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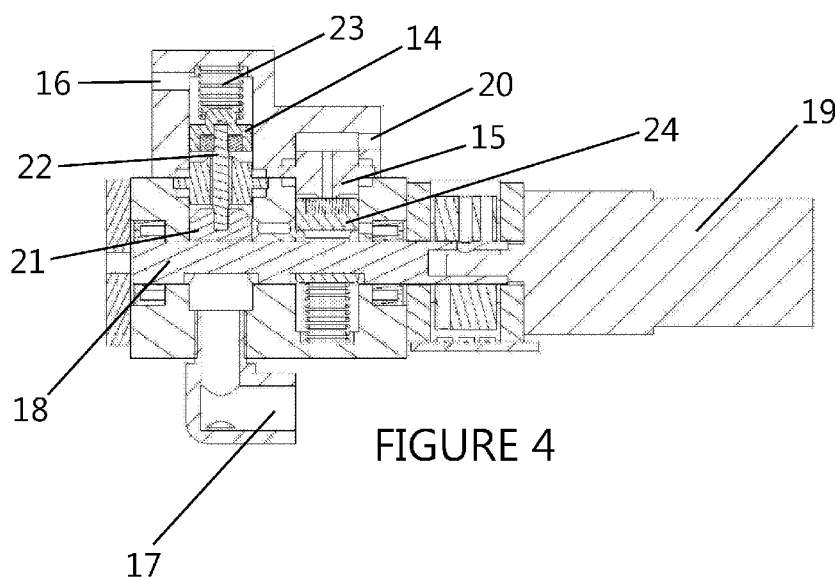


FIGURE 4

(57) Abstract: A device for filling a small portable pressure vessel from a larger pressure vessel with a compressed fluid such as carbon dioxide. The device comprises an inlet adapted to receive fluid from a pressurized source, and an outlet adapted to connect to a pressure vessel. Between the inlet and the outlet there is a fill valve and a vent valve and at least one cam shaft configured to rotate and operate the valves.



Automated Gas Canister filler

FIELD OF THE INVENTION

The present invention relates to an apparatus and method of filling a smaller pressurized gas vessel from a larger pressurized gas source. More particularly, the larger pressurized gases source is preferably a pressurized gas vessel. More particularly still, the method and apparatus are semi autonomous and/or easily portable.

BACKGROUND TO THE INVENTION

Pneumatic power systems are used in a variety of applications, and particularly with regard to tools. Traditionally, pneumatic tools have been designed to be connected to a source of compressed air, such as a stationary air compressor. More recently, portable pressure sources have been developed by which a small vessel containing a pressurised fluid, such as carbon dioxide, may be connected via a regulator to a tool. These systems allow the tools to be used in a more portable fashion without being restricted by the long hosing requirements of conventional set ups.

In this type of portable device, the mass of fluid stored in the vessel in order to power the device must be sufficient for a practical number of operations, but not so large that portability suffers unduly. As a result, it may be necessary to change the portable canisters, or re-fill them relatively often.

Other examples of pneumatic devices (generally referred to as a “motion transfer devices”) may be a hammer drill, jack hammer, grinder, nail gun or paintball gun, or any other device known to be driven pneumatically.

For these portable pneumatic applications, preferably, the driving fluid is carbon dioxide, which is inexpensive and non flammable. Further, carbon dioxide may be stored in the liquid phase at attainable pressure, thereby allowing for a larger mass to be stored within a limited space. In cases where carbon dioxide is used, this means that at room temperature, the vessel will preferably contain both liquid and gaseous carbon dioxide, (at a pressure of typically 750 psi or thereabouts for example).

It should be appreciated that the driving fluid may not be carbon dioxide. The driving fluid could be any other fluid with properties suited to the particular application. However, due to potential venting of the apparatus to atmosphere, it is highly preferred that the driving fluid is non-flammable.

- 5 Traditionally, there are two types of filling systems for filling a small portable pressure vessel with a fluid like carbon dioxide for example. Firstly, there are large scale filling plants that invariably use a high pressure pump to force the carbon dioxide into the portable pressure vessel (while maintaining a safe vapour space above the liquefied CO₂ in the small canister). These systems are typically closed, and do
10 not allow any gas to escape to the atmosphere.

The second type of system is typically used on a smaller scale, where the portable canisters are filled onsite for example. In these situations, a larger pressurised CO₂ bottle is used to fill smaller portable pressure vessels. In this type of setup, the filling is done entirely manually by opening and closing the respective bottle valves until the
15 desired weight of the portable canister is achieved. The driving force to transfer the CO₂ comes from the pressure differential and not a pump.

A manual filling system while simple, requires the user to know what they are doing in order to avoid large wastage, and/or dangerous overfill conditions as well as achieving sufficient fill weight.

- 20 The present method and apparatus provides a semi-autonomous system that is small and portable and goes at least some way to mitigating one or more of the above problems or at least provides a useful choice.

In this specification where reference has been made to patent specifications, other external documents, or other sources of information, this is generally for the purpose of
25 providing a context for discussing the features of the invention. Unless specifically stated otherwise, reference to such external documents is not to be construed as an admission that such documents, or such sources of information, in any jurisdiction, are prior art, or form part of the common general knowledge in the art.

SUMMARY OF THE INVENTION

In one aspect, the present invention broadly consists in a filling apparatus for filling a pressure vessel with fluid comprising:

- 5 an inlet adapted to receive fluid from a pressurized source,
- an outlet adapted to connect to a pressure vessel, and a fluid pathway between said inlet and said outlet,
- a fill valve located in said path between said inlet and said outlet,
- a vent valve located in said path between said fill valve and said outlet,
- 10 at least one cam shaft configured to rotate and operate said fill valve and said vent valve.

According to another aspect rotation of said at least one cam shaft causes opening and closing of the respective fill valve and/or vent valve, but forces from the valves acting
15 on the cam shaft cannot rotate the cam shaft due to high gearing.

According to another aspect said fill valve and said vent valve are operated by the same cam shaft.

20 According to another aspect said cam shaft at least one cam shaft includes cam surfaces configured to operate said fill valve and said vent valve respectively, and said shaft has at least the following angular positions with corresponding valve conditions:

- i) a filling position with the fill valve open and vent valve closed,
- ii) a venting position with the fill valve closed and the vent valve open.

25

According to another aspect said shaft has at least the following additional angular positions with corresponding valve conditions:

- iii) a filling stop position with the fill valve closed and the vent valve closed,
- said filling stop position located between said filling position and said venting
30 position.

According to another aspect said shaft includes two angular positions corresponding with a filling stop position with the fill valve closed and the vent valve closed.

According to another aspect each said angular position is located 90 degrees from the last.

- 5 According to another aspect said cam shaft is coupled to (directly or indirectly), and rotated by, an electric motor.

According to another aspect said apparatus further comprises:

- 10 a weighing arm displaceable under the weight of said pressure vessel and a sensor configured to output a weight signal indicative of the weight of said pressure vessel acting on said arm.

According to another aspect said apparatus further comprises:

- 15 a controller operationally coupled to said motor and adapted to receive said signal from said sensor.

According to another aspect said pressure vessel is flexibly suspended from said weighing arm.

- 20 According to another aspect said pressure vessel is flexibly suspended from said weighing arm by a flexible fill hose.

According to another aspect said controller includes an **initial vent cycle** wherein:

- 25 the controller causes the motor to move the cam shaft to a venting position with the fill valve closed and the vent valve open, and

the controller monitors said weight signal over time, and

if a change in said weight signal indicates the rate of change of weight is below a first predetermined threshold, said controller causes the motor to move the cam shaft to close said vent valve and initiate a filling cycle.

30

According to another aspect said first predetermined threshold is between 0.001 and 10.0 g/sec.

According to another aspect said first predetermined threshold is between 0.05 and 5.0g/sec.

5 According to another aspect during said initial vent cycle the controller causes the motor to move the cam shaft to close said vent valve and outputs an error signal, if said first predetermined threshold is not reached before a second predetermined threshold.

According to another aspect said controller does not allow the fill valve to be opened, unless a predetermined reset criteria is met.

10

According to another aspect said reset criteria requires a user to remove the pressure vessel from the filling apparatus.

According to another aspect said second predetermined threshold is a time limit.

15

According to another aspect said second predetermined threshold is dependent on an indicated size of the pressure vessel.

According to another aspect said time limit is approximately 30 seconds.

20

According to another aspect said second threshold is a predetermined decrease in weight of the pressure vessel.

25 According to another aspect said second predetermined threshold is dependent on an indicated size of the pressure vessel.

According to another aspect said second threshold is between 10% and 30% of the pressure vessel fill weight.

30 According to another aspect said controller includes a **fill cycle** wherein:

the controller causes the motor to move the cam shaft to a fill position with the fill valve open and the vent valve closed, and

the controller monitors said weight signal over time, and

if a change in said weight signal indicates the rate of change of weight is below a third predetermined threshold, said controller causes the motor to move the cam shaft to close said fill valve and initiate a pressure venting cycle.

- 5 According to another aspect said third predetermined threshold is between 0.1 and 10g/sec.

According to another aspect said third predetermined threshold is between 0.5 and 5.0g/sec.

10

According to another aspect during said pressure vent cycle the controller causes the motor to move the cam shaft to open said vent valve, until a fourth predetermined threshold criteria is met.

- 15 According to another aspect said fourth predetermined threshold is a time limit.

According to another aspect said fourth predetermined threshold is dependent on an indicated size of the pressure vessel.

- 20 According to another aspect said time limit is approximately 30 seconds.

According to another aspect said fourth threshold is a predetermined decrease in weight of the pressure vessel.

- 25 According to another aspect said fourth predetermined threshold is dependent on an indicated size of the pressure vessel.

According to another aspect said fourth threshold is between approximately 2% and 5% of the vessel fill weight.

30

According to another aspect said controller causes the motor to move the cam shaft to said fill position with the fill valve open and the vent valve closed, after said fourth threshold is reached.

According to another aspect said controller causes said apparatus to execute a plurality of vent then fill cycles while the pressure vessel weight remains below a predetermined fill weight.

5

According to another aspect said controller causes the motor to move the cam shaft to close said fill valve, open said vent valve, and outputs an error signal, if the pressure vessel weight remains below a said predetermined fill weight after a predetermined number of fill then vent cycles.

10

According to another aspect said predetermined number of fill then vent cycles is between 3 and 10 vent then fill cycles.

According to another aspect said apparatus further comprises a user interface configured to allow a user to operate the apparatus.

15

According to another aspect said user interface allows a user to select a size of the pressure vessel to be filled that is stored in memory.

According to another aspect said user interface allows a user to choose a unique identifier associated with a pressure vessel to be filled.

20

According to another aspect said controller does not allow filling of said pressure vessel, without first executing an initial vent cycle according to any one of claims 11 to 22, unless selection of a said a unique identifier is made.

25

According to another aspect said user interface allows a user to choose a pre-set pressure vessel fill weight.

According to another aspect the invention broadly consists in a filling apparatus for filling a pressure vessel with fluid, comprising:

30

an inlet adapted to receive fluid from a pressurized source,

an outlet adapted to connect to a pressure vessel, and a fluid pathway between said inlet and said outlet,

a fill valve located in said path between said inlet and said outlet,

a vent valve located in said path between said fill valve and said outlet,

- 5 a controller operationally coupled to said fill valve and said vent valve, and adapted to receive a signal from a sensor indicative of the weight of said vessel, and said controller includes an initial vent cycle wherein:

the controller causes the fill valve to close and the vent valve to open, and

- 10 the controller monitors said weight signal over time, and if a change in said weight signal indicates the rate of change of weight is below a first predetermined threshold, said controller causes the vent valve to close and the fill valve to open to initiate filling said vessel.

- 15 According to another aspect said apparatus further includes a weighing arm displaceable under the weight of said pressure vessel and said sensor is configured to output a weight signal indicative of the weight of said pressure vessel acting on said arm.

- According to another aspect said first predetermined threshold is between 0.001 and
20 10.0 g/sec.

According to another aspect said first predetermined threshold is between 0.05 and 5.0g/sec.

- 25 According to another aspect during said initial vent cycle the controller causes said vent valve to close, and outputs an error signal if said first predetermined threshold is not reached before a second predetermined threshold.

- According to another aspect said controller does not allow the fill valve to be opened,
30 unless a predetermined reset criteria is met.

According to another aspect said reset criteria requires a user to remove the pressure vessel from the filling apparatus.

According to another aspect said second predetermined threshold is a time limit.

According to another aspect said second predetermined threshold is dependent on an
5 indicated size of the pressure vessel.

According to another aspect said time limit is approximately 30 seconds.

According to another aspect said second threshold is a predetermined decrease in weight
10 of the pressure vessel.

According to another aspect said second predetermined threshold is dependent on an
indicated size of the pressure vessel.

15 According to another aspect said second threshold is between 10% and 30% of the
pressure vessel fill weight.

According to another aspect said controller includes a **fill cycle** wherein:

the controller causes the fill valve to open and the vent valve to close, and
20 the controller monitors said weight signal over time, and
if a change in said weight signal indicates the rate of change of weight is below a third
predetermined threshold, said controller causes said fill valve to close and initiate a
pressure venting cycle.

25 According to another aspect said third predetermined threshold is between 0.1 and
10g/sec.

According to another aspect said third predetermined threshold is between 0.5 and
5.0g/sec.

30

According to another aspect during said pressure vent cycle the controller causes the
vent valve to open, until a fourth predetermined threshold criteria is met.

According to another aspect said fourth predetermined threshold is a time limit.

According to another aspect said fourth predetermined threshold is dependent on an indicated size of the pressure vessel.

5

According to another aspect said time limit is approximately 30 seconds.

According to another aspect said fourth threshold is a predetermined decrease in weight of the pressure vessel.

10

According to another aspect said fourth predetermined threshold is dependent on an indicated size of the pressure vessel.

15 According to another aspect said fourth threshold is between approximately 2% and 5% of the vessel fill weight.

According to another aspect said controller causes said fill valve to open and said vent valve to close, after said fourth threshold is reached.

20 According to another aspect said controller causes said apparatus to execute a plurality of vent then fill cycles while the pressure vessel weight remains below a predetermined fill weight.

25 According to another aspect said controller causes said fill valve to close, said vent valve to open and outputs an error signal, if the pressure vessel weight remains below a said predetermined fill weight after a predetermined number of fill then vent cycles.

According to another aspect said predetermined number of fill then vent cycles is between 3 and 10 vent then fill cycles.

30

According to another aspect said apparatus further comprises a user interface configured to allow a user to operate the apparatus.

According to another aspect said user interface allows a user to select a size of the pressure vessel to be filled that is stored in memory.

5 According to another aspect said user interface allows a user to choose a unique identifier associated with a pressure vessel to be filled.

According to another aspect said controller does not allow filling of said pressure vessel, without first executing an initial vent cycle according to any one of claims 44 to 56, unless selection of a said a unique identifier is made.

10

According to another aspect said user interface allows a user to choose a pre-set pressure vessel fill weight.

15 According to another aspect the invention broadly consists in a **filling apparatus for filling a pressure vessel** with fluid, comprising:

an inlet adapted to receive fluid from a pressurized source,

an outlet adapted to connect to a pressure vessel, and a fluid pathway between said inlet and said outlet,

a fill valve located in said path between said inlet and said outlet,

20 a vent valve located in said path between said fill valve and said outlet,

a controller operationally coupled to said fill valve and said vent valve, and adapted to receive a signal from a sensor indicative of the weight of said vessel, and said controller includes a **fill cycle** wherein:

the controller causes the fill valve to open and the vent valve to close, and

25 the controller monitors said weight signal over time, and

if a change in said weight signal indicates the rate of change of weight is below a third predetermined threshold, said controller causes said fill valve to close and initiate a pressure venting cycle.

30 According to another aspect said third predetermined threshold is between 0.1 and 10g/sec.

According to another aspect said third predetermined threshold is between 0.5 and 5.0g/sec.

According to another aspect during said pressure vent cycle the controller causes the
5 vent valve to open, until a fourth predetermined threshold criteria is met.

According to another aspect said fourth predetermined threshold is a time limit.

According to another aspect said fourth predetermined threshold is dependent on an
10 indicated size of the pressure vessel.

According to another aspect said time limit is approximately 30 seconds.

According to another aspect said fourth threshold is a predetermined decrease in weight
15 of the pressure vessel.

According to another aspect said fourth predetermined threshold is dependent on an indicated size of the pressure vessel.

20 According to another aspect said fourth threshold is between approximately 2% and 5% of the vessel fill weight.

According to another aspect said controller causes said fill valve to open and said vent valve to close, after said fourth threshold is reached.
25

According to another aspect said controller causes said apparatus to execute a plurality of vent then fill cycles while the pressure vessel weight remains below a predetermined fill weight.

30 According to another aspect said controller causes said fill valve to close, said vent valve to open and outputs an error signal, if the pressure vessel weight remains below a said predetermined fill weight after a predetermined number of fill then vent cycles.

According to another aspect said predetermined number of fill then vent cycles is between 3 and 10 vent then fill cycles.

According to another aspect said apparatus further comprises a user interface configured
5 to allow a user to operate the apparatus.

According to another aspect said user interface allows a user to select a size of the pressure vessel to be filled that is stored in memory.

10 According to another aspect said user interface allows a user to choose a unique identifier associated with a pressure vessel to be filled.

According to another aspect said controller does not allow filling of said pressure vessel, without first executing an initial vent cycle according to any one of claims 44 to
15 56, unless selection of a said a unique identifier is made.

According to another aspect said user interface allows a user to choose a pre-set pressure vessel fill weight.

20 According to another aspect said pressurized source is a second pressure vessel larger than said pressure vessel.

According to another aspect said pressurized source is not a high pressure pump.

25 According to another aspect the invention broadly consists in a filling method comprising:

fluidly connecting a portable pressure vessel to a pressurized source,
opening a vent valve to initiate fluid flow from said portable pressure vessel to atmosphere,
30 monitoring the rate of change in weight of said portable pressure vessel,
establishing a tare weight of said portable pressure vessel when said rate of change in weight of said portable pressure vessel is below a first predetermined threshold.

According to another aspect the invention broadly consists in a filling method comprising:

- fluidly connecting a portable pressure vessel to a pressurized source,
- 5 opening a fill valve to initiate fluid flow from said pressurized source to said portable pressure vessel,
- monitoring the rate of change in weight of said portable pressure vessel,
- closing said fill valve and opening a vent valve, if said change in weight of said portable pressure vessel is below a third predetermined threshold.

10

According to another aspect the invention broadly consists in filling method including the apparatus of any one or more of clauses 1 to 96.

According to another aspect the invention broadly consists in filling apparatus

- 15 substantially as herein described and with reference to any one or more of the drawings.

According to another aspect the invention broadly consists in filling method

substantially as herein described and with reference to any one or more of the drawings.

20 **DEFINITIONS**

- The term “comprising” as used in this specification and claims means “consisting at least in part of”. When interpreting each statement in this specification and claims again that includes the term “comprising”, features other than that or those prefaced by
- 25 the term may also be present. Related terms such as “comprise” and “comprises” are to be interpreted in the same manner.

In this specification “semi-autonomous” means a system that requires a user to manually connect and disconnect a portable pressure vessel from the filling apparatus,

- 30 but automatically controls the filling of the pressure vessel once connected.

In this specification the words “bottle”, “canister”, “container”, and “pressure vessel” are used interchangeably to describe a portable pressure vessel to be filled from a larger source of pressurized fluid.

- 5 In this specification the word “fluid” means liquid and/or gas.

In this specification the “tare weight” of a pressure vessel is the weight of the vessel when empty. In this specification the “fill weight” of a pressure vessel is the weight of fluid (CO₂ for example) that is to be stored in the vessel. As a result, the “total weight”
10 is the sum of the fill weight and the tare weight.

The invention consists in the foregoing and also envisages constructions of which the following gives examples only.

15

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will be described by way of example only and with reference to the drawings, in which:

- 20 Figure 1 is a perspective view of one embodiment of the canister filling apparatus shown mounted to a horizontal surface.

Figure 2 is a side view of the filling apparatus mounted to a vertical pole.

Figure 3 is a cross-section view of the filling apparatus of Figure 1.

Figure 4 is a detailed cross-section view of the valve arrangement of Figure 3.

- 25 Figure 5 is a detailed view of the valve arrangement of Figure 4.

Figure 6 is a perspective view of the cam of Figure 5.

Figure 7 is a typical graph of gas weight and rate of change of gas weight during an emptying cycle.

- Figure 8 is a graph of added gas weight and gas weight change over a number of fill and
30 vent cycles.

Figure 9 is a flow chart illustrating the control logic of one embodiment.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

While it is to be understood that the present invention relates broadly to any application where filling a smaller pressure vessel from a larger pressurized gases source is desirable, the most preferred fluid is CO₂. The following examples refer specifically to CO₂ supplied from a larger pressure vessel, which is where the present invention finds its most preferable application.

The pressure in a vessel that contains liquid and gaseous carbon dioxide is dependant on the temperature (rather than on the quantity of liquid in the vessel). For this reason the bottle must be weighed in order to determine the quantity of carbon dioxide within. The pressure within the vessel cannot be used as an accurate indication as it can with compressed gases with no liquid phase present.

In addition, if the temperature of the vessel rises, a critical point is reached where the pressure increases dramatically. For this reason the amount of liquid in the vessel is limited in order to leave a volume of gas into which the liquid can expand if it is heated. Typically a carbon dioxide canister has a recommended fill weight that gives approximately 34% of the volume as liquid. With this volume of liquid in the canister, the temperature can rise to 50 deg C and the pressure will be limited to approximately 2000 psi.

The portable canister is also fitted with a burst disk which is typically set to vent at a pressure of approximately 2200 psi. The canisters are typically rated to approximately 3000 psi, so the burst disk gives a reasonable safety margin against failure.

As a portable vessel is filled, the pressure inside the portable vessel will increase rapidly. As the liquid forms in the portable vessel, the pressure within will be similar to the supply vessel if they are at a similar temperature. If the temperatures are equal, an equilibrium is reached and the filling will stop. This can occur well before the portable gas canister is as full as it could/should be.

To be able to transfer more liquid from the larger gas source bottle, it is necessary to lower the pressure of the portable vessel by lowering its temperature. This is done by venting off a small volume of liquid from the portable bottle to atmosphere. The latent heat required to evaporate the liquid is absorbed largely from the remaining liquid, resulting in the temperature of the liquid and the canister falling. In order to reach the

desired fill weight in the portable canister, several fill-vent cycles may be required.

Typically a portable liquid carbon dioxide bottle will be marked with the fill weight but will not be marked with its tare weight. To fill such a bottle to its recommended weight, the bottle must first be emptied so that the weighing balance can be tared. The
5 bottle can then be filled until the correct fill weight is reached.

However, a problem can arise with this method when venting a large volume of carbon dioxide from the portable canister. For example, during venting of the contents of the portable gas canister, so much heat is absorbed by the evaporating gas that the remaining liquid can freeze. Once the remaining liquid is frozen, the rate of venting
10 falls dramatically, and may even cease.

If the liquid in the bottle freezes, it is necessary for the user to wait for the bottle to absorb sufficient heat for the solid carbon dioxide to melt. However, the user may think that the bottle is empty because very little gas will be venting (in this state, the venting flow rate is so slow that any hissing may have stopped). The user may then
15 assume that the bottle is empty, tare the weighing balance, and then consequently over fill the bottle to a potentially dangerous state.

In order to address these issues, the present method and apparatus provide a semi-autonomous system that is particularly suited to portable applications.

Figure 1 illustrates a filling system 1, with a portable pressure vessel 3 connected to it
20 via filling hose 8. The filling hose 8 includes a hose fitting 9, for engaging with the pressure vessel 3 in a fluid tight manner as is known in the art. Typically, pressure vessel 3, includes a valve to prevent escape of the pressurized fluid through the pressure vessel opening. Preferably, hose fitting 9 includes a feature to open the valve as it engages with the pressure vessel 3, as is known in the art.

25

In Figure 1, the filling system 1 is shown attached to a horizontal bench 4, by a clamp arrangement 5. High pressure fluid (preferably CO₂) is provided to the system through inlet hose 6. Preferably, the high pressure fluid source is a large pressure vessel (not shown). For example CO₂ is commonly available in 5-100kg bottles that can be used to

fill the smaller pressure vessels. Smaller portable pressure vessels are typically available in a range of 'standard' sizes e.g. 12, 20 and 40 Oz.

- With particular reference to Figure 3 and Figure 4, further details of the filling system 1 will be described. Filling system 1 is preferably powered by battery 10, in order to improve the portability of the device and enable operation in locations where external power is not available or inconvenient. Alternatively, filling system 1 may accept power from an external source.
- Controller 2, is provided to facilitate the operation of the autonomous features of filling system 1. A user interface 11, is operationally coupled with controller 2, to allow a user to select various operational parameters and operate the device. Preferably, the user interface 11, also includes a display 12 and or a plurality of user controls 13.
- Filling system 1 includes a filling valve 14 and a vent valve 15 located in the fluid passageway between the filling system inlet 16 and the filling system outlet 17. The outlet side 20 of vent valve 15 is in communication (directly or indirectly) with the atmosphere and may include a noise suppression device (not shown) to reduce the noise of high pressure gas venting during use. It will be appreciated that the vent valve 15, is "in" the fluid passageway to the extent that it is in fluid communication with the primary passage between the inlet 16 and outlet 17. The direction and path of flow within the passageway will depend on the specific condition of valves 14 and 15, as described in more detail later.
- Filling valve 14 and vent valve 15 are operated by cam shaft 18, which is in turn rotated by transducer 19. Preferably, transducer 19 is an electric motor and gear box. For example the motor may be a brushed DC motor with a gear box ratio of approximately 1:200. The gear box ratio is selected so that the shaft preferably rotates (360 degrees) in approximately 2 seconds. This speed is sufficiently fast to allow the fill valve to close quickly when the target weight is reached to achieve the required accuracy.

The high gearbox ratio also allows a relatively small motor to produce sufficient torque to drive the camshaft. Another desired result of the gearbox is that when the motor is

turned off, there is sufficient friction to prevent the camshaft from turning under the load from the valves. Alternatively, the valves 14,15 may be operated by separate cams 18, each in turn operated by a corresponding transducer 19.

5 Rotation of cam shaft 18 causes the opening and closing of the fill valve 14 and/or vent valve 15. The cam shaft 18 includes cam surfaces shaped to operate the valves in several sequences according to the angular position of the cam shaft. The cam shaft preferably has 2 control positions, FILL, VENT and two intermediate positions where both valves are closed. For example:

- 10 i) with the camshaft 18 in a FILL position, vent valve 15 is closed and fill valve 14 is open.
- ii) with the camshaft 18 in a VENT position, vent valve 15 is open and fill valve 14 is closed.

15 The fill valve 14 has a cam follower 21 which rides directly on the top of the cam 18. The cam follower has a pin 22 which passes through the valve orifice to push the valve seal off the seat. The valve is arranged in this way so that the gas pressure from the supply bottle acts to close the valve to give a reliable seal. A return spring 23 is provided to overcome friction and ensure that the valve closes when the cam is lowered.

20

In the vent valve 15, the valve seal is attached directly to the cam follower 24. The cam follower has a slot 25 through which the cam shaft 18 passes, to allow the cam follower 24 to be actuated from the bottom surface of the cam. A return spring 26 is provided to overcome friction and the weight of the cam follower to ensure that the valve closes

25 when the cam is raised. The valve 15 is configured so that the pressure from the canister 3 holds the seal closed.

FILL position

30 With the high point of the cam (acting on fill valve 15) in the upper position, the fill valve 15 is pushed up to open. At the same time, vent valve 16 is pushed by the spring to close. Carbon dioxide will therefore flow through the fill valve in to the canister, with no venting to atmosphere.

Intermediate closed position

As the camshaft 18 is moved through 90 degrees, the peaks of the cam 18 are positioned horizontally. In this position, both the fill valve 14 and vent valve 15 close. When in this position, the supply bottle and the canister 3 are both sealed.

5

VENT position

As the cam shaft 18 is moved through a further 90 degrees, the peaks of the cam shaft are positioned in their lowest point (i.e. downwards). In this position, the fill valve 14 is closed due to the force of the return spring 23 and the supply bottle pressure, while the cam follower of the vent valve will be pulled down, opening the vent valve.

10

Intermediate closed position

As the camshaft moves through a further 90 degrees the peaks of the cam are again horizontal. This allows both fill valve 14 and vent valve 15 to close. The supply bottle and the canister are both sealed.

15

The position of the cam shaft 18 is determined by the controller via a disk including a magnet at each valve position. The magnets are detected by 3 hall effect sensors, one for each of the FILL position, VENT position and one for both CLOSED positions. It will be appreciated that other methods may be used to allow the controller 2 to confirm the angular position of the cam shaft 18. For example, via limit switches, or a rotary encoder etc.

20

One important advantage of the cam shaft and geared motor arrangement is that when the cam shaft (and valves respectively) are in any of the 4 positions, no power is consumed to maintain that position and the corresponding condition of the fill valve 14 and vent valve 15. This arrangement is ideal for the preferred battery operation allowing maximum portability and ease of use and maximizing electrical efficiency. The peak torque required from the motor comes when the fill valve is opened and the cam needs to overcome the force due to the pressure from the supply bottle acting over the orifice of the valve. The high gearbox ratio chosen for the motor enables a relatively small and low cost motor to achieve this torque. It will be appreciated that other types of motor/actuator arrangements are also possible for rotating the cam (or cams).

30

One other feature of the cam shaft is that it has a seal at both ends. This is to ensure that the pressure of the carbon dioxide does not act on the end of the shaft so that the forces are balanced so that there is no end thrust.

5

With particular reference to Figure 3, the bottle 3 is preferably hung from the end of a weighing arm 27 via fill hose 8. Weighing arm 27 pivots at or near one end (not shown) and preferably transfers load to a load cell sensor 28 via a spring 29. The spring 29 provides a small amount of deflection of the arm under load and allows the use of a
10 fixed stop to limit the load that can be applied to the load cell. This arrangement provides a degree over-load protection for the load cell 28. In addition, the flexible hose 8 also allows the bottle to hang vertically thereby minimizing any weighing error if the system 1 is not clamped exactly horizontally.

15 One advantage of the weighing arm arrangement is that any loads due to knocks or pulling sideways on the bottle, are transferred into the frame of the device and do not overload the load cell 28. Any small amount of friction in the pivot of arm 27 will only have a negligible effect on the measured weight, due to the relatively long length of the arm.

20

The hose 8 from the fill valve 14 to the canister 3 runs along the length of arm 27. This hose 8 passes from the fixed valve 14 to the moving end of the arm 23, so any stiffness or residual strain in the hose 8 could apply a load to the load cell 28 resulting in potential error to the weight reading. To mitigate this, the hose 8 is preferably as
25 flexible as possible. For example, the hose 8 may have a nylon core with braided polyester reinforcement and a polyurethane outer layer for protection. The length of hose 8 between the fixed end and the end of the arm is preferably maximized so that the force produced by flexing the hose is as small as possible.

30 The filling system 1 is preferably small and lightweight so that it can easily be moved from place to place and facilitate onsite refilling of portable pressure vessels 3.

Typically, portable pressure vessels 3 come in a number of standard sizes. For example, typical canisters may be a 12oz bottle, a 20oz bottle or a 40oz bottle. Pneumatic devices are typically designed to operate with these standard size bottles. However, while the fill weight is typically fixed, the weight of an empty 20oz bottle for example, may be quite different between manufacturers. That is, a number of manufacturers may make 20oz bottles (i.e. designed to received 20oz of fluid), but the weight of the empty bottles may vary considerably between manufacturers.

Portable bottles are usually filled until they reach a target weight and therefore it is important to know the empty bottle weight accurately. Otherwise dangerous overfill conditions may result. In order to achieve this, the filling system 1 initially conducts a “tare” process. Alternatively, the controller may be programmed via a user interface with the known tare weight of a bottle 3 to be filled.

Tare process

The first step of the filling system is to use the user interface 11 to select a desired fill weight. Preferably, the user interface 11, buttons 13 and display 12 are used to select a vessel size to be filled. With this information selected, the controller can set various parameters as appropriate for the selected bottle size as described in more detail later.

20

When initially connected to the filler system 1, and the fill process initiated, the controller 2 preferably enters a “tare” process and vents all the contents of the canister 3 to atmosphere. If the portable canister was initially quite full, prolonged venting will likely cause freezing of the valve and/or contents of the portable canister. Therefore, while the frozen contents prevent carbon dioxide being vented to the atmosphere, the bottle may still be far from completely empty. This could result in a dangerous overfill, if the vessel is presumed empty, when it is not.

Controller 2, therefore preferably monitors the weight of the canister during the initial vent cycle. If the rate of change of weight drops below a first predetermined threshold, the canister is presumed empty, and the controller will initiate the filling cycle. This criteria ensures that the pressure vessel is close enough to completely empty to eliminate over fill risk, while preventing the potentially unduly long time period before

absolutely all the gas is vented. Figure 7 illustrates a typical graph of gas weight and change in weight per sample vs time when venting.

5 The first predetermined threshold is dependent on the restriction of the vent valve and so may vary depending on the detail of the valve design. The first predetermined threshold of weight change is preferably selected to allow confidence that the portable canister 3 is essentially empty, while making sure the initial vent cycle is not unduly lengthy.

10 For example, it has been found that a predetermined threshold of between 0.005 and 5 g per second is adequate. More preferably, a first threshold of between 0.01 g per second and 1gm per second works well. Most preferably, this first threshold is approximately set to 0.067 g per second.

15 In order to implement this initial venting step, the controller 2 samples the output signal from the load cell 28 every 300 milliseconds, for example. Therefore, a predetermined threshold of 0.067grams/s can be expressed as a change of less than 0.02 grams between two consecutive samples. It will be appreciated by those skilled in the art that there are many other techniques for measuring and implementing the pre-determined threshold
20 rate of change for determining when the initial vent phase should be terminated according to the invention.

In order to avoid a situation where prolonged venting of the portable canister causes freezing, (and as a result the rate of change of weight falls below the first predetermined
25 threshold), the filling system 1 limits the amount of continuous venting. If the limit is reached, the controller 2 generates an error signal and alerts the user via display 12 and/or an audible alarm etc. In addition, after such an error signal is activated, the controller may require the user to remove the portable canister from the filling apparatus in order to reset the controller.

30

This preferred lock-out step requires the user to assess the pressure vessel for freezing before reconnecting it to try filling again. Once reset, the controller will start from the

beginning of the process and initiate another initial vent and tare process until the vessel 3 is empty.

Once the controller has determined that the vessel 3 is empty, (by confirming that the rate of change in weight has dropped below the first threshold and not encountering a venting limit), the tare weight is established from the load cell reading. This empty vessel tare weight, can then be used to fill the vessel to a target fill weight.

It is preferred that the user is given an opportunity to store the 'Tare' weight of the vessel 3 in memory for later use. For example, each vessel 3 may be given a unique identifier (eg: name, number etc) that can be stored in memory against the appropriate fill settings (such as tare weight and/or vessel fill weight). The next time that same vessel 3 is required to be filled, it can be selected via the user interface 11. When selected, the appropriate settings are retrieved from memory by the controller. For example, individual vessels 3 can be assigned a number (e.g. between 1 & 20) and the controller can store the settings in non-volatile memory. The controller may have any number of memory storage and the user interface may be simple or a full screen type.

Importantly, the initial tare process does not need to be executed by the controller when filling a 'known' vessel 3. Accordingly, if the vessel 3 is not completely empty, there is no need to waste the CO₂ within (or time), and the vessel can be topped up to its desired fill weight because the controller can retrieve the tare weight from memory.

Freeze prevention

To implement 'freeze prevention', the controller 2 preferably also monitors the total weight change of the portable canister 3 during the initial vent phase. If the total weight change exceeds a second predetermined threshold, the controller triggers an error (and may also require a user to remove the bottle in order to reset the system and allow any filling). The controller, can preferably detect when the bottle is removed by monitoring the load cell (or any other suitable method), e.g. after receiving an error signal as described above, the controller will not allow the can to rotate to the fill position unless the load cell has detected no load for a period of time. After re-connection, the load cell will register a non-zero load and the cycle can begin again.

According to one embodiment, the second predetermined threshold is preferably a maximum change in weight that is dependent on the portable canister size selected. For example, the maximum allowable weight change may be a percentage of the fill weight
5 for the selected canister 3. Preferably, the second predetermined weight threshold is between 10% and 30% of the vessel fill weight. ie. 4.0 ounces for a 20 ounce portable canister, (being 20%).

Alternatively, according to another embodiment (or in addition to previous
10 embodiments) the controller may limit the maximum time the initial vent cycle is allowed to continue. If the rate of change of mass of the portable canister does not fall below the first predetermined threshold within a maximum time limit, the controller triggers an error signal, and may additionally require the user to remove the bottle and reset the controller. It is preferred that unless this (removal and re-connection) is done
15 by the user, the controller will not allow any further filling. For example a time limit of 30 seconds may be set for all vessel sizes. Alternatively, the time limit may be determined with reference to the vessel size such that different time limits are applied to different size vessels.

20 In a further alternative, the controller may implement more than one limiting criteria on the initial vent cycle in the event that the rate of change of mass does not fall below the predetermined first threshold. That is, the controller may monitor a maximum time and a maximum change in weight and trigger an error signal if either criteria is met.

25 *Filling process*

The preferred filling process will be described with particular reference to Figures 8-9 and includes several example fill-vent cycles as noted earlier in order to reach the desired fill weight.

30 After completing the initial 'tare process' (or skipping it for a 'known' vessel), the controller can begin filling the vessel 3 to the desired fill weight. To do this the controller moves the cam shaft 18 to the FILL position where the vent valve 15 is closed and the fill valve 14 is open, so that CO₂ begins to flow into vessel 3. As CO₂

flows into vessel 3, the pressure within will increase and the filling rate slows and would eventually stop (often before the desired fill weight is reached).

The controller 2 monitors the output of the load cell 28 as the weight of vessel 3 increases. If the rate of change of weight of the vessel 3 falls below a third predetermined threshold, the controller moves the cam shaft 18 to the VENT position. The third predetermined threshold is according to one embodiment between 0.1g/s and 10g/s. Alternatively, and more particularly the third threshold may be between 0.5g/s and 5g/s. In the most preferred embodiments, the third threshold is approximately 1.5g/s.

The venting of a small amount of CO₂ during filling, allows the temperature and pressure within vessel 3 to drop. As a result, the vessel 3 can be filled further. The controller monitors a fourth threshold for determining how long to vent the vessel 3 during filling.

According to one aspect, the fourth threshold is a predetermined change in weight of vessel 3. For example, the controller will cause the cam shaft to rotate to close the vent valve 15, after a predetermined reduction in vessel weight (since the vent valve was opened) has occurred, e.g. 20grams. Alternatively, the fourth criteria is preferably dependent on the selected fill weight of the container e.g. a percentage or ratio such as 2% or 3.5% or 5%. In addition, it is anticipated that more than one fourth threshold may be applied. It is most preferred that at least one fourth threshold is a time limit. This is preferred to account for a situation where the supply source is empty, and the portable vessel 3 does not fill. In this situation, the change in weight (during venting) may never reach the fourth threshold level, and therefore a secondary time limit is useful to prevent the system from 'venting' indefinitely.

In a further alternative, the fourth predetermined threshold may be a fixed time e.g. 30 seconds (not dependent on vessel size). Alternatively the fourth criteria may be a fixed time that depends on the selected fill weight of the vessel.

In a still further alternative, the fourth predetermined threshold may be a rate of change of weight. e.g. if the rate of change of weight (decreasing), falls below a predetermined level.

- 5 Once the fourth predetermined threshold is satisfied, the controller moves the cam shaft 18 to the fill position, to allow further fluid (e.g. CO₂) to flow into vessel 3. As illustrated in Figure 8, it may require several fill-vent cycles to reach the desired fill weight. The controller monitors the vessel weight and rotates the cam shaft 18 to a closed position (i.e. fill valve 14 and vent valve 15 closed), when the target weight is
10 reached.

It is also preferable that the controller limits the number of vent then fill cycles. For example, if the vessel fails to reach its target weight after a predetermined number of cycles, the controller outputs an error signal (for example 7 cycles). This may occur for
15 example, if the user inputs a container size and/or fill weight that is larger than the container or if the supply bottle is empty. In the case of an incorrect canister size, this error will alert the user to a potential overfill situation. The error signal may comprise an audible alarm and/or visual alert. In addition, the controller preferably moves the cam shaft 18 to the vent position to relieve the danger of an over fill.

20

The flow chart of Figure 9, illustrates a preferred filling system process, as described above.

- The foregoing description of the invention includes preferred forms thereof.
25 Modifications may be made thereto without departing from the scope of the invention as defined by the accompanying claims.

Claims:

1. **A filling apparatus for filling a pressure vessel with fluid, comprising:**
an inlet adapted to receive fluid from a pressurized source,
an outlet adapted to connect to a pressure vessel, and a fluid pathway between
5 said inlet and said outlet,
a fill valve located in said path between said inlet and said outlet,
a vent valve located in said path between said fill valve and said outlet,
at least one cam shaft configured to rotate and operate said fill valve and said
vent valve.
10
2. A filling apparatus as claimed in claim 1, wherein rotation of said at least one
cam shaft causes opening and closing of the respective fill valve and/or vent valve, but
forces from the valves acting on the cam shaft cannot rotate the cam shaft due to high
gearing.
15
3. A filling apparatus as claimed in any of the previous claims, wherein said fill
valve and said vent valve are operated by the same cam shaft.
4. A filling apparatus as claimed in claim 3, wherein said cam shaft at least one
20 cam shaft includes cam surfaces configured to operate said fill valve and said vent valve
respectively, and said shaft has at least the following angular positions with
corresponding valve conditions:
 - i) a filling position with the fill valve open and vent valve closed,
 - ii) a venting position with the fill valve closed and the vent valve open.25
5. A filling apparatus as claimed in claim 4, wherein said shaft has at least the
following additional angular positions with corresponding valve conditions:
 - iii) a filling stop position with the fill valve closed and the vent valve closed,
said filling stop position located between said filling position and said venting
30 position.

6. A filling apparatus as claimed in claim 5, wherein said shaft includes two angular positions corresponding with a filling stop position with the fill valve closed and the vent valve closed.

5 7. A filling apparatus as claimed in claim 5 or claim 6, wherein each said angular position is located 90 degrees from the last.

8. A filling apparatus as claimed in any one of claims 4 to 7, wherein said cam shaft is coupled to (directly or indirectly), and rotated by, an electric motor.

10

9. A filling apparatus as claimed in any one of claims 1 to 8, wherein said apparatus further comprises:

a weighing arm displaceable under the weight of said pressure vessel and a sensor configured to output a weight signal indicative of the weight of said pressure vessel acting on said arm.

15

10. A filling apparatus as claimed in claim 9, wherein said apparatus further comprises:

a controller operationally coupled to said motor and adapted to receive said signal from said sensor.

20

11. A filling apparatus as claimed in claim 11, wherein said pressure vessel is flexibly suspended from said weighing arm by a flexible fill hose.

25

12. A filling apparatus as claimed in any one of claims 10 to 11, wherein said controller includes an **initial vent cycle** wherein:

the controller causes the motor to move the cam shaft to a venting position with the fill valve closed and the vent valve open, and

30

the controller monitors said weight signal over time, and

if a change in said weight signal indicates the rate of change of weight is below a first predetermined threshold, said controller causes the motor to move the cam shaft to close said vent valve and initiate a filling cycle.

13. A filling apparatus as claimed in claim 12, wherein said first predetermined threshold is between 0.001 and 10.0 g/sec.

5

14. A filling apparatus as claimed in any one of claims 12 to 13, wherein during said initial vent cycle the controller causes the motor to move the cam shaft to close said vent valve and outputs an error signal, if said first predetermined threshold is not reached before a second predetermined threshold.

10

15. A filling apparatus as claimed in claim 16, wherein said controller does not allow the fill valve to be opened, unless a predetermined reset criteria is met, and said reset criteria requires a user to remove the pressure vessel from the filling apparatus.

15

16. A filling apparatus as claimed in any one of claims 14 to 15, wherein said second predetermined threshold is a time limit.

20

17. A filling apparatus as claimed in claim 14 to 16, wherein said second predetermined threshold is dependent on an indicated size of the pressure vessel.

25

18. A filling apparatus as claimed in any one of claims 14 to 15, wherein said second threshold is a predetermined decrease in weight of the pressure vessel.

19. A filling apparatus as claimed in claim 18, wherein said second predetermined threshold is dependent on an indicated size of the pressure vessel.

30

20. A filling apparatus as claimed in claim 19, wherein said second threshold is between 10% and 30% of the pressure vessel fill weight.

21. A filling apparatus as claimed in any one of claims 10 to 20, wherein said controller includes a **fill cycle** wherein:

the controller causes the motor to move the cam shaft to a fill position with the fill valve open and the vent valve closed, and

the controller monitors said weight signal over time, and

if a change in said weight signal indicates the rate of change of weight is below a third
5 predetermined threshold, said controller causes the motor to move the cam shaft to close
said fill valve and initiate a pressure venting cycle.

]

10 22. A filling apparatus as claimed in claim 21, wherein said third predetermined threshold is between 0.5 and 5.0g/sec.

23. A filling apparatus as claimed in any one of claims 21 to 22, wherein during said pressure vent cycle the controller causes the motor to move the cam shaft to open said
15 vent valve, until a fourth predetermined threshold criteria is met.

24. A filling apparatus as claimed in claim 23, wherein said fourth predetermined threshold is a time limit.

20 25. A filling apparatus as claimed in claim 24, wherein said fourth predetermined threshold is dependent on an indicated size of the pressure vessel.

26. A filling apparatus as claimed in claim 23, wherein said fourth threshold is a
25 predetermined decrease in weight of the pressure vessel.

27. A filling apparatus as claimed in claim 26, wherein said fourth predetermined threshold is dependent on an indicated size of the pressure vessel.

30 28. A filling apparatus as claimed in claim 27, wherein said fourth threshold is between approximately 2% and 5% of the vessel fill weight.

29. A filling apparatus as claimed in any one of claims 23 to 28, wherein said controller causes the motor to move the cam shaft to said fill position with the fill valve open and the vent valve closed, after said fourth threshold is reached.

5 30. A filling apparatus as claimed in claim 29, wherein said controller causes said apparatus to execute a plurality of vent then fill cycles while the pressure vessel weight remains below a predetermined fill weight.

10 31. A filling apparatus as claimed in claim 30, wherein said controller causes the motor to move the cam shaft to close said fill valve, open said vent valve, and outputs an error signal, if the pressure vessel weight remains below a said predetermined fill weight after a predetermined number of fill then vent cycles.

15 32. A filling apparatus as claimed in claim 31, wherein said predetermined number of fill then vent cycles is between 3 and 10 vent then fill cycles.

20 33. A filling apparatus as claimed in any one of the previous claims, wherein said apparatus further comprises a user interface configured to allow a user to operate the apparatus.

34. A filling apparatus as claimed in claim 33, wherein said user interface allows a user to select a size of the pressure vessel to be filled that is stored in memory.

25 35. A filling apparatus as claimed in claim 33, wherein said user interface allows a user to choose a unique identifier associated with a pressure vessel to be filled.

30 36. A filling apparatus as claimed in claim 35, wherein said controller does not allow filling of said pressure vessel, without first executing an initial vent cycle according to any one of claims 12 to 20, unless selection of a said a unique identifier is made.

37. **A filling apparatus for filling a pressure vessel with fluid, comprising:**

an inlet adapted to receive fluid from a pressurized source,
an outlet adapted to connect to a pressure vessel, and a fluid pathway between
said inlet and said outlet,

- 5 a fill valve located in said path between said inlet and said outlet,
a vent valve located in said path between said fill valve and said outlet,
a controller operationally coupled to said fill valve and said vent valve, and
adapted to receive a signal from a sensor indicative of the weight of said vessel, and
said controller includes an initial vent cycle wherein:

10 the controller causes the fill valve to close and the vent valve to open,
and

the controller monitors said weight signal over time, and
if a change in said weight signal indicates the rate of change of weight is
below a first predetermined threshold, said controller causes the vent valve to close and
the fill valve to open to initiate filling said vessel.

15

38. A filling apparatus for filling a pressure vessel as claimed in claim 44, wherein
said apparatus further includes a weighing arm displaceable under the weight of said
pressure vessel and said sensor is configured to output a weight signal indicative of the
weight of said pressure vessel acting on said arm.

20

39. A filling apparatus as claimed in any one of claims 37 to 38, wherein said first
predetermined threshold is between 0.05 and 5.0g/sec.

25 40. A filling apparatus as claimed in any one of claims 37 to 39, wherein during said
initial vent cycle the controller causes said vent valve to close, and outputs an error
signal if said first predetermined threshold is not reached before a second predetermined
threshold.

30 41. A filling apparatus as claimed in claim 40, wherein said controller does not
allow the fill valve to be opened, unless a predetermined reset criteria is met, and said
reset criteria requires a user to remove the pressure vessel from the filling apparatus.

42. A filling apparatus as claimed in any one of claims 40 to 41, wherein said second predetermined threshold is a time limit.

43. A filling apparatus as claimed in claim 40 to 42, wherein said second
5 predetermined threshold is dependent on an indicated size of the pressure vessel.

44. A filling apparatus as claimed in any one of claims 40 to 41, wherein said second threshold is a predetermined decrease in weight of the pressure vessel.

10

45. A filling apparatus as claimed in claim 44, wherein said second predetermined threshold is dependent on an indicated size of the pressure vessel.

46. A filling apparatus as claimed in claim 45, wherein said second threshold is
15 between 10% and 30% of the pressure vessel fill weight.

47. A filling apparatus as claimed in any one of claims 37 to 46, wherein said controller includes a **fill cycle** wherein:

20 the controller causes the fill valve to open and the vent valve to close, and

the controller monitors said weight signal over time, and

if a change in said weight signal indicates the rate of change of weight is below a third predetermined threshold, said controller causes said fill valve to close and initiate a pressure venting cycle.

25 48. A filling apparatus as claimed in claim 47, wherein said third predetermined threshold is between 0.1 and 10g/sec.

49. A filling apparatus as claimed in any one of claims 47 to 48, wherein during said
30 pressure vent cycle the controller causes the vent valve to open, until a fourth predetermined threshold criteria is met.

50. A filling apparatus as claimed in claim 49, wherein said fourth predetermined threshold is a time limit.

51. A filling apparatus as claimed in claim 50, wherein said fourth predetermined
5 threshold is dependent on an indicated size of the pressure vessel.

52. A filling apparatus as claimed in claim 49, wherein said fourth threshold is a predetermined decrease in weight of the pressure vessel.

10

53. A filling apparatus as claimed in claim 52, wherein said fourth predetermined threshold is dependent on an indicated size of the pressure vessel.

54. A filling apparatus as claimed in claim 53, wherein said fourth threshold is
15 between approximately 2% and 5% of the vessel fill weight.

55. A filling apparatus as claimed in any one of claims 49 to 54, wherein said controller causes said fill valve to open and said vent valve to close, after said fourth threshold is reached.

20

56. A filling apparatus as claimed in claim 55, wherein said controller causes said apparatus to execute a plurality of vent then fill cycles while the pressure vessel weight remains below a predetermined fill weight.

25 57. A filling apparatus as claimed in claim 56, wherein said controller causes said fill valve to close, said vent valve to open and outputs an error signal, if the pressure vessel weight remains below a said predetermined fill weight after a predetermined number of fill then vent cycles.

30 58. A filling apparatus as claimed in claim 57, wherein said predetermined number of fill then vent cycles is between 3 and 10 vent then fill cycles.

59. A filling apparatus as claimed in any one of the previous claims, wherein said apparatus further comprises a user interface configured to allow a user to operate the apparatus.

5 60. A filling apparatus as claimed in claim 59, wherein said user interface allows a user to select a size of the pressure vessel to be filled that is stored in memory.

61. A filling apparatus as claimed in claim 59, wherein said user interface allows a user to choose a unique identifier associated with a pressure vessel to be filled.

10

62. A filling apparatus as claimed in claim 61, wherein said controller does not allow filling of said pressure vessel, without first executing an initial vent cycle according to any one of claims 12 to 20, unless selection of a said a unique identifier is made.

15

63. A filling apparatus as claimed in claim 59, wherein said user interface allows a user to choose a pre-set pressure vessel fill weight.

64. **A filling apparatus for filling a pressure vessel** with fluid, comprising:
20 an inlet adapted to receive fluid from a pressurized source,
an outlet adapted to connect to a pressure vessel, and a fluid pathway between said inlet and said outlet,
a fill valve located in said path between said inlet and said outlet,
a vent valve located in said path between said fill valve and said outlet,
25 a controller operationally coupled to said fill valve and said vent valve, and adapted to receive a signal from a sensor indicative of the weight of said vessel, and said controller includes a **fill cycle** wherein:
the controller causes the fill valve to open and the vent valve to close, and
the controller monitors said weight signal over time, and
30 if a change in said weight signal indicates the rate of change of weight is below a third predetermined threshold, said controller causes said fill valve to close and initiate a pressure venting cycle.

65. A filling apparatus as claimed in claim 64, wherein said third predetermined threshold is between 0.1 and 10g/sec.

5 66. A filling apparatus as claimed in any one of claims 64 to 65, wherein during said pressure vent cycle the controller causes the vent valve to open, until a fourth predetermined threshold criteria is met.

67. A filling apparatus as claimed in claim 66, wherein said fourth predetermined
10 threshold is a time limit.

68. A filling apparatus as claimed in claim 67, wherein said fourth predetermined threshold is dependent on an indicated size of the pressure vessel.

15

69. A filling apparatus as claimed in claim 66, wherein said fourth threshold is a predetermined decrease in weight of the pressure vessel.

70. A filling apparatus as claimed in claim 69, wherein said fourth predetermined
20 threshold is dependent on an indicated size of the pressure vessel.

71. A filling apparatus as claimed in claim 70, wherein said fourth threshold is between approximately 2% and 5% of the vessel fill weight.

25 72. A filling apparatus as claimed in any one of claims 66 to 71, wherein said controller causes said fill valve to open and said vent valve to close, after said fourth threshold is reached.

73. A filling apparatus as claimed in claim 72, wherein said controller causes said
30 apparatus to execute a plurality of vent then fill cycles while the pressure vessel weight remains below a predetermined fill weight.

74. A filling apparatus as claimed in claim 73, wherein said controller causes said fill valve to close, said vent valve to open and outputs an error signal, if the pressure vessel weight remains below a said predetermined fill weight after a predetermined number of fill then vent cycles.

5

75. A filling apparatus as claimed in claim 74, wherein said predetermined number of fill then vent cycles is between 3 and 10 vent then fill cycles.

76. A filling apparatus as claimed in any one of the previous claims, wherein said
10 apparatus further comprises a user interface configured to allow a user to operate the apparatus.

77. A filling apparatus as claimed in claim 76, wherein said user interface allows a user to select a size of the pressure vessel to be filled that is stored in memory.

15

78. A filling apparatus as claimed in claim 76, wherein said user interface allows a user to choose a unique identifier associated with a pressure vessel to be filled.

79. A filling apparatus as claimed in claim 78, wherein said controller does not
20 allow filling of said pressure vessel, without first executing an initial vent cycle according to any one of claims 12 to 20, unless selection of a said a unique identifier is made.

80. A filling apparatus as claimed in claim 76, wherein said user interface allows a
25 user to choose a pre-set pressure vessel fill weight.

81. A filling apparatus as claimed in any one of the previous claims, wherein said pressurized source is a second pressure vessel larger than said pressure vessel.

30 82. A filling apparatus as claimed in any one of the previous claims, wherein said pressurized source is not a high pressure pump.

83. A filling method comprising:

fluidly connecting a portable pressure vessel to a pressurized source,
opening a vent valve to initiate fluid flow from said portable pressure vessel to
atmosphere,

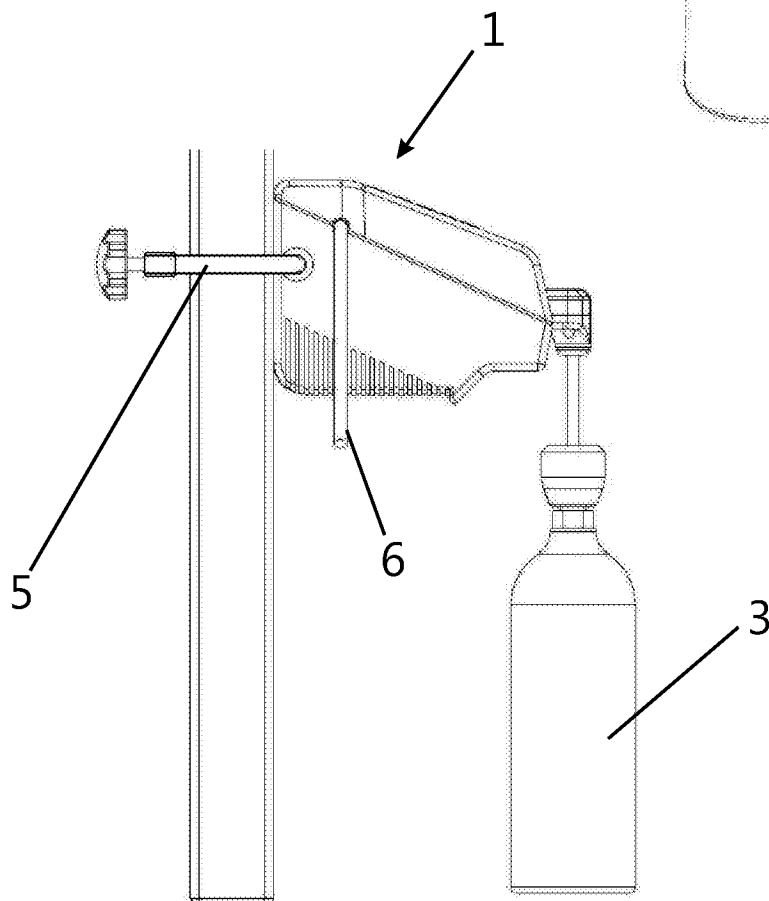
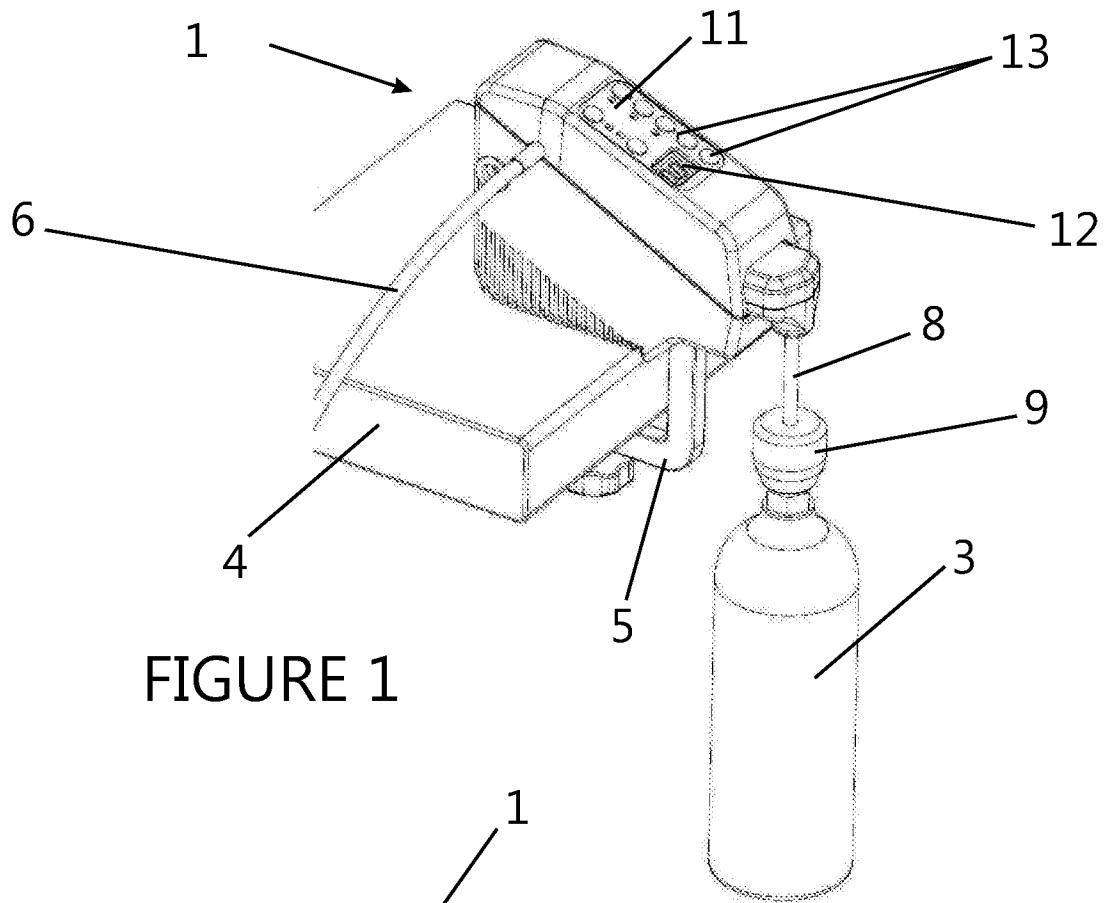
- 5 monitoring the rate of change in weight of said portable pressure vessel,
establishing a tare weight of said portable pressure vessel when said rate of
change in weight of said portable pressure vessel is below a predetermined threshold.

84. A filling method comprising:

- 10 fluidly connecting a portable pressure vessel to a pressurized source,
opening a fill valve to initiate fluid flow from said pressurized source to said
portable pressure vessel,
monitoring the rate of change in weight of said portable pressure vessel,
closing said fill valve and opening a vent valve, if said change in weight of said
portable pressure vessel is below a predetermined threshold.

15

85. A filling method including the apparatus of any one or more of claims 1 to 82.



2/5

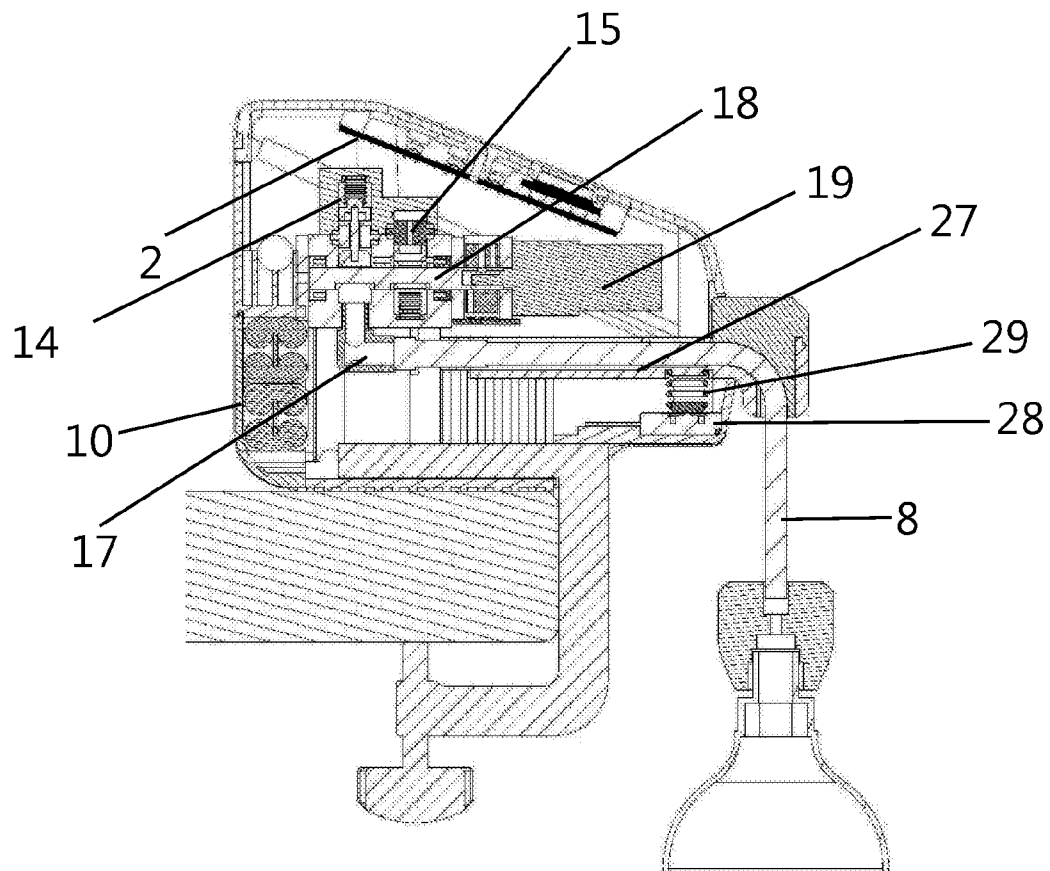


FIGURE 3

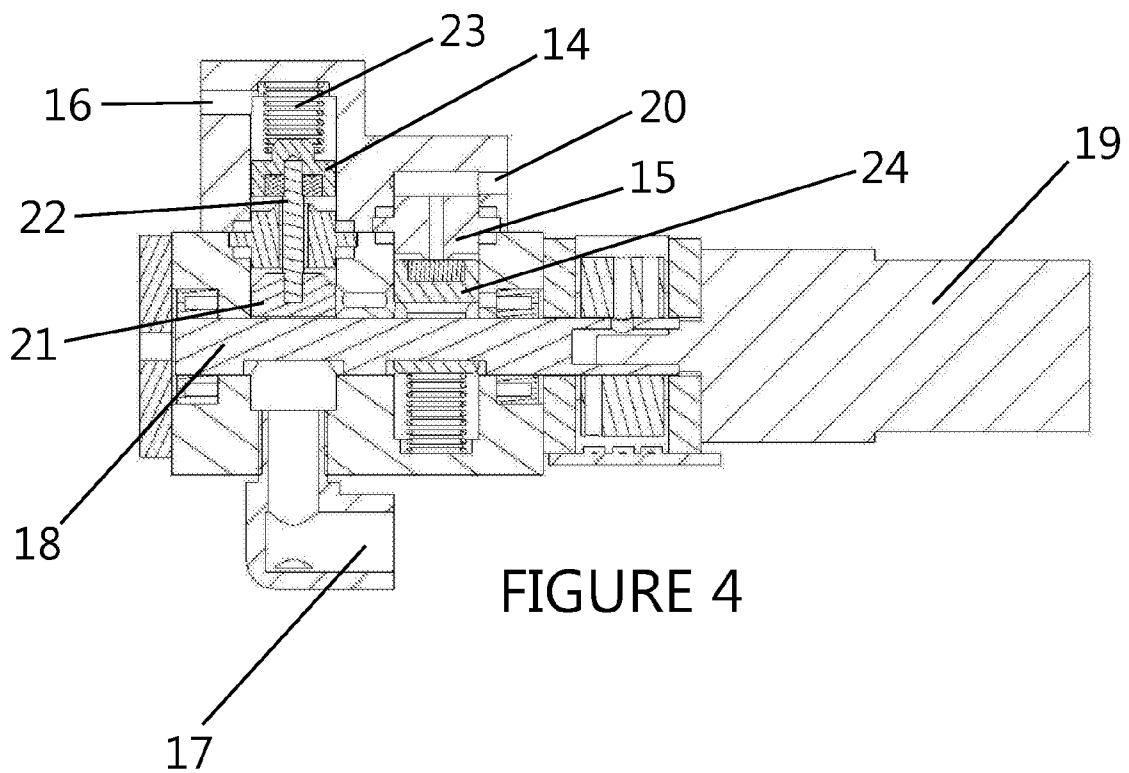


FIGURE 4

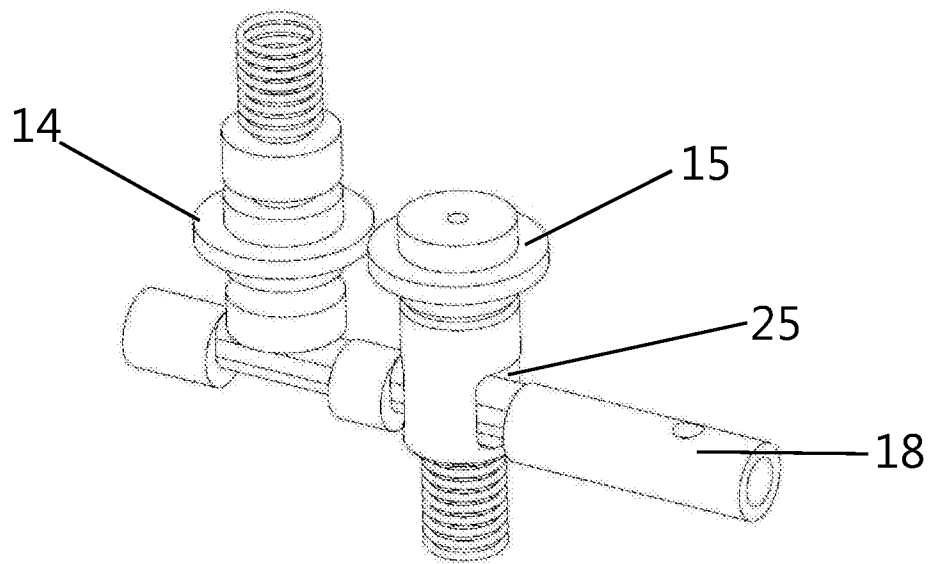


FIGURE 5

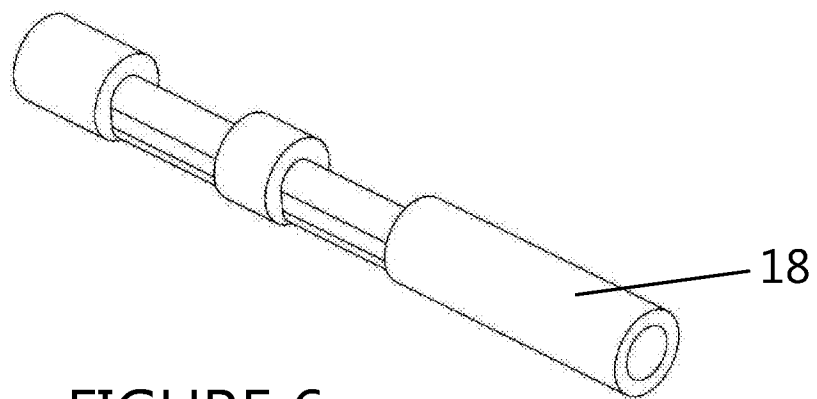


FIGURE 6

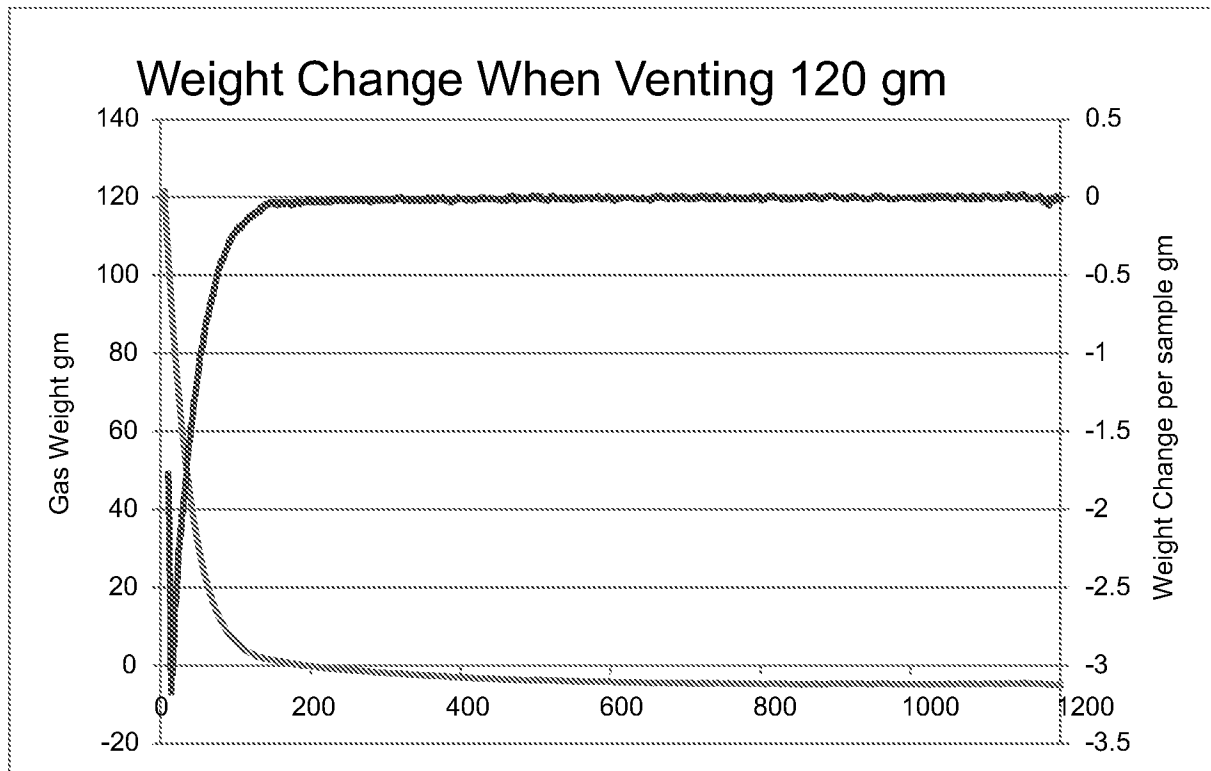


FIGURE 7

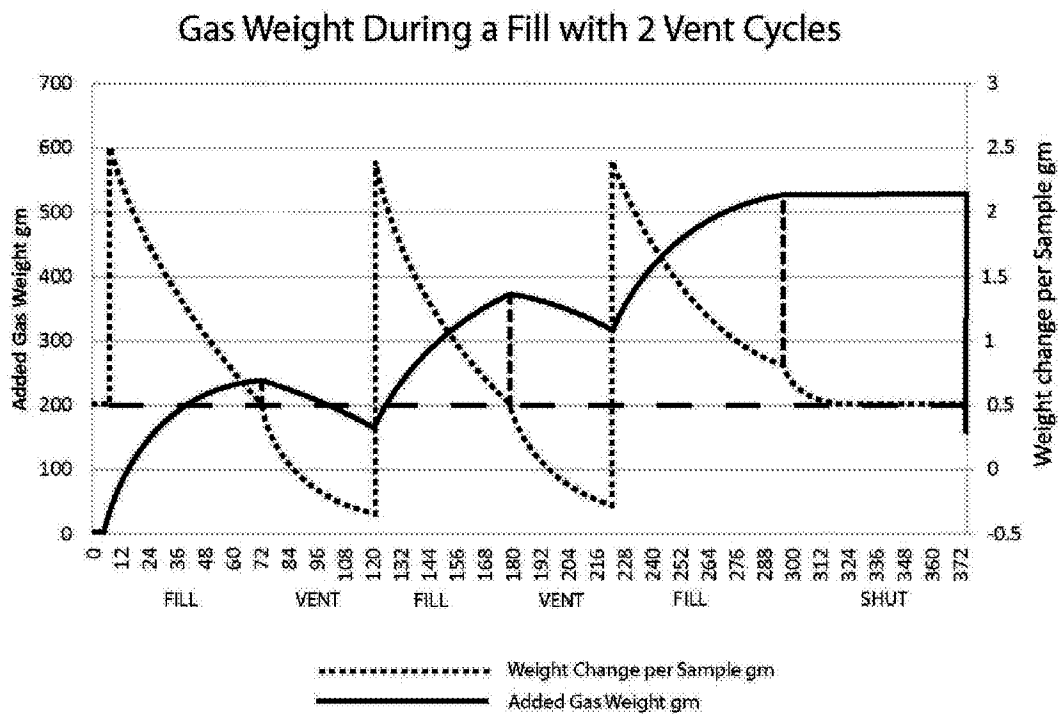


FIGURE 8

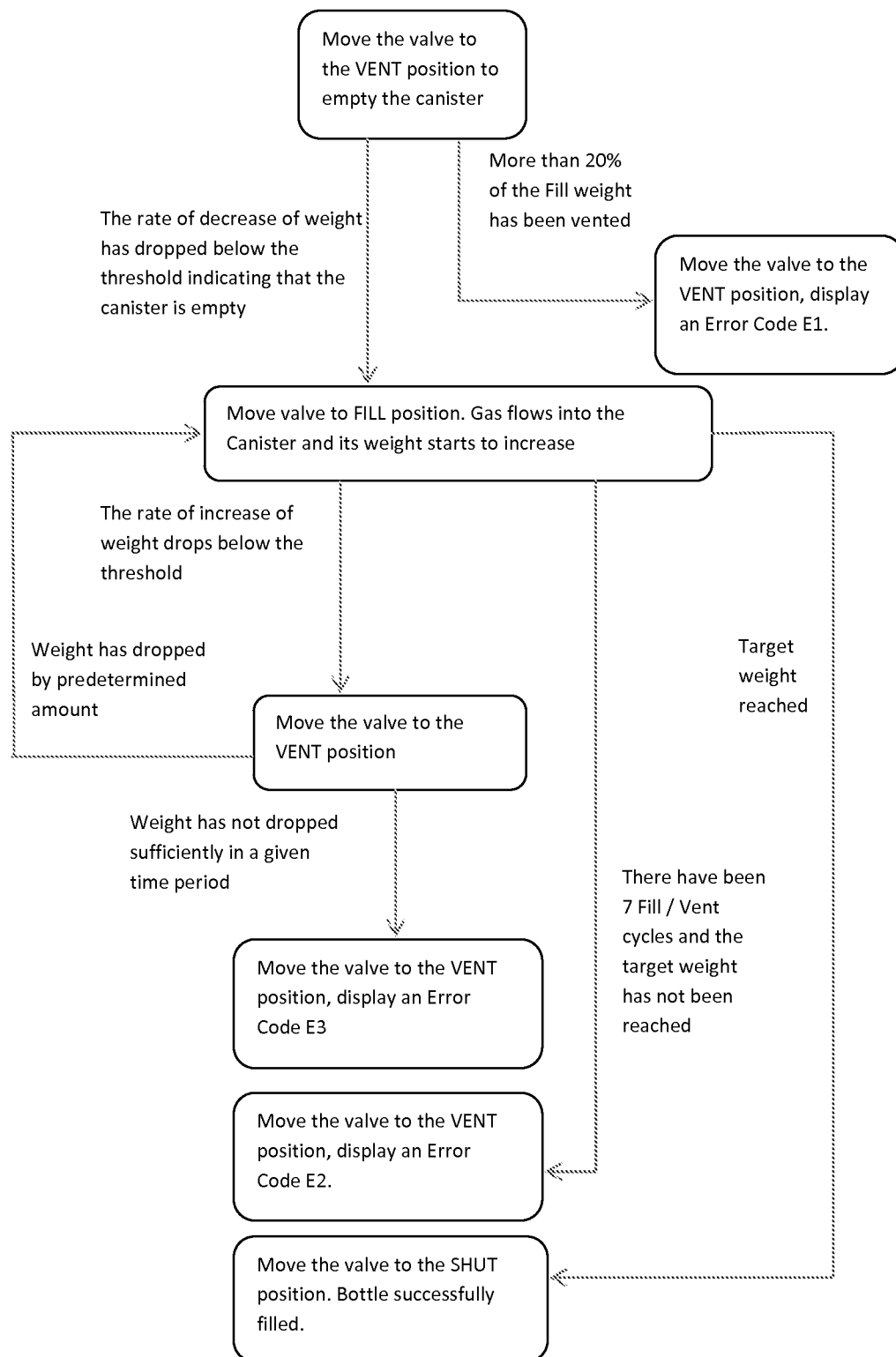


FIGURE 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2013/051521

A. CLASSIFICATION OF SUBJECT MATTER

F17C 13/10 (2006.01) F17C 5/02 (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

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

EPODOC, WPI, TXTE, Google: f17c5, f17c7, f17c13, vent, exhaust, empty, emit, vacate, rate, speed, pace, time, weight, mass, light, load, scale, remain, left, carbon, c02, dry ice

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	



Further documents are listed in the continuation of Box C



See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search
21 June 2013Date of mailing of the international search report
21 June 2013

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INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/IB2013/051521
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 220193 B1 (SPRIOMEC AB) 06 May 1987 figs.2-4 and col.1 ln.3-8	1-36
T	http://www.safety-marine.co.uk/spages/carbon-dioxide-fire-extinguishers.htm (Retrieved from the internet 14 June 2013) Section: Why Don't Carbon Dioxide Fire Extinguishers Have Pressure Gauges?	12-85

Form PCT/ISA/210 (fifth sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2013/051521**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See Supplemental Box for Details

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Supplemental Box**Continuation of: Box III**

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

- Claims 1-36 are directed to an apparatus for filling a pressure vessel. The feature of actuating the fill and vent valves with a camshaft is specific to this group of claims.
- Claims 37-85 are directed to a method of filling a pressure vessel. The feature of the means to measure the rate of change of weight to identify when the cylinder is empty is specific to this group of claims.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

When there is no special technical feature common to all the claimed inventions there is no unity of invention.

In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. Therefore there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a priori*.

INTERNATIONAL SEARCH REPORT Information on patent family members		International application No. PCT/IB2013/051521	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
EP 220193 B1	06 May 1987	EP 0220193 B1	06 Dec 1989
		SE 442544 B	13 Jan 1986
		SE 8404666 A	13 Jan 1986
		US 4648431 A	10 Mar 1987
		WO 8601871 A1	27 Mar 1986
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			