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(54) **PORTABLE PUMP**

(57) A portable pump includes a reciprocating air compressor arrangement (410), the air compressor arrangement including: a crank that drives a connecting rod (418) and a piston within a cylinder (416), the connecting rod having a first end and a second end, the first end of the connecting rod connected to the crank and the second end of the connecting rod connected to the piston (414), with the crank provided to actuate the piston in a reciprocating motion within and relative to the cylinder so as to compress air within the cylinder, the reciprocating air compressor arrangement having a one-way inlet valve allowing air to enter the cylinder, and a one-way outlet valve allowing compressed air to exit the cylinder; an electric motor having a drive shaft mounted to the crank, with the drive shaft rotatable about a drive shaft axis, and with the drive shaft axis at least substantially coaxially aligned with an axis of rotation of the crank; a control unit in electrical communication with the electric motor to control operation of the pump; a power supply in electrical communication with the control unit to supply power to the control unit and electric motor; the electric motor, the reciprocating air compressor arrangement, the control unit and the power supply each contained within a common housing (402); and an outlet fluidly connected to the outlet valve (422) of the reciprocating air compressor arrangement for fluidly engaging with an object to be pumped, characterized in that the inlet valve is a one-way flapper inlet valve, and is biased into a partially open position.

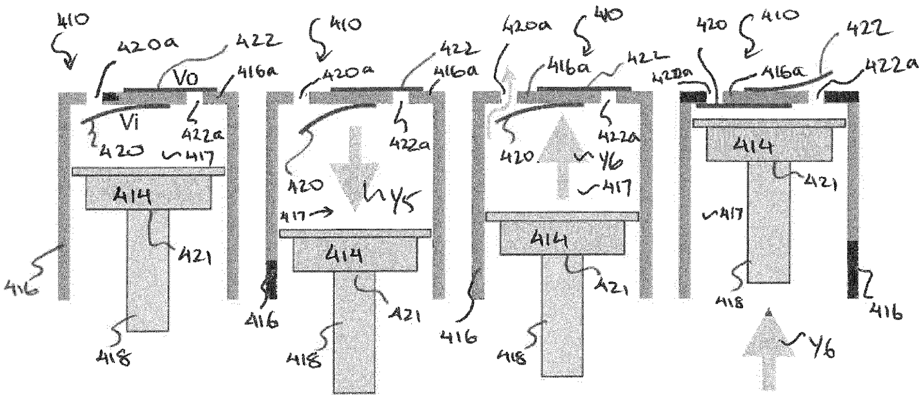

FIG.5a FIG.5b FIG.5c FIG.5c

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Description

Technical Field

[0001] The present invention relates to a reciprocating air compressor arrangement. The invention has particular application in the context of a portable, hand-held pump for filling objects with gases such as air and so will hereinafter generally be described in this context.

[0002] It is to be appreciated, however, that the invention is not limited to portable hand-held pumps. The invention may be applied to a range of air compressor sizes and designs, including those used in commercial, industrial and domestic applications.

Background of Invention

[0003] Pumps used to fill objects to a high pressure typically incorporate a reciprocating air compressor. These types of compressors tend to be large and heavy in size and require an external power supply. This, in turn, makes such pumps difficult to transport and less useful if an external power supply is not readily available.

[0004] The above problems are exacerbated for cyclists who require portability, a pump that is light weight, and one that pumps up tyres quickly. While some cyclists use carbon dioxide canisters (known as CO_2 inflators), these canisters have a number of disadvantages, including the fact that they are intended for only a single use. Another problem is that they become very cold during use and may expose a user to potential burns, particularly on their hands and fingers.

[0005] Other pumping solutions include traditional manual hand pumps, often designed to be releasably mounted to and carried on a bicycle frame. These are light weight but are slow to use, in that they require a relatively large amount of time to inflate a tyre.

[0006] While some portable, battery powered air pumps do exist, they tend to be of a relatively large size, cumbersome, of substantial weight (500 grams, or more), and are designed to be stand-alone. However, due to the recent advances in high discharge lithium batteries, small, high pressure compressors are starting to be realised. The Applicant's commercially successful FUMPA™ bike pump, the subject of foreign patents, and recently allowed US Patent Application 15/750,130, describes a portable pump, whereby a reciprocating air compressor is actuated by a brushless motor via a gear assembly, and is powered by a high discharge lithium battery. The components are all contained within a thermally conductive housing thereby improving the thermal efficiency of the compressor.

[0007] A potential limitation noted by the Applicant in the pump of allowed US Patent Application 15/750,130 is that it is impractical for a cyclist to carry the unit in their cycling jersey pocket, given the relatively large size and the weight of the unit. The relatively large size is mainly due to the use of a bulky gear assembly to drive the compressor via the brushless motor. As the pump is too large to directly engage onto a bicycle tyre's valve, a hose and fitting arrangement is provided to supply compressed air from the unit to the tyre. Further to this, the inflation time of the pump described in allowed US Patent Application 15/750,130 is very sensitive to the compressor's compression ratio. Very high compression ratios are required to reduce the inflation time of a bicycle tyre. The high compression ratios require clearances smaller than 0.2mm between the compressor's piston and the top of the compressor's cylinder when the piston is at top dead centre, and such clearances can only be achieved using expensive CNC machining processes. This adds significant time and cost to manufacturing of the compressor parts, which is undesirable.

[0008] The Applicant's commercially successful miniFUMPA™, the subject of foreign patents, including US Patent 10,837,433, is a more portable pump than their FUMPA™ pump and so has, at least in part, addressed the portability issue of the FUMPA™ pump referred to above. The Applicant's miniFUMPA™ is the smallest electric pump currently available. However, it has a weight of around 200 grams, a pump length of around 75mm, a height of around 70mm (not including the nozzle) and a thickness 30-35mm, making it too big to fit into a pocket, or a small handbag.

[0009] Thus, there is a need for a truly pocket-sized pump, having a weight of around 100 grams, a height of less than around 50mm and a thickness around 25mm. At this weight and dimensions, the pump could be taken on any bicycle journey in a user's pocket or in very small carry bag or handbag. Commuter cyclists would likely find such a pump appealing, as it could be placed in their bag or pocket on their way to work.

[0010] It would therefore be desirable to provide an air compressor arrangement of a very small size, and which can be incorporated into a battery-powered pump. Moreover, it would be desirable to provide a battery-powered pump design that is pocket sized, rechargeable, and can achieve fast pump up times that are less sensitive to the compressor's compression ratio. Finally, it would be desirable to provide a portable battery-powered bike pump that is dimensionally smaller than currently available bike pumps.

[0011] Finally, it would be desirable to provide an air compressor arrangement that at least partially addresses the issue of the compressor motor having to overcome an initially high start-up torque which can easily result in motor and/or circuit burnout; and which may desirably obviate the need for the given air compressor to require an unloader valve, which is a common air compressor failure point.

[0012] Before turning to a summary of the present invention, it is to be appreciated that the discussion of the background to the invention is included to explain the context of the invention. This is not to be taken as an addition that any of the material referred to is published, known or part of the common general knowledge.

[0013] The contents of the applicant's US Patent Application 15/750,130 and US Patent 10,837,433 are herein incorporated by reference.

Summary of the Invention

[0014] According to a broad aspect of the present invention, there is provided a reciprocating air compressor arrangement. The arrangement includes a crank that drives a connecting rod and a piston within a cylinder. The connecting rod has a first end and a second end. The first end of the connecting rod is connected to the crank and the second end of the connecting rod is connected to the piston. The crank is provided to actuate the piston in a reciprocating motion within and relative to the cylinder so as to compress air within the cylinder. The reciprocating air compressor arrangement has a one-way flapper inlet valve allowing air to enter the cylinder, and an outlet valve allowing compressed air to exit the cylinder. The inlet valve is biased to a partially open position and, during use, is movable between the partially open position, a closed position and a fully open position.

[0015] Reference to a 'flapper valve' in this specification is to be considered interchangeable with the term 'reed valve'.

[0016] The outlet valve may be of any suitable one-way valve design. Like the inlet valve, the outlet may be a flapper valve. However, other outlet valve types are also contemplated, including a check valve.

[0017] Preferably, the cylinder includes a cylinder head, and the outlet valve includes an outlet port, with the outlet port extending through the cylinder head to allow for a flow of compressed air to exit the cylinder.

[0018] In one preferred form of the invention, the inlet valve includes an inlet port, with the inlet port extending through the cylinder head to allow for a flow of air to enter the cylinder.

[0019] In another preferred form of the invention, the piston includes a piston head, and the inlet valve includes an inlet port, with the inlet port extending through the piston head to allow for a flow of air to enter the cylinder.

[0020] It is envisaged that the air compressor arrangement is preferably switchable between ON and OFF modes, and the inlet valve remains in the partially open position when the air compressor arrangement is in the OFF mode.

[0021] The reciprocating air compressor arrangement of the present invention has a number of potentially useful applications, especially in the context of a portable pump. In this regard, and according to another broad aspect of the present invention, there is provided a portable pump including a reciprocating air compressor arrangement generally of the type referred to above. The reciprocating air compressor arrangement includes a crank that drives a connecting rod and a piston within a cylinder. The connecting rod has a first end and a second end. The first end of the connecting rod is connected to the crank and the second end of the connecting rod is connected to the piston. The crank is provided to actuate the piston in a reciprocating motion within and relative to the cylinder so as to compress air within the cylinder. The reciprocating air compressor arrangement includes a one-way flapper inlet valve allowing air to enter the cylinder, and an outlet valve allowing compressed air to exit the cylinder. The portable pump further includes an electric motor having a drive shaft mounted to the crank, with the drive shaft rotatable about a drive shaft axis, and with the drive shaft axis at least substantially coaxially aligned with an axis of rotation of the crank. The portable pump further includes a control unit in electrical communication with the electric motor to control operation of the pump; and a power supply in electrical communication with the control unit to supply power to the control unit and electric motor. The electric motor, the reciprocating air compressor arrangement, the control unit and the power supply are each contained within a common housing. An outlet is fluidly connected to the outlet valve of the reciprocating air compressor arrangement for fluidly engaging with an object to be pumped. The inlet valve is biased to a partially open position and, during use, is movable between the partially open position, a closed position and a fully open position.

[0022] The portable pump is preferably switchable between ON and OFF modes, with the inlet valve remaining in the partially open position when the portable pump is in the OFF mode.

[0023] In one preferred embodiment, the power supply of the portable pump is a rechargeable battery having a C rating of at least approximately 20, and capable of providing a maximum current of at least 4 Amps.

[0024] The electric motor of the portable pump is preferably a brushless DC motor having a motor diameter of between approximately 20 and 30mm and, more preferably, approximately 23mm.

[0025] In a preferred form, the pump has a total weight of less than 100 grams, and can pump up at least one bicycle road or commuter bike tyre to approximately 80psi on a single charge.

[0026] The invention has the potential for incorporating a housing of very small dimensions when compared to the housings of existing portable pumps. In this regard, the housing may have a length of between approximately 45 and 65mm, a height of less than approximately 50mm, and a width (or thickness) of approximately 25mm.

[0027] In a preferred form, the pump outlet is provided on or mounted to the housing. The outlet may include a collar extending outwardly from the housing, with the collar including a valve receiving bore for receiving a valve of the object to be pumped.

Brief Description of Drawings

[0028] It will be convenient to hereinafter describe preferred embodiments of the invention with reference to the accompanying figures. The particularity of the figures is to be understood as not limiting the preceding broad description of the invention.

Figure 1 is a schematic side view of a prior art air compressor arrangement.

Figure 2 is a schematic side view of another prior art air compressor arrangement.

Figures 3a to 3c show further schematic side views of a prior art air compressor arrangement similar to that of Figure 1, with Figures 3a to 3c showing an operating sequence of the air compressor arrangement.

Figures 4a to 4c show schematic side views of another prior art air compressor arrangement, with Figures 4a to 4c showing an operating sequence of the air compressor arrangement.

Figures 5a to 5d show schematic side views of an air compressor arrangement according to a first embodiment of the present invention, with Figures 5a to 5d showing an operating sequence of the air compressor arrangement.

Figures 6a to 6d show schematic side views of an air compressor arrangement according to a second embodiment of the present invention, with Figures 6a to 6d showing an operating sequence of the air compressor arrangement.

Figure 7 is an isometric view of a portable pump according to the present invention. Figure 7 also provides a size comparison of the portable pump of the present invention with the applicant's existing FUMPA™ and miniFUMPA™ portable pumps, which are the respective subjects of allowed US Patent Application 15/750,130 and US Patent 10,837,433.

Detailed Description

[0029] As referred to previously, there is growing demand for portable, battery powered bicycle pumps in the cycling industry. Current electric bike pumps are generally large and cumbersome, weighing around 500 grams. These pumps are far too big to mount onto a bicycle or fit in one's pocket. The applicant's miniFUMPA™ pump (the subject of US Patent 10,837,433) is the smallest electric pump currently available. However, it has a weight of around 200 grams, a length of approximately 75mm, a height of approximately 70mm (not including the nozzle) and a thickness (or width) of around 30-35mm. This makes it too big to fit into a pocket, or a small handbag. As stated previously, there is a need for a truly pocket-sized pump, having a weight of around 100 grams, a height of less than 50mm and thickness of around 25mm. At this weight and dimension, the pump could be taken on practically any bicycle journey in a user's pocket or very small carry bag/handbag. Commuter cyclists would find such a pump appealing as it could be placed in their bag or pocket on their way to work.

[0030] To realise such a small pump, all aspects of the pump need to be miniaturised. Electric bike pumps generally consist of a reciprocating air compressor, a motor to drive the air compressor, a battery for use as the power source, control circuitry and enclosure to house all parts. The bulk of the size and weight of a pump comes from the air compressor, motor and battery. Therefore, in order to reduce the size and weight, these three components must be made as small as possible.

[0031] Figure 1 shows the basic design of a prior art reciprocating air compressor 10. The main components are the crank 12, driven by the motor (not shown), which moves the piston 14 up and down within a cylinder 16 via a connecting rod 18. A one-way flapper inlet valve 20 (having an inlet port 20a) brings air into the cylinder 16 when the piston 14 is moving in a downwards direction, whilst a one-way flapper outlet valve 22 (having an outlet port 22a) allows compressed air to be removed from the top 24 of the air compressor 10 when the piston 14 is moving in an upwards direction. The Force (F_c) required to drive the piston 14 up to the top of the cylinder 16 can be estimated as follows:

$$F_c = F_m \cos(\theta_1) \qquad (1)$$

[0032] Where

$$F_m = \frac{\tau}{L_c} \quad (2)$$

[0033] Where τ is the torque the motor can provide.

[0034] Reducing parameters such as cylinder diameter (and therefore piston diameter), or crank size (and therefore length L_c) will reduce the volume of air being compressed, which in turn reduces the compression ratio. This will undesirably result in an increase in pump up time and the maximum pressure the pump can achieve. A certain amount of reduction can be tolerated depending on how long a user can wait for their tyre to be pumped, or what pressure they need. However, too much reduction in these dimensions will result in a pump that is less useful. Further to this, inlet and outlet valves need to be mounted to the air compressor, and these can only be reduced in size within practical limits before their performance is reduced to their detriment.

[0035] One parameter that can be reduced is the length of the connecting rod 18, as shown in the prior art air compressor of Figure 2. Reducing the length of the connecting rod 118 in Figure 2 (compared to the length of the connecting rod 18 in Figure 1) reduces the overall height of the air compressor, whereby L_2 < Li. However, in doing so $\theta_2 > \theta_1$, and so a smaller crank force F_c is generated for the same amount of motor torque.

[0036] This reduction in F_c is detrimental, especially when the designer is attempting to design an air compressor 10/110 that can be driven by the smallest motor possible. Miniature motors (both brushed and brushless) are inefficient in nature, and they generally only achieve high torques when run at maximum speeds. Therefore, on start-up, the available motor torque is a design constraint. For small motors, available motor torque is generally proportional to motor diameter. As motor diameter is one of the main parameters affecting the pump thickness dimension, there are difficulties in trying to provide enough torque to rotate the air compressor 10/110, whilst using a motor of suitable small diameter.

[0037] Larger air compressors overcome this motor torque limitation by obviously selecting a larger sized motor. Further to this, designers will often design a low-pressure volume directly after the outlet valve so that on motor start-up, the air compressor is pumping air into a volume that is essentially at zero-gauge pressure. This is achieved through use of non-return and/or exhaust valves. Due to size constraints however, such a design is not achievable on a miniature air compressor.

[0038] Figures 3a to 3c illustrate an operating sequence of prior art air compressor 210. Air compressor 210 is very similar to air compressor 10 shown in Figure 1. Figure 3a shows the air compressor 210 in its at-rest position. It can be seen that in the at-rest position the one-way flapper inlet valve 220 (having an inlet port 220a) and the one-way flapper (or reed) outlet valve 222 (having an outlet port 222a) are both biased into their respective closed positions. As shown in Figure 3b, when the piston 214 moves in a downwards direction Y1 within the cylinder 216 the negative air pressure temporarily created within the cylinder chamber 217 causes the inlet valve 220 to open, thereby allowing the inflow of air into the chamber 217. The inlet valve 220 closes once the piston 214 reaches its lowermost position within the cylinder 216. When the piston 214 moves in an upwardly direction Y2 (see Figure 3c) within the cylinder 216, the inlet valve 220 remains temporarily closed, but the increasing pressure within the chamber causes the outlet valve 222 to open, through which compressed air is expelled from within the chamber 217.

[0039] Figures 4a to 4c illustrate an operating sequence of prior art air compressor 310. The operation of air compressor 310 is similar to that of air compressor 210 shown in Figures 3a to 3c. However, one fundamental difference between air compressors 210 and 310 is that the inlet valve 220 of air compressor 210 is mounted in the cylinder head 216a, whereas the inlet valve 320 of air compressor 310 is mounted within the piston head 314a.

[0040] It can be seen in Figure 4a that in the at-rest position the one-way flapper inlet valve 320 and the one-way flapper outlet valve 322 are biased into their respective closed positions. As shown in Figure 4b, when the piston 314 moves in a downwards direction Y3 within the cylinder 316 the negative air pressure temporarily created within the cylinder chamber 317 causes the inlet valve 320 to open, thereby allowing the inflow of air into the chamber 317. The inlet valve 320 closes once the piston 314 reaches its lowermost position within the cylinder 316. When the piston 314 moves in an upwardly direction Y4 (see Figure 4c) within the cylinder 316, the inlet valve 320 remains temporarily closed, but the increasing pressure within the chamber causes the outlet valve 322 to open, through which compressed air is expelled from within the chamber 317.

[0041] Reciprocating air compressors 210/310 of the type shown in Figures 3a to 3c and 4a to 4c generally rely on reed (or flapper) one-way valves to let air into and out of the cylinder. These valves are usually manufactured from high fatigue strength thin steel material. They are generally cantilevered, flat in shape and move up and down depending in the pressure differential they experience on each of their surfaces.

[0042] If an air compressor like the one shown in Figures 3a to 3c (or that shown in Figures 4a to 4c) is connected to a bicycle tyre that is already at a high pressure (50psi for example), then on motor start-up, a significant motor torque might be required to turn the crank from a stationary position and to open the outlet valve 222. Further to this, as reed valves are simple structures that often do not have the luxury of a high-quality seals, the outlet valve 222 can leak, causing pressure inside the cylinder 216 to be equal to the pressure inside the tyre. This results in very high start-up torques being needed to start the compression process. If the motor cannot provide the torque, the motor stalls and can result in motor and/or circuit burnout.

[0043] To overcome this issue, the applicant has found that this increase in motor torque requirement can be offset by changing the shape of the inlet valve 220 to that shown in Figures 5a to 5d (and that shown in Figures 6a to 6d).

[0044] One embodiment of the invention is now shown in Figures 5a to 5d, wherein a reciprocating air compressor arrangement 410 of a portable bike pump 400 (see Figure 7) according to one embodiment of the present invention is illustrated.

[0045] The arrangement 410 includes a crank (not shown) that drives a connecting rod 418 and a piston 414 within a cylinder 416. The connecting rod 418 has a first end (not shown) and a second end 421. The first end of the connecting rod 418 is connected to the crank and the second end 421 of the connecting rod 418 is connected to the piston 414. The crank is provided to actuate the piston 414 in a reciprocating motion within and relative to the cylinder 416, so as to compress air within the cylinder 416. The arrangement 410 has a one-way flapper inlet valve 420 with an inlet port 420a allowing air to enter the cylinder 416, and a one-way flapper outlet valve 422 (with an outlet port 422a) allowing compressed air to exit the cylinder 416. It is to be appreciated that, if desired, the outlet valve 422 need not be a flapper valve. For example, the outlet valve could be a check valve. Figure 5a shows the arrangement at rest, whereby the piston 414 is stationary within the cylinder 416. It is important to appreciate from Figure 5a that the inlet valve 420 is biased into a partially open position when the arrangement 410 is at rest. The fact that the inlet valve 420 is partially open when the arrangement 410 is at rest is considered unique to the present bike pump; and is also considered unique to the applicant's inventive air compressor arrangements.

[0046] The inlet valve 420 is, during use, movable between the partially open position shown in Figures 5a and 5c, the closed position shown in Figure 5d, and the fully open position shown in Figure 5b.

[0047] The outlet valve 422 is movable between the closed positions shown in Figures 5a to 5c, and the open position shown in Figure 5d.

[0048] Figure 5a shows the air compressor 410 in its at-rest position, with the one-way flapper inlet valve 420 in a partially open position, and the one-way flapper outlet valve 422 in a closed position. As shown in Figure 5b, when the piston 414 moves in a downwards direction Y5 within the cylinder 416 the negative air pressure temporarily created within the cylinder chamber 417 causes the inlet valve 420 to further open, thereby further allowing the inflow of air into the chamber 417. The outlet valve 422 remains in its closed position. The inlet valve 420 returns to its partially open position when the piston commences moving in the upwards direction Y6 shown in Figure 5c, whereby a small amount of air can still escape through the inlet port 422a. However, when the piston 414 approaches its uppermost position in the cylinder shown in Figure 5d, sufficient air pressure within the cylinder 416 is created to fully close the inlet valve 420, and also open outlet valve to allow pressurised air to exit through outlet port 422a.

[0049] From the above comments, it is to be understood that the shape of the inlet valve 420 is designed so that it is encouraged to leak, which is counter the design of conventional valves. This is achieved by manufacturing the inlet valve 420 with a curve so that it sits open in its at-rest state. When the motor is stationary (and the piston 414 is therefore stationary) air inside the cylinder 416 is maintained at zero-gauge pressure. Even if the outlet valve 422 is leaking when engaged onto a bicycle tyre, the curve in the inlet valve 420 ensures air can escape from the cylinder 416 to the atmosphere.

[0050] On motor start-up, if the piston 414 is moving in the downward direction, the inlet valve 420 will further open to ensure air is entering the cylinder 416. Once the piston 414 moves upwards (as shown in Figure 5c) air will initially leak through the inlet valve 420. This greatly reduces the torque requirements on the motor to turn the crank. Once the motor gets to its top running speed (and therefore able to provide its highest level of torque), the applicant has found that the inlet valve 420 would close fully when the piston 414 was moving in an upward position (shown in Figure 5d), desirably resulting in adequate air compression during the reciprocating process.

[0051] The applicant has found that utilising curved inlet valves allowed brushless out-runner motors as small as 23mm in diameter to power 14mm diameter air compressor pistons/cylinders. The applicant did find a trade-off, however. A curved inlet valve 420 resulted in a reduction in maximum achievable pressure. For small volume tyres (for example, road bicycle tyres, 700x23c, approximately 800ml in volume), a pressure of only about 80-90 psi is achievable; while for larger commuter bike tyres (700x28c up to 700x35c tyres) a pressure of about 70-80psi is achievable. These pressures are less than what is achievable with traditional flat reed valve designs (120psi and greater). However, as commuter bicycle tyres only require pressures of up to 80psi, this method to reduce the required motor torque is a plausible solution.

[0052] One of the other constraints of a pocket-sized pump is the size of the battery. Motor driven air compressors require large currents, and so high discharge lithium polymer batteries are commonly used to supply power. However, there is a limit to the amount of current that can be drawn from a battery. The battery must be able to handle the high currents required to drive the compressor, without affecting is performance, or worse, being damaged due to excessive current draw.

[0053] The rate (C) at which a battery can be safely discharged is dependent on both the maximum discharge current (I) that the battery experiences, and the battery's capacity (p). These three variables are related as follows:

$$I = \rho C$$

[0054] Battery sizes of similar dimension to miniature motors (23mm) can be manufactured with a C rating of approximately 20C. This is less than the current design requirements of the pump the subject of US Patent 10,837,433. For high discharge lithium batteries currently available in sizes close to the diameter of the motor requirements of a miniature pump, 200-300mAh batteries are an option. Therefore, from the equation above, a maximum current of only 4-6 Amps of current is available from such small batteries.

[0055] The applicant has found that if a flat inlet valve (such as of the prior art types illustrated in Figures 1 to 4c) is used, it was almost impossible to achieve tyre pressures greater than 50psi without motor stall occurring. Further to this, currents exceeding 6 Amps were common. However, using a curved inlet valve resulted in tyre pressures exceeding 80psi and currents of less than 5 amps were possible. The provision of a curved inlet valve ensured pressures were achievable whilst ensuring batteries were not being damaged due to excessive current draw.

[0056] Figures 6a to 6d illustrate an operating sequence of an air compressor arrangement 510 according to another embodiment of the present invention. The operation of air compressor arrangement 510 is similar to that of air compressor arrangement 410 shown in Figures 5a to 5d. One fundamental difference between air compressor arrangements 410 and 510 is that the inlet valve 420 of air compressor arrangement 410 is mounted in the cylinder head 416a, whereas the inlet valve 520 of air compressor arrangement 510 is mounted within the piston head 514a. In other respects, air compressor arrangements 410 and 510 are the same.

[0057] Figure 7 shows an embodiment of micro bicycle tyre pump 400 according to an embodiment of the present invention in isometric view.

[0058] Advantageously, the pump 400 is extremely light weight, with a total weight of less than 100 grams. The pump 400 is capable of pumping up at least one bicycle road or commuter bike tyre to approximately 80psi on a single charge.

[0059] The pump 400 includes a novel reciprocating air compressor arrangement generally of the type previously described.

[0060] The pump 400 includes a housing 402. Within the housing 400 (and therefore not clearly shown) there is provided a power supply in the form of a high discharge lithium battery, and an electric motor having a drive shaft that connects directly to the reciprocating air compressor arrangement. In this regard, the drive shaft is rigidly mounted to the crank, with the rotation axes of the drive shaft and the crank aligned.

[0061] The electric motor is in the form of a brushless DC motor having a motor diameter of between approximately 20 and 30mm and, more preferably, approximately 23mm.

[0062] Although not shown in Figure 7, the housing of pump 400 includes a charge port. The charge port allows the use of an external charger to charge the pump's internal battery.

[0063] The pump 400 includes a compressed air outlet 404 for engagement with a bicycle tyre valve (not shown). The outlet 404 is fluidly connected to the outlet valve of the reciprocating air compressor arrangement. The outlet 404 is mounted on or to the housing 402, and includes a valve receiving bore 406 for receiving a valve of the tyre (or other object) to be pumped. As the pump 400 is so small, it easily fits between the spokes of a bicycle wheel without use of a hose extending between the outlet 404 and the tyre valve.

[0064] The pump 400 further includes a control unit in electrical communication with the electric motor to control operation of the pump and the power supply. The control unit may be a printed circuit board that consists of control circuitry that turns the motor ON and OFF via a switch and monitors the battery's voltage.

[0065] In operation, the portable pump 400 is turned on by a user via switch 408. Once turned on, the electric motor starts running which, in turn, rotates the drive shaft. The rotating drive shaft turns/rotates the crank, causing the connecting rod and piston to reciprocate axially within the cylinder. One-way flapper inlet and outlet valves of the air compressor arrangement ensure that air is compressed inside the cylinder and forced through the outlet 404. This process is carried out many times a second as the piston axially reciprocates within the cylinder. The unique design of the inlet valve, whereby it is biased into a partially open position (including when the pump is initially turned ON), desirably avoids the need for the motor to overcome an initially high start-up torque which can easily result in motor and/or circuit burnout.

[0066] Advantageously, the design of the portable pump 400 allows it to be manufactured small enough so that it can be mounted directly onto a tyre valve. Indeed, the pump 400 can be considered to be of a micro size when compared to existing pump designs, including the applicant's pumps the subjects of US Patent 10,837,433 and US Patent Application 15/750,130. This means that no additional hose or fittings are required to transfer the compressed air to the tyre, as the pump can fit between most conventional 700mm diameter bicycle wheel spoke configurations and directly onto the tyre valve, thereby further reducing the size and weight of the pump 400. The pump 400 is manufactured without a gearbox or outlet hose, and so this enables the pump 400 to be of a very small size when compared to existing pump designs. The pump 400 has a length only in the order of approximately 45 to 65mm, a height of less than approximately 50mm and a width (or thickness) of approximately 25mm. These small dimensions allow the pump to fit easily into a cyclist's jersey pocket or small handbag.

[0067] Figure 7 is useful in that it provides size comparisons between the applicant's new pump 400, and their existing (and market leading) pumps 500, 600, the subjects of US Patent 10,837,433 and allowed US Patent Application 15/750,130, respectively. It is important to appreciate that the smaller dimensions of their latest pump 400 compared to their existing pumps 500, 600 hasn't been achieved simply by miniaturising components of the pumps 500, 600 such that they fit into the smaller housing 402 of pump 400. Instead, the smaller size of pump 400 was the result of considerable re-design and invention by the applicant and, in particular, the complete re-design of the inlet valve of the air compressor arrangement.

[0068] Finally, it is to be appreciated that the applicant's unique inlet valve design could conceivably be applied to any conventional air compressor arrangement. This, in turn, may desirably obviate the need for a given air compressor arrangement to require an unloader valve, which is a common failure point.

[0069] It is to be understood that various alterations, modifications and/or additions may be introduced into the construction and arrangement of the parts previously described without departing from the spirit or ambit of this invention.

Claims

1. A portable pump including:

   a reciprocating air compressor arrangement, the air compressor arrangement including: a crank that drives a connecting rod and a piston within a cylinder, the connecting rod having a first end and a second end, the first end of the connecting rod connected to the crank and the second end of the connecting rod connected to the piston, with the crank provided to actuate the piston in a reciprocating motion within and relative to the cylinder so as to compress air within the cylinder, the reciprocating air compressor arrangement having a one-way inlet valve allowing air to enter the cylinder, and a one-way outlet valve allowing compressed air to exit the cylinder;
   an electric motor having a drive shaft mounted to the crank, with the drive shaft rotatable about a drive shaft axis, and with the drive shaft axis at least substantially coaxially aligned with an axis of rotation of the crank;
   a control unit in electrical communication with the electric motor to control operation of the pump;
   a power supply in electrical communication with the control unit to supply power to the control unit and electric motor;
   the electric motor, the reciprocating air compressor arrangement, the control unit and the power supply each contained within a common housing; and
   an outlet fluidly connected to the outlet valve of the reciprocating air compressor arrangement for fluidly engaging with an object to be pumped,
   characterized in that the inlet valve is a one-way flapper inlet valve, and is biased into a partially open position.

2. A portable pump according to claim 1, **characterized in that** the cylinder includes a cylinder head, and the outlet valve includes an outlet port, with the outlet port extending through the cylinder head to allow for a flow of compressed air to exit the cylinder.

3. A portable pump according to claim 1 or 2, **characterized in that** the inlet valve includes an inlet port, with the inlet port extending through the cylinder head to allow for a flow of air to enter the cylinder.

4. A portable pump according to claim 1 or 2, **characterized in that** the piston includes a piston head, and the inlet valve includes an inlet port, with the inlet port extending through the piston head to allow for a flow of air to enter the cylinder.

5. A portable pump according to any one of the preceding claims, **characterized in that**, during operation of the portable pump, the inlet valve is movable between the partially open position, a fully open position and a closed position.

6. A portable pump according to claim 5, **characterized in that** the portable pump is switchable between ON and OFF modes, and the inlet valve remains in the partially open position when the portable pump is in the OFF mode.

7. A portable pump according to any one of the preceding claims, **characterized in that** the power supply is a rechargeable battery having a C rating of at least approximately 20, and capable of providing a maximum current of at least 4 Amps.

8. A portable pump according to any one of the preceding claims, **characterized in that** the electric motor is a brushless

DC motor having a motor diameter of between approximately 20 and 30mm, and preferably approximately 23mm.

9. A portable pump according to any one of the preceding claims, **characterized in that** the pump has a total weight of less than 100 grams, and can pump up at least one bicycle road or commuter bike tyre to approximately 80psi on a single charge.

10. A portable pump according to any one of the preceding claims, **characterized in that** the housing has a length of between approximately 45 and 65mm, a height of less than approximately 50mm, and a width (or thickness) of approximately 25mm.

11. A portable pump according to any one of the preceding claims, **characterized in that** the outlet is provided on or mounted to the housing.

12. A portable pump according to claim 11, **characterized in that** the outlet includes a collar extending outwardly from the housing, the collar including a valve receiving bore for receiving a valve of the object to be pumped.

13. A portable pump according to any one of claims 1 to 12, **characterized in that** the outlet valve is a flapper valve or a check valve.

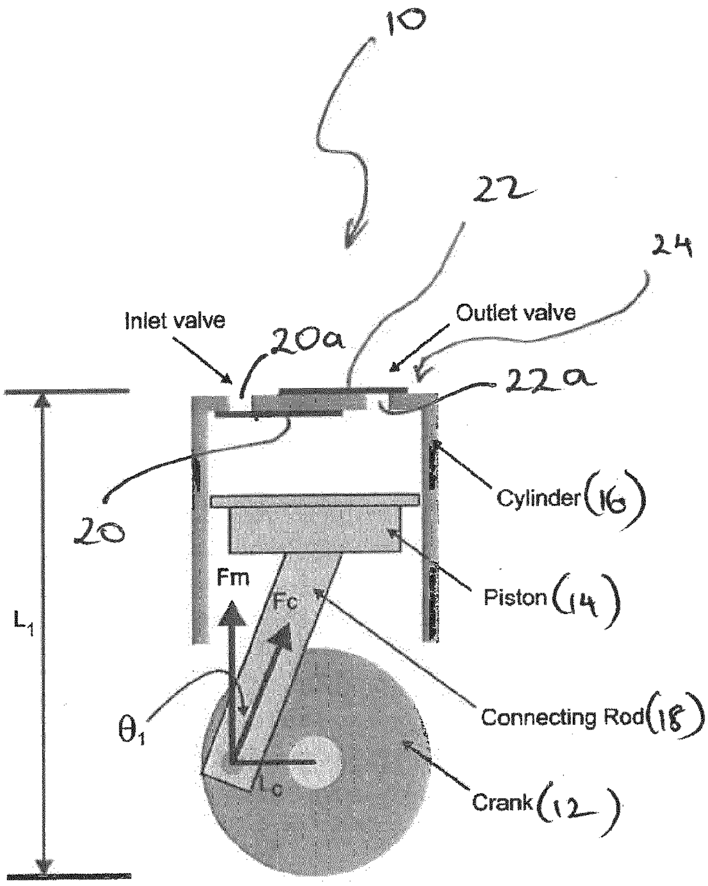
10
22
24
Inlet valve
20a
Outlet valve
22a
20
Cylinder(16)
Piston(14)
Fm
Fc
L1
θ1
Connecting Rod(18)
Lc
Crank(12)

FIG. 1

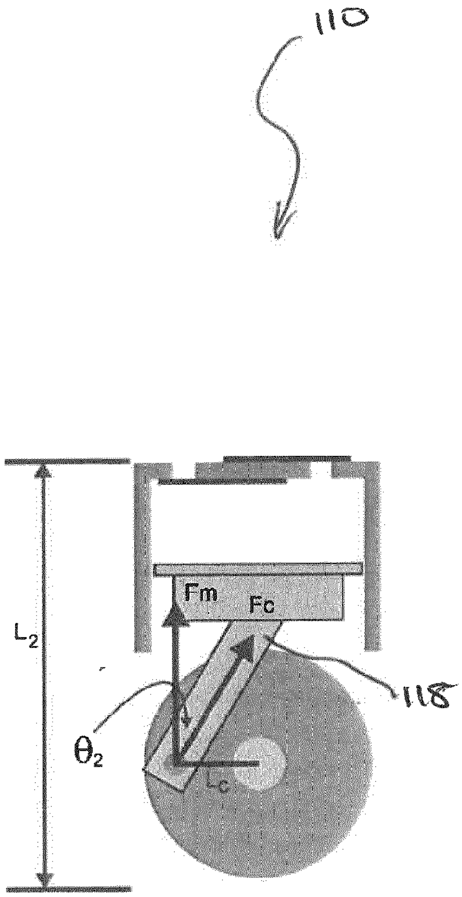
110
L2
Fm
Fc
118
θ2
Lc

FIG. 2

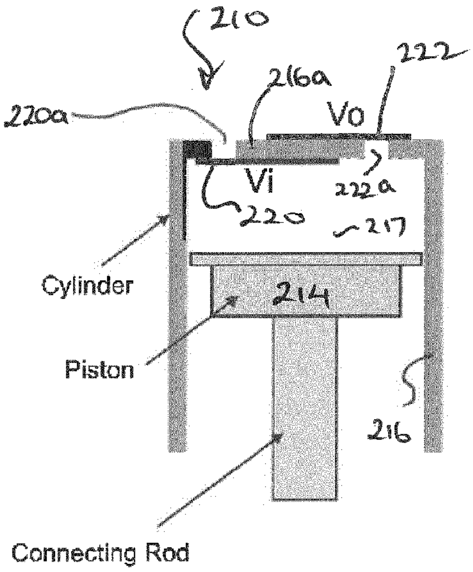

FIG 3a

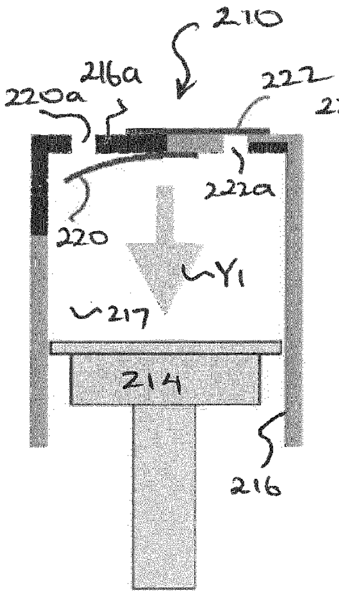

FIG. 3b

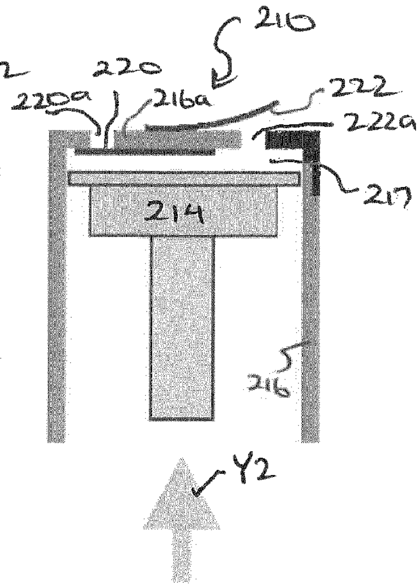

FIG. 3c

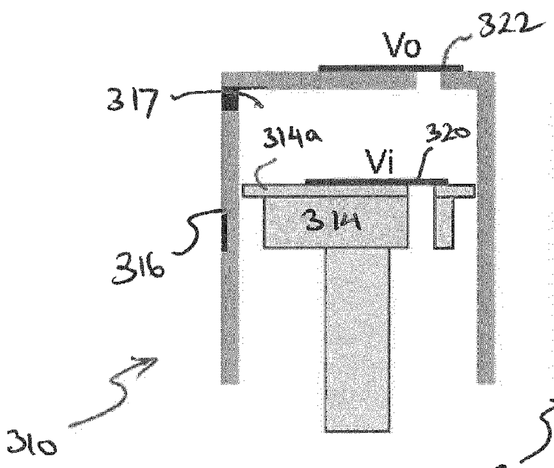

FIG. 4a

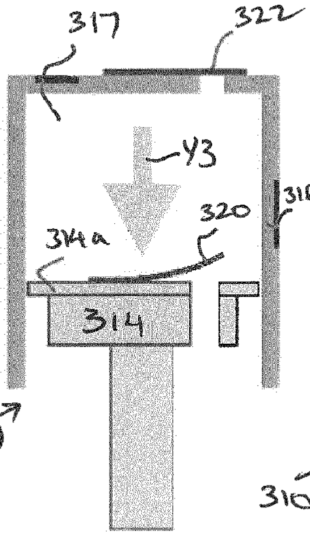

FIG. 4b

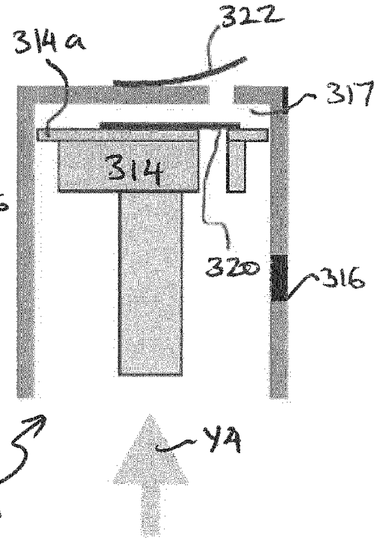

FIG. 4C

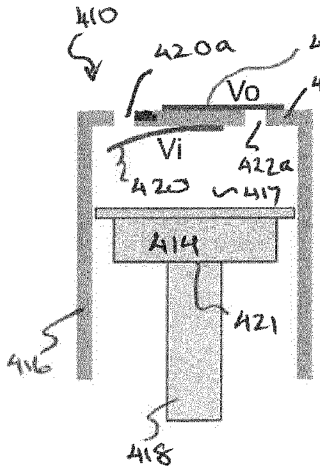

FIG.5a

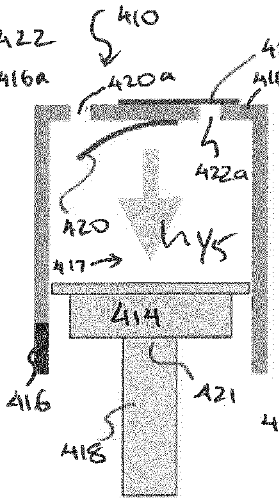

FIG.5b

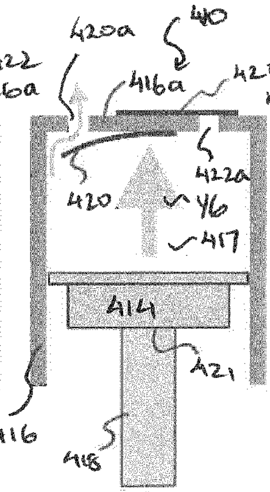

FIG.5c

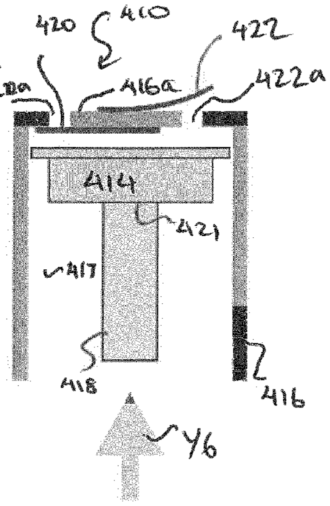

FIG.5c

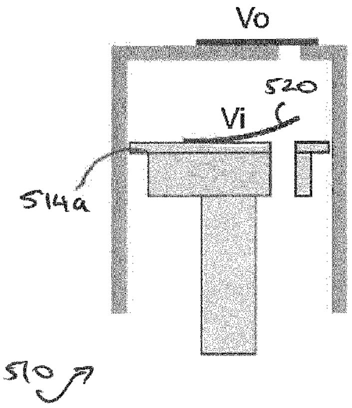

FIG. 6a

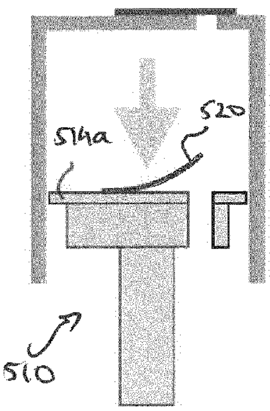

FIG. 6b

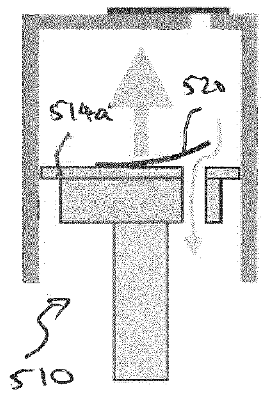

FIG. 6c

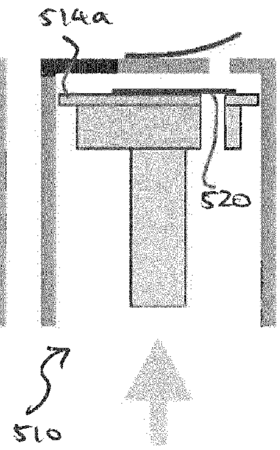

FIG. 6d

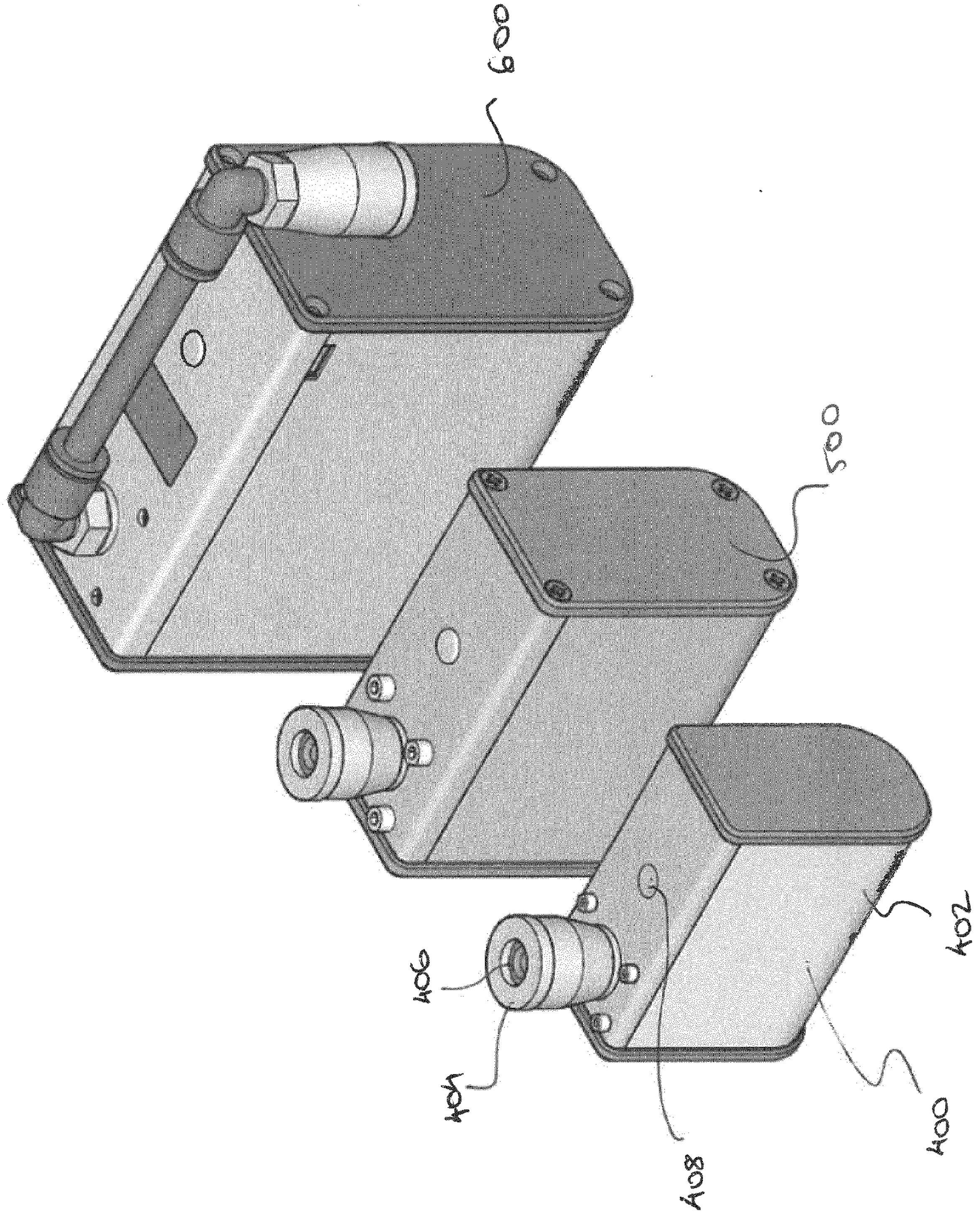

FIG. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 22 17 2008

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	US 3 776 666 A (LUDWIG P) 4 December 1973 (1973-12-04) * the whole document * -----	1-13	INV. F04B35/06 F04B39/10 F04B39/00
Y	JP 6 442168 B2 (HITACHI APPLIANCES INC) 19 December 2018 (2018-12-19) * paragraph [0020] * * figures 1-13 * -----	1-13	
Y A	JP 2000 320458 A (KOFU MEIDENSHA KK) 21 November 2000 (2000-11-21) * the whole document * -----	4,13 1-3,5-12	
A,D	US 10 837 433 B2 (WALMSLEY DEV PTY LTD [AU]) 17 November 2020 (2020-11-17) * the whole document * -----	1-13	
A	US 9 931 654 B2 (WEST SCOTT ALLEN [US]; WEST JASON GUST [US]) 3 April 2018 (2018-04-03) * the whole document * -----	1-13	TECHNICAL FIELDS SEARCHED (IPC)
A	US 9 291 056 B2 (L LIVERMORE NAT SECURITY LLC [US]) 22 March 2016 (2016-03-22) * column 25, line 4 - line 19 * * figure 24 * -----	1-13	F04B
A	US 2006/083628 A1 (KANAI HIROSHI [JP] ET AL) 20 April 2006 (2006-04-20) * paragraph [0048] * * figures 2-13 * -----	1-13	
A	EP 3 431 759 B1 (HITACHI INDUSTRY EQUIPMENT SYSTEMS CO LTD [JP]) 30 December 2020 (2020-12-30) * paragraphs [0055] - [0061] * * figure 5 * -----	1-13	

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	20 September 2022	Lange, Christian

CATEGORY OF CITED DOCUMENTS

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EP 22 17 2008

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20-09-2022

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 3776666	A	04-12-1973	NONE		
JP 6442168	B2	19-12-2018	JP 6442168	B2	19-12-2018
			JP 2016003635	A	12-01-2016
JP 2000320458	A	21-11-2000	NONE		
US 10837433	B2	17-11-2020	EP 3418567	A1	26-12-2018
			ES 2784976	T3	02-10-2020
			US 2018372079	A1	27-12-2018
US 9931654	B2	03-04-2018	NONE		
US 9291056	B2	22-03-2016	US 2014318363	A1	30-10-2014
			WO 2015153488	A1	08-10-2015
US 2006083628	A1	20-04-2006	EP 1586774	A1	19-10-2005
			JP WO2004061306	A1	11-05-2006
			US 2006083628	A1	20-04-2006
			WO 2004061306	A1	22-07-2004
EP 3431759	B1	30-12-2020	CN 109281821	A	29-01-2019
			EP 3431759	A1	23-01-2019
			JP 2019019766	A	07-02-2019
			US 2019024652	A1	24-01-2019

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Patent documents cited in the description

- US 750130 **[0006] [0007] [0013] [0028] [0066] [0067]**
- US 10837433 B **[0008] [0013] [0028] [0029] [0054] [0066] [0067]**