 200 and the floating piston 700 via the first flow passage 304 in the suspension rod 300.

[0114] In the example of figures 15 to 19 the first working fluid 400 is supplied to the first floating piston sub-volume 118 between the rod cylinder piston 200 and the floating piston 700 via the bore feed tube 800.

[0115] In both cases the introduction of pressurised second working fluid 402 pushes the floating piston 700 towards the second end 14 of the rod cylinder 100 and causes the rod cylinder piston 200 and the floating piston 700 to **de-couple** and thus supply enough force to overcome the features of the coupling apparatus which hold them together (for example overcome the magnetic force between them where magnets are employed, or supply enough force to disengage the engagement features / latch parts where mechanical engagement features are employed.

[0116] In the configuration of figures 12, 17, should a force be applied to the suspension rod 300 in the direction shown in figures 12, 17 (i.e. away from the second end 14), the floating piston 700 will tend to follow the rod cylinder piston 200 (albeit being in the **de-coupled state** and hence being spaced apart from it) and cavitation will not occur, as no pressure drop will be needed to pull the floating piston 700 and no volume change in the fluid of the first floating piston sub-volume 118 will occur, and hence no cavitation will occur.

[0117] The rate of fluid flow out of the second flow port 122 may be controlled to provide damping to the movement of the rod cylinder piston 200.

[0118] Hence there is provided a double acting cylinder that can mitigate or avoid cavitation. This is achieved by the rod cylinder piston and floating piston being configured to have a coupled state and an uncoupled state. Hence any volume change in the fluid constrained by the floating piston is prevented or minimised by the ability of the rod cylinder piston and floating piston to separate during a shock/impulse load.

[0119] Thus systems in which the solutions of the present disclosures are used will avoid pressure changes on the hydraulic fluid which may result in cavitation whilst obviating the need for conventional cavitation solutions (e.g. an accumulator) to be added. Hence a doubling acting cylinder of the present disclosure enables systems which avoid cavitation but do not need to include such conventional cavitation solutions (e.g., an accumulator), which enables more compact, lighter and simpler systems (compared to examples of the related art) to be realised.

[0120] Attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

[0121] All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

[0122] Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0123] The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. A double acting cylinder assembly comprising:

a rod cylinder which extends from a first end to a second end along a longitudinal axis, the rod cylinder being hollow and defines a chamber;

a rod cylinder piston located in, and operable to move along, the rod cylinder chamber to define a first rod cylinder sub-chamber region on one side of the rod cylinder piston and a second rod cylinder sub-chamber region on the other side of the rod cylinder piston;
a floating piston located in, and operable to slide along, the rod cylinder chamber; wherein:

the rod cylinder piston and floating piston are configured to have:
a **coupled state** in which the rod cylinder piston and floating piston are coupled to one another such that the floating piston is moveable with the rod cylinder piston along the rod cylinder chamber; and
a **de-coupled state** in which the rod cylinder piston and floating piston are spaced apart from one another to define a first floating piston sub-volume of the rod cylinder chamber between the rod cylinder piston and floating piston.

2. A double acting cylinder assembly as claimed in claim 1 wherein the rod cylinder piston and floating piston comprise a coupling apparatus;
wherein coupling engagement provided by the coupling apparatus between the rod cylinder piston and floating piston is configured to be sufficient to:

hold the rod cylinder piston and floating piston together in the **coupled state;**
allow the rod cylinder piston and floating piston to provide the **de-coupled state.**

3. A double acting cylinder assembly as claimed in claim 1 wherein the rod cylinder piston and floating piston comprise magnetic material and at least one of the rod cylinder piston and floating piston comprise a magnet;
wherein the force of attraction between the rod cylinder piston and floating piston is configured to be sufficient to:

hold the rod cylinder piston and floating piston together in the **coupled state;**
allow the rod cylinder piston and floating piston to provide the **de-coupled state;** and
urge the floating piston from the **de-coupled state** to the **coupled state.**

4. A double acting cylinder assembly as claimed in any one of claims 1 to 3 wherein

the double acting cylinder assembly further comprises a suspension rod which extends from the rod cylinder piston inside the second rod cylinder sub-chamber region, through an aperture at the second end of the rod cylinder;
wherein an annulus is defined between the suspension rod and the rod cylinder.

5. A double acting cylinder assembly as claimed in any one of claims 1 to 4 wherein the floating piston is located in, and operable to slide along, the first rod cylinder sub-chamber region between a stop located between the first end and the rod cylinder piston such that:

in the **coupled state** the floating piston is moveable with the rod cylinder piston and in the **coupled state** the floating piston 700 is moveable along the first rod cylinder sub-chamber region; and
in the **de-coupled state** the first floating piston sub-volume is a sub-volume of the first rod cylinder sub-chamber region; and

a second floating piston sub-volume is defined between the floating piston and the first end of the rod cylinder.

6. A double acting cylinder assembly as claimed in claim 5 wherein the second floating piston sub-volume of the first rod cylinder sub-chamber region is in fluid communication with a breather port.

7. A double acting cylinder assembly as claimed in claim 5 and claim 6 wherein:

the first floating piston sub-volume is configured to be in fluid communication with a first working fluid circuit via a first flow port; and
the second rod cylinder sub-chamber region configured to be in fluid communication with a second working fluid circuit via a second flow port.

8. A double acting cylinder assembly as claimed in claim 7 configured such that when the first flow port and the second flow port are controlled to be open:

flow of first working fluid into the first floating piston sub-volume from the first working fluid circuit through the first flow port causes relative movement between the rod cylinder piston and the floating piston and,
when the floating piston is in engagement with the stop the flow of first working fluid into the first floating piston sub-volume causes the distance between the rod cylinder piston and the first end of the double acting cylinder assembly to **increase,** causing the second working fluid to flow from the second rod cylinder sub-chamber region to the second working fluid circuit through the second flow port.

9. A double acting cylinder assembly as claimed in any one of claims 1 to 4 wherein the floating piston is located in, and operable to slide along, the second rod cylinder sub-chamber region, between a stop located between the second end and the rod cylinder piston such that:

in the **coupled state** the floating piston is moveable with the rod cylinder piston in the second rod cylinder sub-chamber region; and
in the **de-coupled state** the first floating piston sub-volume is a sub-volume of the second rod cylinder sub-chamber region; and
a second floating piston sub-volume is defined between the floating piston and the second end of the rod cylinder.

10. A double acting cylinder assembly as claimed in claim 9 wherein the second rod cylinder sub-chamber region is in fluid communication with a breather port.

11. A double acting cylinder assembly as claimed in claim 9 and claim 10 wherein:

the first rod cylinder sub-chamber region is configured to be in fluid communication with a second working fluid circuit via a second flow port; and
the first floating piston sub-volume is configured to be in fluid communication with a first working fluid circuit via a first flow port.

12. A double acting cylinder assembly as claimed in any one of claims 9 to 11 configured such that when the first flow port and the second flow port are controlled to be open:
flow of first working fluid into the first floating piston sub-volume from the first working fluid circuit through the first flow port causes relative movement between the rod cylinder piston and the floating piston to cause the floating piston to be urged towards the stop to cause the second working fluid to flow from the first rod cylinder sub-chamber region to the second working fluid circuit through the second flow port and to **reduce** the distance between the rod cylinder piston and the first end of the double acting cylinder assembly.

13. A double acting cylinder assembly as claimed in claims 8, 12 when dependent on claim 4 wherein the suspension rod defines a first flow passage which extends between the first flow port and an opening defined by the rod cylinder piston configured to deliver the first working fluid to the first floating piston sub-volume between the rod cylinder piston and the floating piston.

14. A double acting cylinder assembly as claimed in claims 8, 12 when dependent on claim 4 further comprising a bore feed tube which extends through the first end of the rod cylinder piston, and through the floating piston to deliver the first working fluid to the first floating piston sub-volume between the rod cylinder piston and the floating piston.

15. A double acting cylinder assembly as claimed in any one of the preceding claims wherein the rod cylinder piston and floating piston are configured to seal against the rod cylinder chamber.

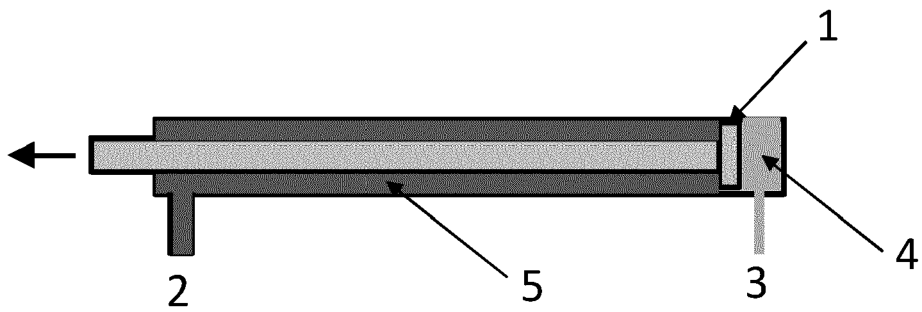

Fig. 1 (related art)

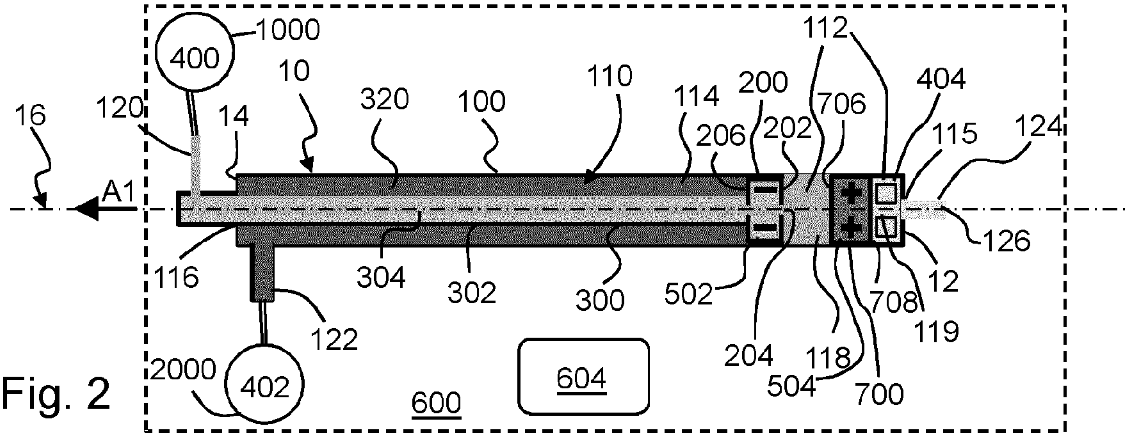

Fig. 2

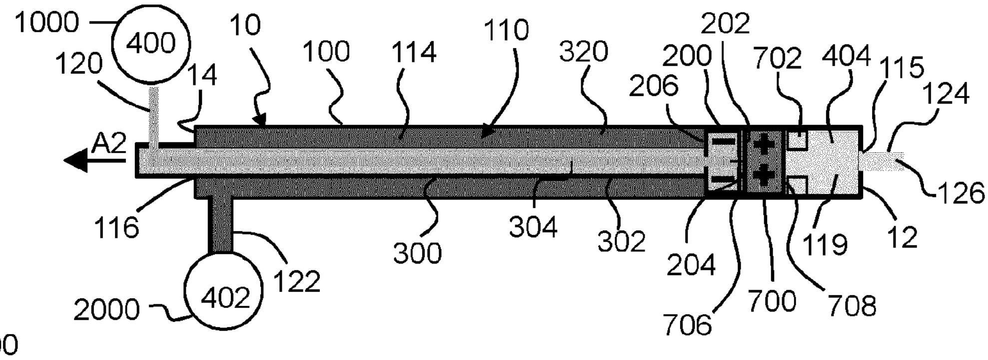

Fig. 3

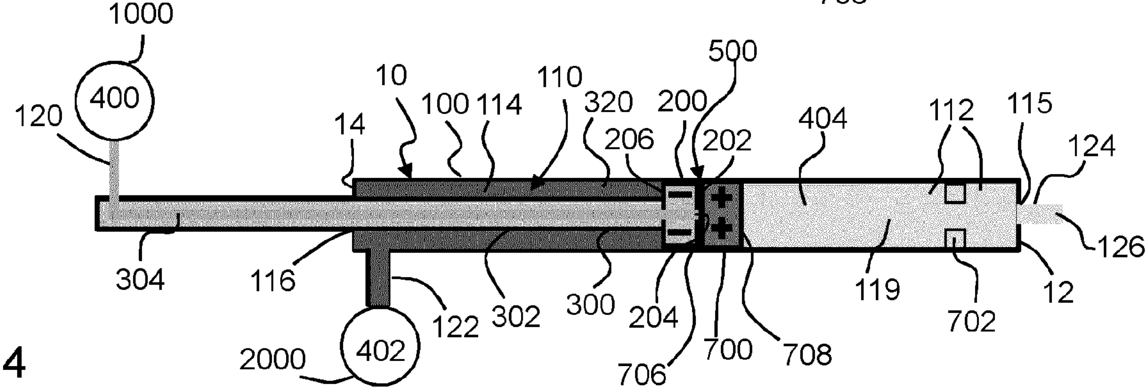

Fig. 4

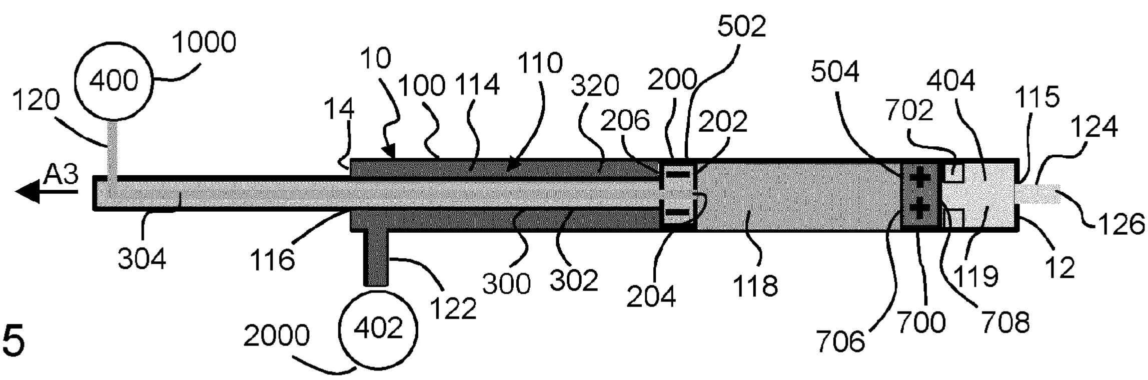

Fig. 5

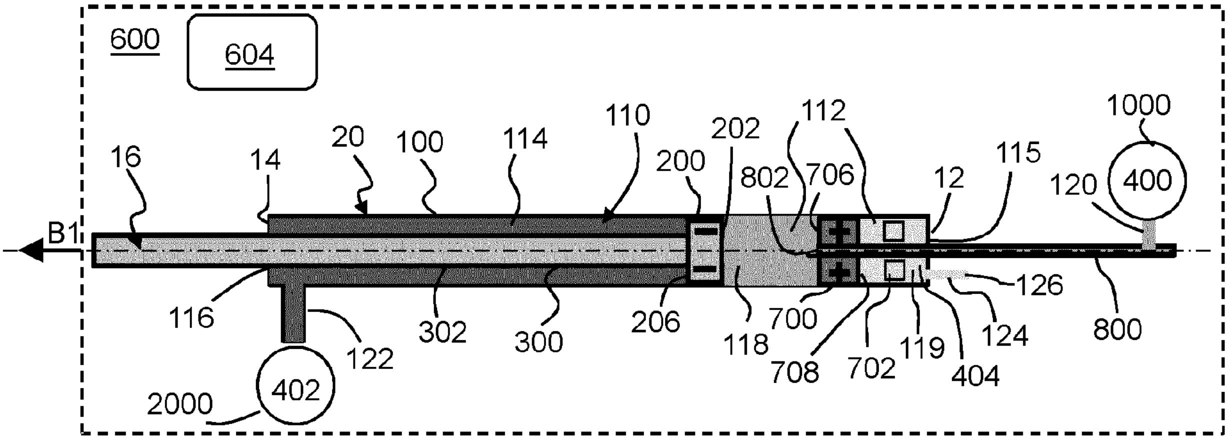

Fig. 6

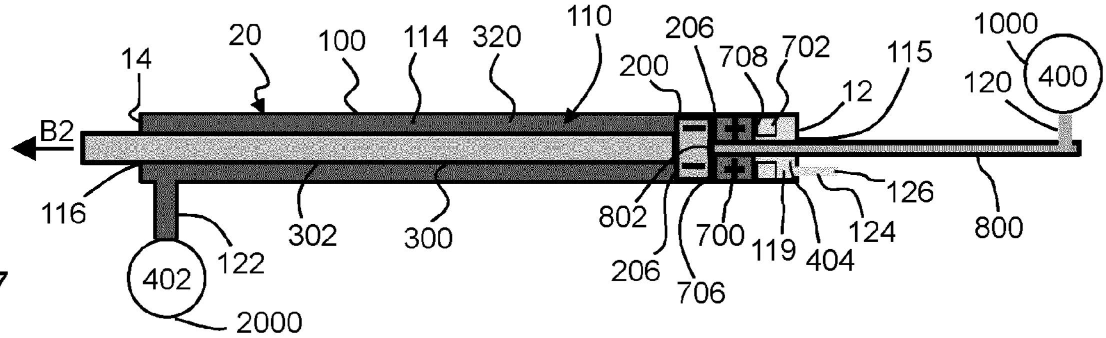

Fig. 7

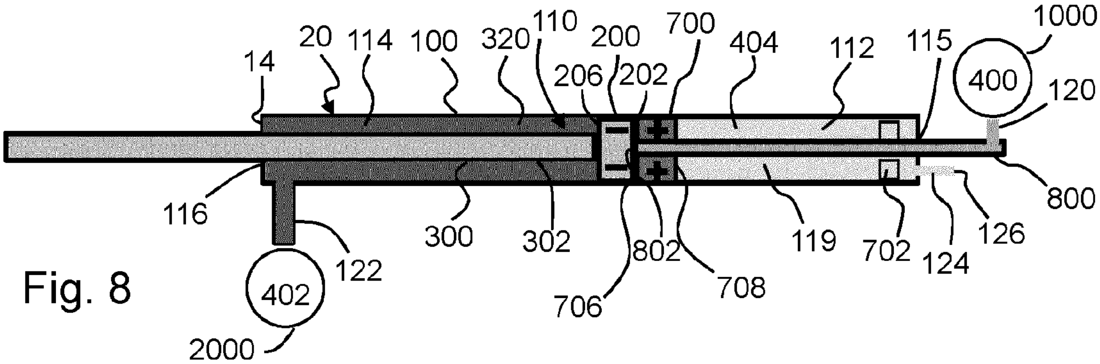

Fig. 8

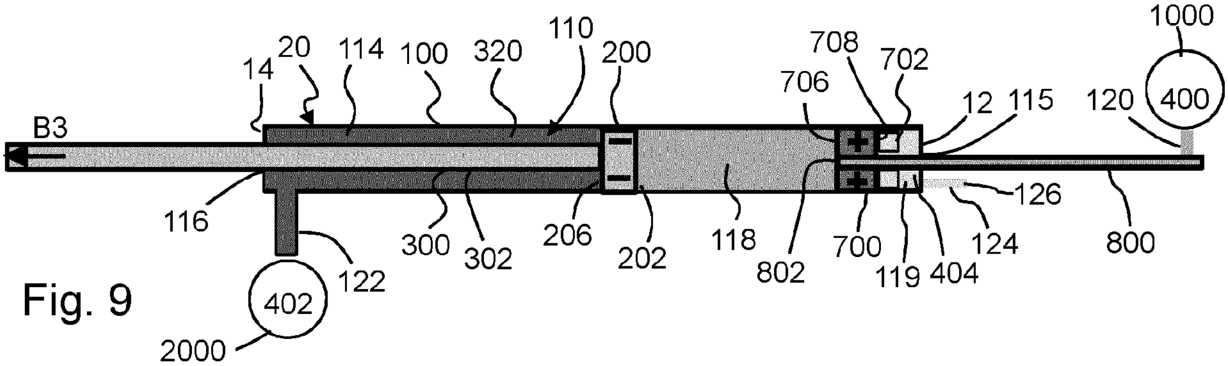

Fig. 9

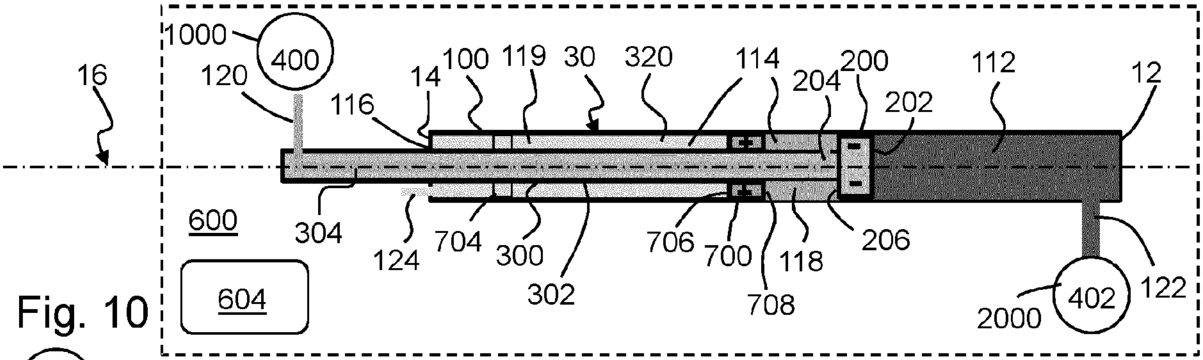

Fig. 10

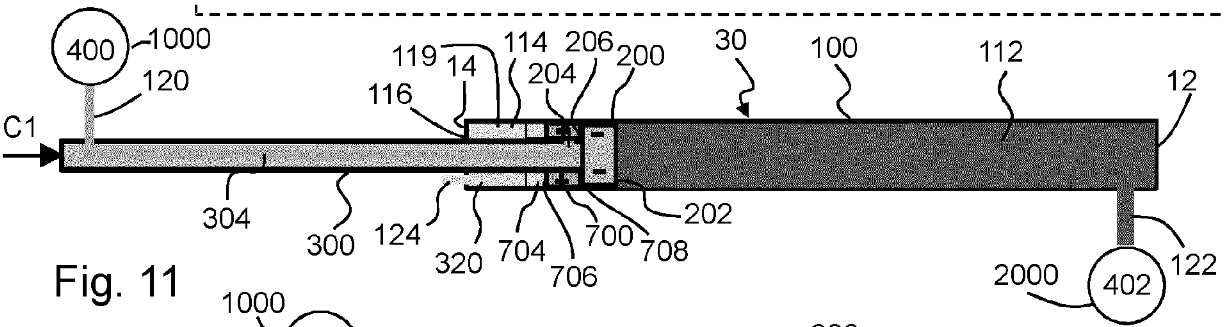

Fig. 11

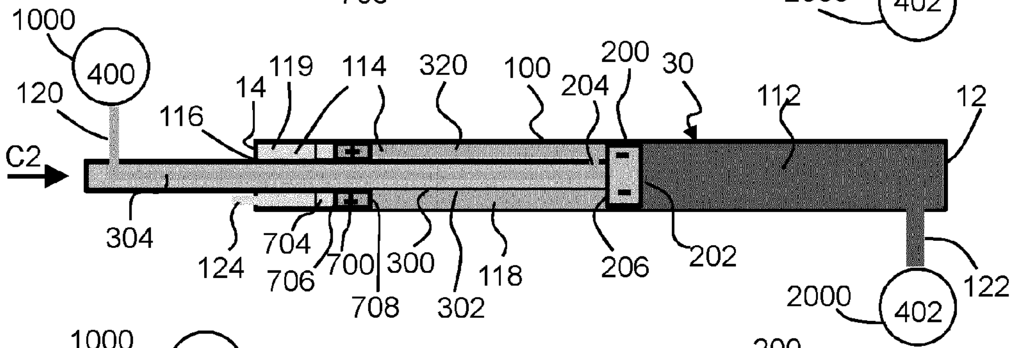

Fig. 12

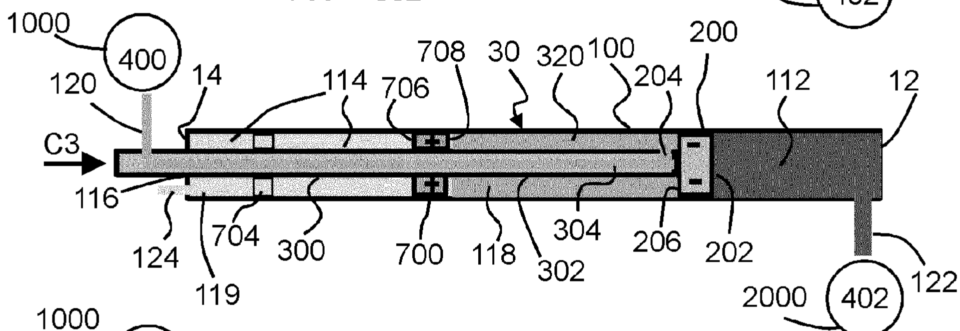

Fig. 13

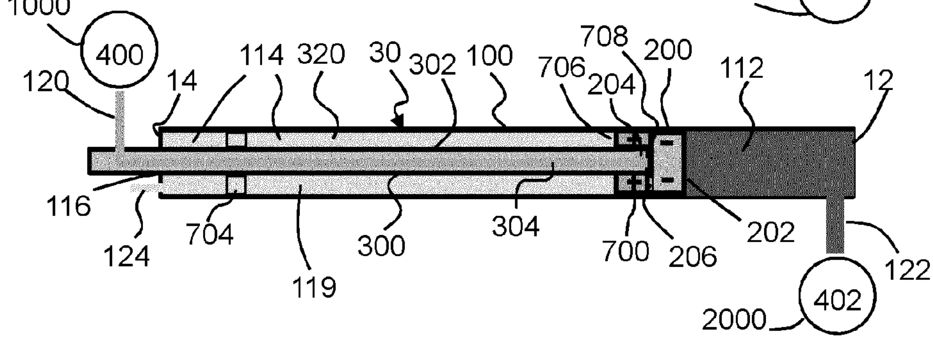

Fig. 14

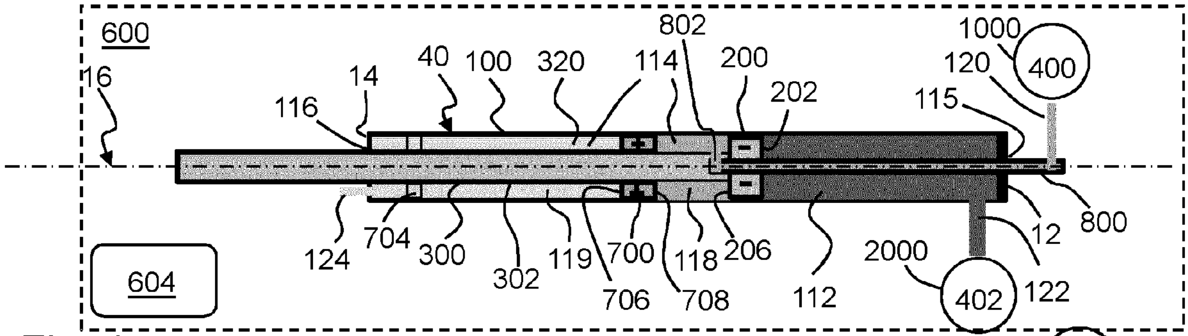

Fig. 15

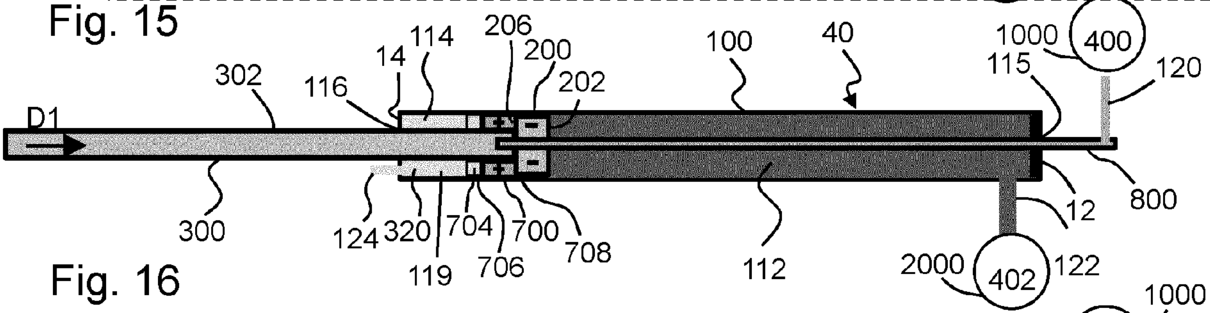

Fig. 16

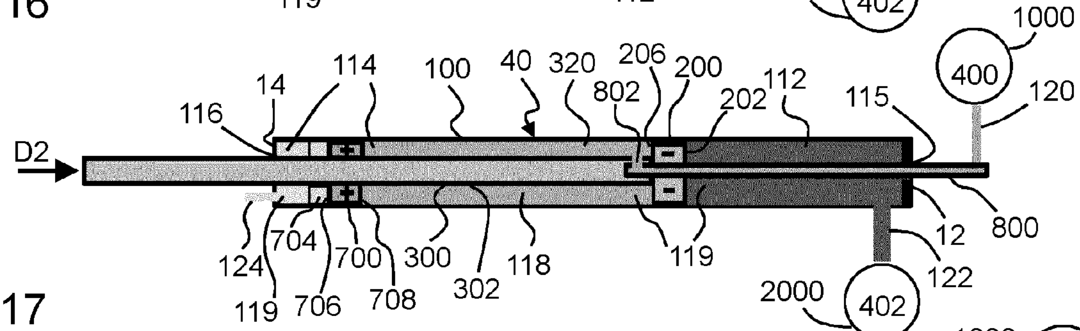

Fig. 17

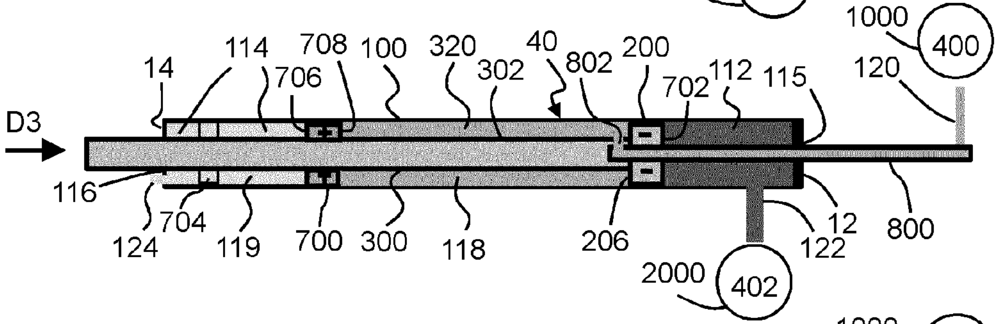

Fig. 18

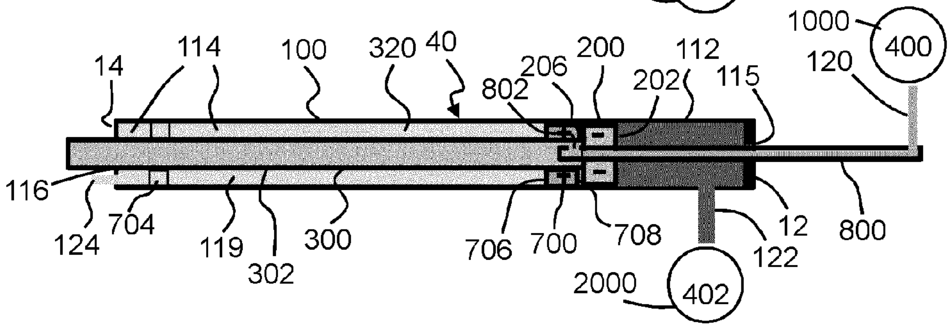

Fig. 19

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 23 27 5025

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	US 10 962 030 B1 (VANDERWEIDE KAREN M [US]) 30 March 2021 (2021-03-30) * claim 1; figures 1-10 *	1,4-12, 15 2,3,13, 14	INV. F41A25/02
A	US 6 227 098 B1 (MASON JAMES D [US]) 8 May 2001 (2001-05-08) * claim 1; figure 4 *	1	
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F41A
F15B
F15D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	25 July 2023	Beaufumé, Cédric

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EPO FORM 1503 03.82 (P04C01)

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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E : earlier patent document, but published on, or after the filing date
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L : document cited for other reasons

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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25-07-2023

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82