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CONCENTRATION OF A GAS CONSTITUENT OF AIR

The present invention relates to, *inter alia*, an air compressor, a gas-concentrating apparatus which may include at least one such compressor, and a method of concentrating
5 and supplying gas. The invention has particular, but not exclusive, application to oxygen concentration for therapeutic purposes.

Administration of oxygen for inhalation is a therapeutic, and often life-saving, treatment, including for pneumonia sufferers, which has been a standard of care in well-resourced
10 settings for more than 50 years. Significant effort has been dedicated to tackling the issue of how to provide oxygen to people in need of it. Two options currently exist: oxygen concentrators and compressed oxygen cylinders. Where electricity is available, oxygen concentrators are typically the more cost-effective option.

To date, the problem of how to provide therapeutic oxygen to people in remote locations, particularly underdeveloped communities, has, in effect, been interpreted as "how does one
15 provide electricity to oxygen concentrators?", reflecting a mindset whereby solutions have been substantially limited to conventional approaches such as fossil fuel-powered generators and solar-powered systems. In particular a lack of availability of therapeutic
20 oxygen to neonates in such locations leads to otherwise preventable deaths from conditions such as pneumonia, as already mentioned, and prematurity.

Solar electricity-generating systems for powering oxygen concentrators not only are expensive but must also be over-specified to ensure sufficient power availability for
25 operation of the concentrator during night-time hours. Adiabatic air compressors of the type typically used in oxygen concentrators are very inefficient, with about 80% of the electricity used to power them generating waste heat.

According to a first aspect of the present invention, there is provided an air compressor,
30 reciprocatingly drivable by suction, for pressurising atmospheric air and outputting the pressurised air, comprising:

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interengaged first and second air reservoirs, each of which is configured to assume an expanded condition and a contracted condition;

an output;

a first switching means configured such that, in a first condition thereof, it provides
5 fluid communication between the first air reservoir and a source of said suction and, in a second condition thereof, precludes that fluid communication and provides fluid communication between the first air reservoir and atmosphere; and

a second switching means configured such that, in a first condition thereof, it provides fluid communication between the second air reservoir and the output and, in a
10 second condition thereof, it precludes that fluid communication and provides fluid communication between the second air reservoir and atmosphere,

the apparatus being operable such that:

during an air delivery stroke thereof, said switching means assume their first conditions whereby the fluid communication between the first air reservoir and suction
15 source results in withdrawal of air from the first air reservoir and thus movement of the first air reservoir from an expanded condition into a contracted condition, and, owing to the interengagement between the air reservoirs and the fluid communication between the second air reservoir and output, movement of the second air reservoir from an expanded condition into a contracted condition and thus compression of air in the second air
20 reservoir and delivery of the compressed air to the output;

during an air intake stroke thereof, said switching means assume their second conditions whereby the first and second air reservoirs are permitted to revert to their expanded conditions and, owing to the fluid communication between the air reservoirs and atmosphere, air is thus drawn into the first and second air reservoirs from atmosphere; and

25 when the air intake stroke is complete, the switches reassume their first conditions, whereby driving of the apparatus is continuous.

Preferably, either or each switching means comprises a mechanically actuatable switch. Preferably the switch is pneumatic.

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Preferably, either or each switching means is configured with an actuator and the air

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compressor is configured such that the or each actuator is engaged by movement of either or each of the air reservoirs into its contracted condition such that the switching means configured therewith is moved from its first condition into its second condition and is engaged by movement of either or each of the air reservoirs into its expanded condition
5 such that the switching means configured therewith is moved from its second condition into its first condition. Preferably, either or each switching means comprises a limit switch.

Preferably, either or each of the first and second gas reservoirs comprises a deformable
10 receptacle. Preferably, the deformable receptacle comprises bellows.

Either or each of the gas reservoirs may, instead of comprising a deformable receptacle, be defined by a cylinder and a piston arranged to move reciprocatingly in the cylinder, the internal volume of that gas reservoir being delimited by a surface of the piston and an
15 internal surface of the cylinder and varying according to the position of the piston in the cylinder. Preferably, such a gas reservoir would be the first gas reservoir. Accordingly, lubricant provided to the piston and cylinder can then be isolated from, so as not to contaminate, the delivered air.

20 Preferably, the coupling between the first and second reservoirs is mechanical. Preferably, the coupling comprises a bracket via which the reservoirs are interconnected.

Preferably, each of the first and second air reservoirs is biased towards its expanded condition such that air is drawn from atmosphere thereinto when the switching means have
25 assumed their second conditions. Preferably, either or each of the first and second air reservoirs is gravitationally biased towards its expanded condition. Alternatively, either or each of the first and second air reservoirs may be resiliently biased, e.g. spring-biased, towards its contracted condition.

30 In a preferred embodiment of the invention, the air compressor further comprises interengaged third and fourth air reservoirs, each of which is configured to assume an

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expanded condition and a contracted condition, the first switching means is configured such that, in the first condition thereof, it provides fluid communication between the third air reservoir and atmosphere and, in the second condition thereof, it provides fluid communication between the third air reservoir and the suction source, and the second
5 switching means is configured such that, in the first condition thereof, it provides fluid communication between the fourth air reservoir and atmosphere and, in the second condition thereof, it provides fluid communication between the fourth air reservoir and the output, whereby:

during said air intake stroke, the fluid communication between the third air
10 reservoir and the suction source results in withdrawal of air from the first air reservoir by the suction source and thus movement of the first air reservoir from an expanded condition into a contracted condition, and, owing to the interengagement between the third and fourth air reservoirs and the fluid communication between the fourth air reservoir and the output, movement of the fourth air reservoir from an expanded condition into a contracted
15 condition and thus compression of air in the fourth air reservoir and delivery of that air to the output; and

during said air delivery stroke, the third and fourth air reservoirs are permitted to revert to their expanded conditions and, owing to the fluid communication between the third and fourth air reservoirs and atmosphere, air is thus drawn into the third and fourth air
20 reservoirs from atmosphere.

Preferably, either or each switching means includes one or more valves, preferably check valves, which may be disparately arranged in the compressor. One or more valve(s) forming part of one switching means may also form part of the other switching means.

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Preferably, the air compressor of that embodiment is configured such that the first switching means, in the second condition thereof, precludes said fluid communication between the third air reservoir and atmosphere, and such that the second switching means, in the second condition thereof, precludes said fluid communication between the fourth air
30 reservoir and atmosphere.

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Preferably, in the air compressor of that embodiment, the first and second reservoirs are engaged with the third and fourth reservoirs.

Preferably, each of the third and fourth air reservoirs is biased towards its contracted
5 condition such that air is drawn from atmosphere thereinto when the switching means have assumed their second conditions. Preferably, either or each of the third and fourth air reservoirs is gravitationally biased towards its contracted condition. Alternatively, either or each of the third and fourth air reservoirs may be resiliently biased, e.g. spring-biased, towards its contracted condition.

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According to a second aspect of the present invention, there is provided a concentrator operable to concentrate a gas constituent of atmospheric air, the concentrator comprising:

an air compressor apparatus drivable by a suction source;

gas-extracting means arranged to receive flowing pressurised air output from the air
15 compressor apparatus whereby to extract selectively from that air at least one gas constituent other than the constituent to be concentrated; and

outputting means, downstream of the gas-extracting means, configured to deliver a flow of gas rich in the concentrated constituent from the gas extracting means.

20 Preferably, the air compressor apparatus is reciprocating, having an air delivery stroke and an air intake stroke. Preferably, the air compressor apparatus is configured such that, during the air intake stroke, the gas-extracting means is in fluid communication with the suction source, such that the or each extracted gas constituent is drawn from the gas-extracting means by suction.

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In one preferred embodiment of the invention, the air compressor apparatus comprises said air compressor fluidly coupled to the gas-extracting means via said output. Preferably, the gas-extracting means includes a molecular sieve and the concentrator is configured such that, during the air intake stroke, the gas-extracting means is in fluid communication with
30 the suction source, such that the or each extracted gas constituent is drawn from the gas-extracting means by suction. Preferably, the concentrator is configured such that the

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fluid communication between the gas-extracting means and suction source is precluded by at least the second switching means in its first condition and permitted by the second switching means in its second condition. Preferably, the first switching means is configured so as to be fluidly interconnected with the suction source, the first switching
5 means and second switching means are fluidly interconnected, and the concentrator is configured such that the fluid communication between the gas-extracting means and the suction source is via the first and second switching means in their second conditions.

In an alternative embodiment of the invention, the air compressor apparatus of the
10 concentrator could comprise mechanically connected rotating blowers instead of bellows. Such an embodiment might be particularly appropriate in non-medical/non-therapeutic applications, in which attendant maintenance requirements do not represent a contamination risk.

15 Preferably, the gas-extracting means comprises a molecular sieve.

In the concentrator according to a preferred embodiment of the invention, said gas-extracting means comprises first and second molecular sieves, the concentrator of that embodiment being configured such that the second switching means, in the first condition
20 thereof, provides fluid communication, via the output, between the first molecular sieve and the first air reservoir such that the air from the second air reservoir is delivered to the first molecular sieve via the output, and the second switching means, in the second condition thereof, provides fluid communication, via the output, between the second molecular sieve and the fourth air reservoir, such that the air from the fourth reservoir is
25 delivered to the second molecular sieve via the output.

Preferably, the concentrator of that embodiment is configured such that the second switching means, in the first condition thereof, provides fluid communication between the second molecular sieve and the suction source, whereby desorbed gas from the second
30 molecular sieve is extracted by the suction source, and the second switching means, in the second condition thereof, provides fluid communication between the first molecular sieve

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and the suction source, whereby desorbed gas from the first molecular sieve is extracted by the suction source. Preferably, the air compressor includes a draw adjustor which is arranged upstream of the suction source so as:

5 to receive air from the first air reservoir when the first switching means is in its first condition and to receive air from the third air reservoir when the first switching means is in its second condition; and

to receive desorbed gas from the second molecular sieve when the second switching means is in its first condition and to receive desorbed gas from the first molecular sieve when the second switching means is in its second condition,

10 the draw adjustor being operable to apportion variably suction from the suction source between the desorbed gas extracted by the suction source and the air withdrawn from the first and third reservoirs.

Preferably, the first and second reservoirs are engaged with the third and fourth reservoirs.

15

Preferably, the or each molecular sieve incorporates a zeolite. Preferably, the gas-extracting means or zeolite is one which selectively extracts or adsorbs, respectively, nitrogen, whereby the concentrated gas constituent is oxygen.

20 According to a third aspect of the present invention, there is provided an apparatus for concentrating a gas constituent of atmospheric air ("concentrating apparatus"), comprising:

said concentrator;

said suction source; and

an output comprising said outputting means,

25 wherein the air compressor apparatus is fluidly connected to the suction source to be drivable thereby.

Preferably, the suction source comprises a conduit configured to carry flowing fluid, the conduit being configured with a gas inlet via which the air compressor apparatus and
30 conduit are fluidly interconnected, such that a vacuum is applied to the air compressor apparatus by the flowing fluid.

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In one preferred embodiment of the invention, the concentrating apparatus comprises a siphon defining the conduit. Preferably, an intake of the siphon is submerged in a liquid supply reservoir which is pre-existing. The liquid supply reservoir may be naturally
5 occurring; for example, it may be defined by a river, stream, lake or the like. Alternatively, the liquid reservoir may be manmade; for example, it may be defined by a dam, water tank or the like. The siphon may have an output which is submerged in liquid in a liquid collection reservoir having a level which is lower than a level of the liquid in the liquid supply reservoir. Alternatively, the siphon output may be open to atmosphere.

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In another preferred embodiment of the invention, the conduit comprises a venturi having a constriction at which the gas inlet is located, whereby the fluid flow applies suction to the air compressor apparatus. The conduit may comprise a pipe, which may be pre-existing, e.g. one which supplies water to a remote community. The conduit may, instead, be one
15 arranged in an environment in which there is a pre-existing liquid flow, e.g. a watercourse or a location where there is tidal flow.

In the preferred embodiments of the invention, the fluid flow in the conduit is driven by pre-existing potential and/or kinetic energy of the fluid, which energy is preferably
20 naturally occurring.

The concentrating apparatus according to one preferred embodiment of the invention comprises, in addition to said concentrator ("the first concentrator"), a further said concentrator ("the second concentrator") the air compressor apparatus of which is fluidly
25 connected to the suction source to be drivable thereby, and the concentrator output includes the outputting means of the second concentrator. Preferably, the air compressor apparatuses of the first and second concentrators are out of step or not in phase, whereby the concentrating apparatus delivers a substantially continuous output of gas rich in the concentrated constituent. Preferably, the air compressor apparatuses of the first and
30 second concentrators are half a cycle out of step or 180° out of phase.

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Preferably, each air compressor apparatus of the concentrating apparatus according to said particularly preferred embodiment comprises a said air compressor. Preferably, the gas-extracting means of each concentrator in the concentrating apparatus according to said particularly preferred embodiment comprises a said molecular sieve.

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The concentrating apparatus may comprises plural said concentrators the air compressor apparatus of each which is fluidly connected to the suction source to be drivable thereby, and may be configured such that the air compressors are driven with phase differences therebetween of $360^\circ/N$ where N is the number of air compressors.

10

Preferably, the concentrating apparatus output includes a gas accumulator downstream of the outputting means of the or each concentrator whereby to receive, from the or each concentrator, the concentrated constituent-rich gas, such that the concentrating apparatus can output at a pressure which is substantially uniform or which fluctuates to a
15 thus-reduced extent.

In a particularly preferred embodiment of the invention, the concentrating apparatus is a therapeutic oxygen concentrator. To this end, the concentrating apparatus output preferably includes a mask, or other suitable facial fitting, downstream of the or each
20 outputting means, via which oxygen-rich gas output by the gas-extracting means can be inhaled. In another preferred embodiment of the invention, 41, the concentrating apparatus is a nitrogen concentrator apparatus, which may be, for example, a food-preserving apparatus or a welding apparatus.

25 In an alternative embodiment of the invention, the concentrating apparatus is a liquid oxygenating apparatus, e.g. a water oxygenating apparatus, configured to deliver the constituent-rich gas to a liquid/water. The concentrating apparatus may, for example, comprise a fish tank oxygenating apparatus, configured to supply oxygen to water in a fish tank.

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Preferably, the apparatus includes a gas accumulator arranged to receive, from the or each

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concentrator, said concentrated constituent-rich gas.

According to a fourth aspect of the present invention, there is provided a method of concentrating a gas constituent of atmospheric air, comprising operation of said
5 concentrating apparatus. Preferably, said gas constituent comprises oxygen.

According to a fifth aspect of the present invention, there is provided a method of administering oxygen-rich gas, comprising operation of said concentrating apparatus to produce said gas, wherein said gas is inhaled.

10

Preferred embodiments of the invention provide a means of creating air pressure cycles required to concentrate oxygen directly from flowing fluid, particularly water.

The invention will now be described, by way of non-limiting example only, with reference
15 to the accompanying drawings, in which:

Figure 1 is a semi-schematic view of an oxygen concentrator apparatus according to a first preferred embodiment of the invention at the beginning of an operational cycle thereof;

Figure 2 is a semi-schematic view of a siphon defining a vacuum source in the
20 apparatus;

Figure 3 is a semi-schematic layout view of the apparatus of the first embodiment halfway through the operational cycle thereof;

Figure 4 is a semi-schematic view of an oxygen concentrator apparatus according to a second preferred embodiment of the invention;

Figure 5 shows bellows and a supporting frame structure of an oxygen concentrator unit which forms part of the apparatus according to either of the first and second
25 embodiments;

Figure 6 is a semi-schematic view of an oxygen concentrator apparatus according to a third preferred embodiment of the invention in which a reciprocating stirrup of the
30 apparatus has just commenced moving downwardly, having reached the top of its stroke;

Figure 7 is a semi-schematic view of the apparatus of the third embodiment in

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which the stirrup is approaching the bottom of its stroke;

Figure 8 is a semi-schematic view of the apparatus of the third embodiment in which the stirrup has reversed in direction, having just reached the bottom of its stroke;

Figure 9 a semi-schematic view of the apparatus of the third embodiment in which
5 the stirrup is approaching the top of its stroke; and

Figure 10 is a graph showing typical air constituent gas adsorption characteristics of a zeolite as incorporated in a molecular sieve forming part of the apparatus according to any one of the embodiments.

10 Shown in schematic form in Figures 1 and 3 is an oxygen concentrator apparatus 1 according to a preferred embodiment of the present invention. The concentrator 1 of the present embodiment is specifically configured for the purposes of providing oxygen, and more particularly, oxygen-rich gas extracted from air, for therapeutic purposes, including in particular for treatment of pneumonia, as will be further described later.

15

The apparatus 1 comprises a vacuum source 3 which, as shown in Figure 2, takes the form of a siphon arrangement 5 comprising an inverted U-shaped fluid conduit 7, a first liquid reservoir 9, containing liquid in which an inlet end of the conduit 7 is submerged, and a second liquid reservoir 11, containing liquid in which an outlet end of the conduit 7 is
20 submerged, the level of the surface of the liquid in the reservoir 11 being lower than the level of the surface of the liquid in the reservoir 9. Both of the reservoirs 9 and 11 are open to atmosphere. The conduit 7 is configured with an air inlet 13, located on a downward section thereof, through which the liquid flowing through the conduit 7 draws air whereby to drive the apparatus 1, as will be described in further detail later. As water is
25 raised through the pipe 7, a static pressure drop is created, owing to conservation of mechanical energy, the pressure drop being proportional to the height the liquid is raised above the conduit outlet or level of the water in the reservoir 11. Connection of smaller-diameter pipe 13 to a section of the pipe 7 in which the water travels downwards gives rise to a usable vacuum.

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The reservoirs 9 and 11 are pre-existing in the environment in which the apparatus 1 is

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utilised; for example, they may be defined by first and second, respectively, regions of a water course, the level of the water in the second region being lower than the level of the water in the first region (so that the former is downstream of the latter). In many instances, the reservoirs will be naturally occurring; for example, where they are defined by a water
5 course, that water course may be a river, stream, creek, tributary or the like.

As will be appreciated by a person skilled in the art, the second liquid reservoir 11 need not be present; the outlet of the conduit may instead open to atmosphere without departure from the invention. Reservoir 9 may thus also, for example, be defined by an elevated
10 body of water which is not flowing, such as a lake.

The apparatus 1 further comprises, referring also to Figure 5 (from which several details of the apparatus 1 are omitted for clarity purposes), a support structure, in the form of a frame 20, first 22 and second 24 bellows supported from the structure 20, and a stirrup 26
15 which is supported from the bellows 22, 24. The bellows 22 is attached, at an upper end thereof, to a plate section 21 of the frame 20, so as to depend therefrom, and the bellows 24 is attached, at an upper end thereof, to a plate section 23 of the frame 20, so as to depend therefrom, the section 23 being arranged below the section 21. An upper section 28 of the stirrup 26 is coupled to a lower end of the bellows unit 22, and a lower section 29 of the
20 stirrup 26 is coupled to a lower end of the bellows unit 24, the stirrup thus being coupled to the support frame 20 via the bellows units 22, 24 so as to be able to move upwardly and downwardly relative to the support frame 20, which is configured to constrain the movement of the stirrup 26 to being solely in a substantially up/down direction. As a result, and as will be described in further detail later, contraction of the bellows 22 draws
25 the stirrup 26 upwardly, such that the stirrup lower section 29 forces the lower end of the bellows unit 24 upwardly, thus causing that unit to contract also and compress air therein.

The apparatus 1 further includes a first switch 30, which will be described in further detail later, and a first air discharge line 40, which fluidly interconnects the bellows unit 22 with
30 a first port 32 of the switch 30. The apparatus 1 additionally includes a vacuum line 42 which fluidly interconnects a second port 34 of the switch 30 to the siphon air inlet 13.

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The apparatus 1 also includes a second switch 50 and a second air discharge line 48 which fluidly interconnects the second bellows 24 and a first port 52 of the second switch 50. In addition, the apparatus 1 comprises a reusable molecular sieve 60 and a gas line 44 which
5 fluidly interconnects a second port 54 of the switch 50 with the molecular sieve 60, and additionally includes an oxygen-rich gas output line 65 and a check valve 67 arranged on the line 65 to permit oxygen-rich gas from the sieve 60 to flow through that line only in the output direction.

10 The apparatus 1 further comprises a gas transfer line 46 which fluidly interconnects a third port 56 of the second switch 50 and a third port 36 of the first switch 30.

The apparatus 1 additionally includes a first actuator 92 connected to the stirrup such that it moves therewith so as to act on an actuator (not shown) of the switch 30, and a second
15 actuator 94, connected to the stirrup such that it moves therewith so as to act on an actuator (not shown) the second switch 50 as will be described in further detail later.

Operation of the apparatus 1 will now be described.

20 In a starting condition of the apparatus 1, shown in Figure 1, the actuator components 92 and 94 are each in a first or "down" position, whereby first switch 30 is in a condition such that inlet 32 is in fluid communication with outlet port 34 (but fluidly isolated from the other ports of the switch 30), and whereby the second switch 50 is in a condition such that inlet port 52 is fluidly interconnected with port 54 (but fluidly isolated from all of the other
25 ports of the switch 50). As a result, under suction applied by the vacuum 3, air is drawn from bellows unit 22, through the passage defined by line 40, switch 30 and line 42, whereby the lower end of the bellows unit 22, as that unit thus contracts, is displaced upwardly, drawing the stirrup 26 upwardly with it so that the lower end of the bellows unit 24 is forced upwardly by the stirrup lower section 29 and the resulting decrease in
30 internal volume of the bellows unit 24 gives rise to compression of air in that unit. Pressurised air thus flows from the bellows unit 24, through the passage defined by the

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line 48, switch 50 and line 44, to the molecular sieve 60, which sieve incorporates a zeolite that selectively removes gaseous nitrogen (N_2) from the pressurised air forced therethrough, as will be known to a person skilled in the art. Oxygen-rich pressurised gas discharged from the outlet end of the sieve 60 urges the check valve 67 open, whereby to
5 be output from the apparatus via the line 65. Coupled to a downstream end of the line 65 is a mask (not shown), as will be known to a person skilled in the art, via which a patient can inhale therapeutic pressurised oxygen-rich gas output via the line 65.

Referring to Figure 3, when the thus upwardly displaced stirrup 26 reaches the top of its
10 stroke, the actuators 92 and 94 engage the corresponding actuators of the switches 30 and 50 respectively, effecting movement of each of them into a second or "up" position, whereby switch 30 is placed in a condition such that the port 36 is in fluid communication with the port 34 (but isolated from the other ports of the switch 30) and such that a fourth
15 port 38 thereof, which opens to atmosphere, is in fluid communication with the port 32, and whereby the second switch 50 is placed in a condition such that the port 56 is in fluid communication with the port 54 and the port 52 is in fluid communication with a fourth port 58 of the switch 50 that is open to atmosphere. As a result, the ongoing suction applied by the vacuum 3, draws gas from the sieve 60, through the passage defined by
20 line 44, switch 50, line 46, switch 30 and line 42, effecting desorption of nitrogen from the zeolite and thence removal thereof, via that passage. At the same time, the bellows unit 24, because it is fluidly connected to atmosphere via the passage defined by line 48 and switch 50, and the bellows unit 22, because it is fluidly connected to atmosphere via the passage defined by line 40 and switch 30, allow downward displacement of the stirrup 26 and a resulting expansion of the bellows units 22 and 24 drawing air from
25 atmosphere. Upon the stirrup, and thus each of the bellows lower ends, reaching the lower end of its stroke, the the actuators 92 and 94 again engage the actuators of switches 30 and 50 respectively, thus effecting movement of them into their "down" positions, as previously described, and the cycle repeats.

30 By adjusting the vertical distance between the conduit outlet and the junction between the pipe 13 and conduit 7, the vacuum pressure (i.e., degree of suction) can be adjusted; the

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higher the junction, the greater the vacuum pressure. However, the junction should be located below the apex of the conduit, as shown in Figure 2, whereby the water flow will carry the gas bubbles, formed in the water due to discharge of nitrogen-rich gas from the unit(s), to the conduit outlet, so that cavitation in the conduit 7 is avoided.

5

The assembly demarcated by the broken-line rectangle in Figure 1 constitutes an oxygen concentrator unit 100.

10 An oxygen concentrator apparatus 1' according to a second preferred embodiment of the invention is shown semi-schematically in Figure 4.

15 The apparatus 1' comprises a pair of oxygen concentrator units 100, each unit 100 being fluidly coupled, via respective line 42 therein, to the vacuum inlet 13. Each unit is also fluidly coupled, via line 65 therein downstream of the respective check valve 67, to the mask.

20 The units are configured such that the phase difference in their cycles is 180°, whereby when one unit 100 has the configuration shown in Figure 1, the other has the configuration shown in Figure 3. Accordingly, when one unit 100 is in its compression stroke or oxygen-delivery phase, the other is in its air intake stroke or nitrogen-expelling phase. Advantageously, there is thus a substantially continuous supply of oxygen-rich gas to the mask, the check valve 67 of each unit 100 when in its nitrogen-expelling phase precluding backward flow, into the sieve 60 of that unit, of oxygen-rich gas from the sieve 60 of the other unit 100 (which is in its oxygen-delivery phase).

25

Either or each of the apparatuses 1 and 1' may further include a gas accumulator (not shown) downstream of the check valve(s) 67 and upstream of the mask, such that the oxygen-rich gas output through the mask is at a pressure which is substantially uniform or which fluctuates to a reduced extent.

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An oxygen concentrator apparatus 1'' according to a third preferred embodiment semi-

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schematically in Figures 6 to 9. The apparatus 1'' operates according to essentially the same principles as the apparatus 1', though has a different topography, in which the pairs of bellows are integrated in a single stirrup/frame structure, as will be described in further detail shortly.

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The apparatus 1'' includes, and is powered by, a vacuum source 3 of the same kind as in the first and second embodiments. The apparatus 1'' further includes a support structure, in the form of a frame 20A, a first pair of bellows 22A, 22B and a second pair of bellows 24A, 24B, both pairs of bellows being supported from the structure 20, and a
10 stirrup 26A which is supported from the pairs of bellows and (like the stirrups in the first and second embodiments) is slidably, or otherwise movably, coupled to the frame in a manner so as to be constrained to axial movement only with respect to the frame. The frame 20A includes an upper section 21A, to which a lower end of the bellows unit 22A and an upper end of the bellows unit 24A are anchored, and a lower section 21B, to which
15 a lower end of the bellows unit 24B and an upper end of the bellows unit 22B are anchored. Each of the sections 21A and 21B may, as in the first and second embodiments, be configured in the form of a plate. An upper section 28A of the stirrup 26A is connected to an upper end of the bellows unit 22A, an intermediate section 27A of the stirrup is connected to the lower end of the bellows unit 24A. A lower section 29A of the stirrup 26A
20 is coupled to a lower end of the bellows unit 22B.

The bellows 22A, 22B alternately output air from which oxygen is to be extracted, whereas the bellows 24A and 24B alternately urge the stirrup 26A towards the top and bottom, respectively, of its stroke, the former doing so by being evacuated and the latter
25 doing so by being inflated, as will be described in further detail later. Although the apparatus 1'' is configured such that the motion of the stirrup 26A is along a substantially upright axis, it will be appreciated that the apparatus 1'' can, without departure from the invention, be modified such that the axis is otherwise orientated, e.g. horizontal (in which case the motion of the stirrup 26A as shown in Figures 6 and 7 is driven by evacuation of
30 bellows 24B solely, i.e. with no gravity assistance offered by the stirrup 26A.

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The apparatus 1" further includes a first switch unit 130 operable to provide, in an alternating manner, fluid communication between the interior of one of the bellows units 24A, 24B while simultaneously providing fluid communication between the interior of the other of those bellows units and atmosphere (as will be described in further detail later), a draw adjustor 70 (also described in further detail later), and an air discharge line fluidly interconnecting a first port P1 of the switch unit 130 and the draw adjustor 70. The apparatus 1" further includes a vacuum line 42A which fluidly interconnects the draw adjustor 70 (also described in further detail later) to the siphon air inlet 13A of the vacuum pump 3.

10

The apparatus 1" also includes a second switch unit 150 and a nitrogen-rich gas discharge line 46B which fluidly interconnects outlet ports (being the "third port" Q3 and "fifth port" Q5) of the switch unit 150 and the draw adjustor 70.

15 The apparatus 1" further includes a line 48A arranged to carry air, alternatingly output by bellows units 22A and 22B, to an inlet port, namely the "first port" Q1, of the switch 150.

The apparatus 1" includes air delivery/exhaust lines 40A, 40B, the former fluidly interconnecting the interior of bellows unit 24A with a port, namely the "fourth port" P4 of the switch unit 130, and the latter fluidly interconnecting the interior of the bellows unit 24B with another port, namely the "second port" P2 of the unit 130.

The apparatus 1" further comprises air transfer lines 48B, 48C, the former extending from the interior of the bellows unit 22A to a check valve 71 of the apparatus 1" (via which check valve the line 48B connects to line 48A), and the latter extending from the interior of the bellows unit 22B to a check valve 72 of the apparatus 1" (via which check valve the line 48C connects to the line 48A). The check valve 71 is operable to open, thereby placing line 48B in fluid communication with line 48A, when air pressure in the line 48B exceeds air pressure in the line 48A. Similarly, the check valve 72 is configured to open, thereby placing the line 48C into fluid communication with the line 48A, only when the fluid pressure in the line 48C exceeds that in the line 48A.

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The apparatus further includes a check valve 73 which is arranged to place the line 48B into fluid communication with atmosphere when fluid pressure in the line 48B is less than atmospheric pressure, and a check valve 74 arranged to open and thereby provide fluid
5 communication between atmosphere and line 48C when fluid pressure in the line 48C is less than atmospheric pressure.

The apparatus 1" further includes a first sieve 60A, a gas transfer line 44A fluidly interconnecting the sieve 60A and a port, namely the "fourth port" Q4, of the switch
10 unit 150, a second sieve 60B, and a gas transfer line 44B fluidly interconnecting the sieve 60B and a port, namely the "second port" Q2, of the switching unit 150, the lines 44A and 44B defining outputting means of the apparatus 1".

The apparatus 1" additionally comprises a nitrogen-rich gas transfer line 65A, a check
15 valve 67A between an output port of the sieve 60A and the line 65A, a check valve 67B between an output port of the sieve 60B and the line 65A, and an oxygen-rich gas accumulator 80 (consistent with that referred to above) to which a downstream end of the line 65A is fluidly connected. The check valves 67A and 67B open to allow flow of oxygen-rich gas, output from the sieves 60A and 60B respectively, when the gas pressure
20 therein exceeds the gas pressure in the line 65A.

The apparatus 1" includes an output line 65B via which oxygen-rich gas supplied to the accumulator 80, via the line 65A, by the sieves 60A, 60B, is delivered to a mask 68, and further includes a check valve or demand valve 69, arranged on line 65B, and configured
25 to open upon inhalation by a person wearing the mask.

The apparatus 1" further includes an efficiency valve 75 arranged on line 48A, comprising a check valve which opens to atmosphere, the operation of which valve will be described in further detail later.

30

Furthermore, the apparatus includes a first actuator 93 connected to the stirrup 26A such

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that it moves therewith so as to operate the switch 130, and a second actuator 93B, connected to the stirrup 26A such that it moves therewith so as to operate the second switch 150.

- 5 Finally, the apparatus includes a bleed line 68 which extends between outlets of the sieves 67A and 67B, the operation of which will be described in further detail later.

Operation of the apparatus 1" will now be described.

- 10 In a starting condition of the apparatus 1", shown in Figure 6, the actuators 93A, 93B are each in a first or "up" position, whereby first switch 130 is in a condition such that the fourth port P4 is in fluid communication with another port, namely the "fifth port" P5, of the switch unit 130, so as to be open to atmosphere, and the port P2 is in fluid communication with port P1, and whereby the second switch unit 150 is in a condition such that a port,
15 namely the "first port" Q1, thereof is in fluid communication with port Q2, and the port Q4 is in fluid communication with port Q5. As a result, under suction applied by the vacuum 3, air is drawn from the bellows unit 24B whereby the top end of that bellows unit, assisted by the weight of the stirrup, downwardly and the bellows unit 22A thus contracts, causing air to be forced from it to the second sieve 60B. Meanwhile, bellows unit 24A
20 expands, drawing in atmospheric air, which enters through port P5, and bellows unit 22B likewise expands, drawing in atmospheric air through check valve 74.

- Air is thus delivered from bellows unit 22A to the second sieve 60B, from which oxygen-rich gas is thus output to the accumulator 80. At the commencement of the downward
25 stroke of the stirrup 26A, the switch units 130 and 150 have only just been toggled, by the actuators 92 and 94 respectively, into the configurations shown in Figure 6, whereby a vacuum is applied to the line 48A as a result of its being placed in fluid communication with the sieve 60B, causing the check valve 75 to open and thus an inrush of atmospheric air to nullify the vacuum (instead of the air in bellows unit 22A being scavenged to nullify
30 the vacuum and thus wasted). The valve 75 then closes and the downward stroke of the stirrup 26A proceeds, the apparatus 1", when the stirrup 26A reaches the bottom of its

- 20 -

stroke, assuming the configuration shown in Figure 7.

Upon the stirrup 26A reaching the bottom of its stroke, the actuator 93A, now assuming a “down” position, toggles the switch unit 130 such that the port P4 is in fluid communication with the port P1 and the port P2 is in fluid communication with the port P3 whereby to be open to atmosphere. Also, the actuator 93B, now also assuming a “down” position, toggles the switch unit 150 such that the port Q1 is in fluid communication with the port Q4, and the port Q3 is in fluid communication with the port Q2. As a result, under suction applied by the vacuum 3, air is drawn from the bellows unit 24A whereby the bottom end of that bellows unit, and thus the stirrup 26A, is drawn upwardly, the bellows unit 22B thus contracting, causing air to be forced from it to the first sieve 60A. Meanwhile, bellows unit 24A expands, drawing in atmospheric air, which enters through port 3, and bellows unit 22A likewise expands, drawing in atmospheric air through check valve 73. Air is thus delivered from bellows unit 22B to the first sieve 60A, from which oxygen-rich gas is thus output to the accumulator 80. At the commencement of the upward stroke of the stirrup 26A, when the switch units 130 and 150 have only just been toggled (to assume the condition shown in Figure 8), a vacuum is applied to the line 48A as a result of its being placed in fluid communication with the sieve 60A, causing the check valve 75 again to open and thus an inrush of atmospheric air to nullify the vacuum (instead of the air in the bellows unit 22B being scavenged to nullify the vacuum and thus wasted). The valve 75 then closes and the upward stroke of the stirrup 26A proceeds, the apparatus 1” when the stirrup 26A reaches the top of its stroke, assuming the configuration shown in Figure 9.

During output of oxygen-rich gas from sieve 67A, the line 68 transfers to sieve 67B a limited amount of that gas, which flushes or purges the desorbed nitrogen-rich gas from the sieve 67B. During output of oxygen-rich gas from sieve 67B, the line 68 transfers to sieve 67A a limited amount of that gas, which flushes or purges the desorbed nitrogen-rich gas from the sieve 67A. The line may, if appropriate, be provided with switching means (not shown), configured to be toggled according to the conditions of the first/second switching means to effect the transfer. The operation of line 68 contributes to the purity of

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the oxygen content of the output oxygen-rich gas.

The draw adjustor 70 is adjustable so as to vary the relative proportions of suction, applied by the vacuum pump 3, to the bellows 24A, 24B (via switch unit 130) and the
5 (nitrogen-removing) suction applied to the sieves 67A, 67B (via switch unit 150).

It will be appreciated that, in respect of a bellows pair consisting of bellows 24A (constituting a "first air reservoir") and bellows 22B (constituting a "second air reservoir"), the stirrup's downward stroke and upward stroke constitute an air intake stroke and an air
10 delivery stroke, respectively, of the apparatus 1", and that, in respect of a bellows pair consisting of bellows 24B (constituting a "third air reservoir") and bellows 22A (constituting a "fourth air reservoir"), the stirrup's downward stroke and upward stroke constitute an air delivery stroke and an air intake stroke, respectively, of the apparatus 1".

15 In each of the embodiments described with reference to the drawings, the actuators and switches which they operate can engage, for example, mechanically or magnetically, though it may be preferable that the engagement be magnetic such that toggling of each switch is effected rapidly and completely upon the respective actuator reaching the appropriate position in its stroke.

20

A graph showing typical air constituent gas adsorption characteristics of zeolite is shown in Figure 10 (taken from *Nelson, Peter R., "Oxygen from air by pressure swing adsorption" (1993). Cape Technikon Theses & Dissertations. Paper 111.*) The vacuum swing adsorption (VSA) process employed in the operation of each of the concentrator
25 apparatuses described with reference to the drawings provides numerous advantages over other (non-vacuum) pressure swing adsorption (PSA) processes exploited for end-of-the-line care. Owing to traversal of steeper parts of the nitrogen isotherms, comparatively little pressure difference (being maximum pressure minus desorption pressure) and, correspondingly, comparatively little energy, is required. A vacuum pressure of, for
30 example, -50kPa can be created by the siphon arrangement 3 whereby, owing to there being negligible losses in the units 100, each unit can output oxygen-rich gas at, for

- 22 -

example, 130kPa. Higher pressures can, of course, be achieved provided the strength of the apparatus components, particularly the bellows, is sufficient. Proof-of-principle measurements have cycled the zeolite between 0.5 atm and 1.5 atm.

- 5 Advantageously, the apparatuses 1, 1' and 1'' are not powered by electricity or fuel combustion but rather via harnessed gravitational potential energy of a pre-existing body of water, which in many cases will be naturally occurring. Because those apparatuses are not powered by fuel combustion, they can operate independent of supply chains and transport infrastructure, and have negligible environmental impact. Also, advantageously,
10 owing there being relatively few moving parts, capital costs and maintenance requirements are minimal.

Advantageously, because the suction applied by the vacuum 3 is continuous, there can be no backflow, from the siphon through the line(s) 42 or line 42A, of gas contaminated by
15 the water, so that the oxygen-rich gas which is output to the mask cannot possibly be contaminated by the water and the sieve(s) cannot be damaged by the water. Each of the apparatuses 1, 1', 1'' outputs oxygen-rich gas at sufficient positive pressure for administration to a person or, if desired, an animal.

- 20 The preferred embodiments of the invention provide a low-cost, low-maintenance, electricity-free, non-fuel-driven oxygen concentrator. Although typically the vacuum pressure created in the siphon 3 is relatively low (and thus useless for many other applications), it is more than adequate for the production, and delivery to a patient, of oxygen-rich gas.

25

In other embodiments of the invention, the vacuum source may be defined by an alternative arrangement in which flowing fluid which could, for example, be travelling horizontally, creates suction. For example, the vacuum source may comprise a conduit formed with a constriction, to which the/each line 42 or line 42A fluidly connects, whereby
30 acceleration, within the constriction, of fluid (liquid and/or gas) which flows through the conduit gives rise to a reduction in pressure and thus suction (via a venturi effect). The

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conduit could comprise a pre-existing conduit, such as a pipe (e.g. a pipe which supplies water to a remote community), fitted with a suitable constriction. Alternatively, the conduit could, for example, be one which is installed within a pre-existing environment in which water flows, such as a watercourse, as previously mentioned, or a location which experiences tidal flows. Such embodiments, which operate by harnessing kinetic energy, rather than gravitational potential energy, of fluid also, advantageously, require no electricity or fuel.

Also possible are embodiments of the invention in which the/each bellows unit arranged upstream of the respective sieve to push air that sieve is instead arranged downstream of the sieve to draw air through it. Such embodiments may be particularly suitable in non-medical/non-therapeutic applications, e.g. for the oxygenating liquid, such as water in a fish tank.

Also possible are embodiments of the invention in which alternative, naturally occurring, energy sources are employed to impart necessary gravitational potential and/or kinetic energy to the fluid the flow of which induces the driving suction. For example wind could be harnessed, via a windmill or wind turbine, to impart such energy.

The invention need not be limited to concentration of oxygen. For example, the apparatuses described with reference to the drawings could, without departure from the invention, be readily modified such that the nitrogen-rich desorbed gas is utilised, either in addition to or instead of the oxygen-rich gas. Owing to the relatively inert nature of the nitrogen-rich gas, that gas may, for example, be used in an inert gas welding application or to provide an inert atmosphere to an enclosed space (in which, for example, food could be preserved). Alternative zeolites may have a particular affinity for gas constituents of air other than nitrogen (including in particular argon, oxygen, hydrogen and carbon dioxide), so that other embodiments of the invention, comprising sieves incorporating any such zeolite, may be used to concentrate a different constituent gas. Such embodiments may have application, for example, to flue gases and post-combustion carbon dioxide capture or in "making" nitrogen - see, for example, the disclosure at

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http://www.uigi.com/nitrogenpsa.html which is incorporated herein by reference -- or carbon dioxide, ethylene or methane.

While various embodiments of the present invention have been described above, it should
5 be understood that they have been presented by way of example only, and not by way of limitation. It will be apparent to a person skilled in the relevant art that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Thus, the present invention should not be limited by any of the above described exemplary embodiments.

10

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

15

- 25 -

The claims defining the invention are as follows:

1. An air compressor, reciprocatingly drivable by suction, for pressurising atmospheric air and outputting the pressurised air, comprising:
 - 5 interengaged first and second air reservoirs, each of which is configured to assume an expanded condition and a contracted condition;
an output;
a first switching means configured such that, in a first condition thereof, it provides fluid communication between the first air reservoir and a source of said suction and, in a
10 second condition thereof, precludes that fluid communication and provides fluid communication between the first air reservoir and atmosphere; and
a second switching means configured such that, in a first condition thereof, it provides fluid communication between the second air reservoir and the output and, in a second condition thereof, it precludes that fluid communication and provides fluid
15 communication between the second air reservoir and atmosphere,
the apparatus being operable such that:
during an air delivery stroke thereof, said switching means assume their first conditions whereby the fluid communication between the first air reservoir and suction source results in withdrawal of air from the first air reservoir and thus movement of the
20 first air reservoir from an expanded condition into a contracted condition, and, owing to the interengagement between the first and second air reservoirs and the fluid communication between the second air reservoir and the output, movement of the second air reservoir from an expanded condition into a contracted condition and thus compression of air in the second air reservoir and delivery of the compressed air to the output;
 - 25 during an air intake stroke thereof, said switching means assume their second conditions whereby the first and second air reservoirs are permitted to revert to their expanded conditions and, owing to the fluid communication between the first and second air reservoirs and atmosphere, air is thus drawn into the first and second air reservoirs from atmosphere; and
 - 30 when the air intake stroke is complete, the switches reassume their first conditions, whereby driving of the apparatus is continuous.

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2. An air compressor according to claim 1, wherein either or each switching means comprises a magnetically actuatable switch.

5 3. An air compressor according to either one of the preceding claims, wherein either or each switching means is configured with an actuator, the air compressor being configured such that the or each actuator is engaged by movement of either or each of the air reservoirs into its contracted condition such that the switching means configured therewith is moved from its first condition into its second condition and is engaged by
10 movement of either or each of the air reservoirs into its expanded condition such that the switching means configured therewith is moved from its second condition into its first condition.

4. An air compressor according to any one of the preceding claims, wherein either or
15 each switching means comprises a limit switch.

5. An air compressor according to any one of the preceding claims, wherein either or each of the first and second gas reservoirs comprises a deformable receptacle.

20 6. An air compressor according to claim 5, wherein the or each deformable receptacle comprises bellows.

7. An air compressor according to any one of the preceding claims, wherein the coupling between the first and second reservoirs is mechanical.

25

8. An air compressor according to any one of the preceding claims, wherein each of the first and second air reservoirs is biased towards its expanded condition such that air is drawn from atmosphere thereinto when the switching means have assumed their second conditions.

30

9. An air compressor according to claim 8, wherein either or each of the first and

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second air reservoirs is gravitationally biased towards its expanded condition.

10. An air compressor according to any one of claims 1 to 9, further comprising interengaged third and fourth air reservoirs, each of which is configured to assume an expanded condition and a contracted condition, wherein the first switching means is
5 configured such that, in the first condition thereof, it provides fluid communication between the third air reservoir and atmosphere and, in the second condition thereof, it provides fluid communication between the third air reservoir and the suction source, and the second switching means is configured such that, in the first condition thereof, it
10 provides fluid communication between the fourth air reservoir and atmosphere and, in the second condition thereof, it provides fluid communication between the fourth air reservoir and the output, whereby:

during said air intake stroke, the fluid communication between the third air reservoir and the suction source results in withdrawal of air from the first air reservoir and
15 thus movement of the first air reservoir from an expanded condition into a contracted condition, and, owing to the interengagement between the third and fourth air reservoirs and the fluid communication between the fourth air reservoir and the output, movement of the fourth air reservoir from an expanded condition into a contracted condition and thus compression of air in the fourth air reservoir and delivery of that air to the output; and

20 during said air delivery stroke, the third and fourth air reservoirs are permitted to revert to their expanded conditions and, owing to the fluid communication between the third and fourth air reservoirs and atmosphere, air is thus drawn into the third and fourth air reservoirs from atmosphere.

25 11. An air compressor according to claim 10, being configured such that the first switching means, in the second condition thereof, precludes said fluid communication between the third air reservoir and atmosphere, and such that the second switching means, in the second condition thereof, precludes said fluid communication between the fourth air reservoir and atmosphere.

30

12. An air compressor according to claim 10 or 11, wherein the first and second

reservoirs are engaged with the third and fourth reservoirs.

13. A concentrator operable to concentrate a gas constituent of atmospheric air, the concentrator comprising:

- 5 an air compressor apparatus drivable by a suction source;
 gas-extracting means arranged to receive flowing pressurised air output from the air compressor apparatus whereby to extract selectively from the air at least one gas constituent other than the constituent to be concentrated; and
 outputting means, downstream of the gas-extracting means, configured to deliver a
10 flow of gas rich in the concentrated constituent from the gas extracting means.

14. A concentrator according to claim 13, wherein the air compressor apparatus is reciprocating, having an air delivery stroke and an air intake stroke.

- 15 15. A concentrator according to claim 14, configured such that, during the air intake stroke, the gas-extracting means is in fluid communication with the suction source, such that the or each extracted gas constituent is drawn from the gas-extracting means by suction.

- 20 16. A concentrator according to any one of claims 13 to 15, wherein the air compressor apparatus comprises an air compressor according to any one of claims 1 to 12 fluidly coupled to the gas-extracting means via said output.

17. A concentrator according to any one of claims 13 to 16, wherein the gas-extracting
25 means includes a molecular sieve.

18. A concentrator according to any one of claims 13 to 16, wherein the air compressor apparatus comprises an air compressor according to any one of claims 10 to 12 fluidly coupled to the gas-extracting means via said output, and said gas-extracting means
30 comprises first and second molecular sieves, the concentrator being configured such that the second switching means, in the first condition thereof, provides fluid communication,

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via the output, between the first molecular sieve and the first air reservoir such that the air from the second air reservoir is delivered to the first molecular sieve via the output, and the second switching means, in the second condition thereof, provides fluid communication, via the output, between the second molecular sieve and the fourth air reservoir, such that
5 the air from the fourth reservoir is delivered to the second molecular sieve via the output.

19. A concentrator according to claim 18, configured such that the second switching means, in the first condition thereof, provides fluid communication between the second molecular sieve and the suction source, whereby desorbed gas from the second molecular
10 sieve is extracted by the suction source, and the second switching means, in the second condition thereof, provides fluid communication between the first molecular sieve and the suction source, whereby desorbed gas from the first molecular sieve is extracted by the suction source.

15 20. A concentrator according to any one of claims 17 to 19, wherein the or each molecular sieve incorporates a zeolite.

21. A concentrator according to claim 19 or 20, wherein the gas-extracting means selectively adsorbs nitrogen.

20

22. An apparatus for concentrating a gas constituent of atmospheric air ("concentrating apparatus"), comprising:

25 a concentrator according to any one of claims 13 to 21;
said suction source; and
an output comprising said outputting means,
wherein the air compressor apparatus is fluidly connected to the suction source to be drivable thereby.

23. An apparatus according to claim 22, wherein the suction source comprises a
30 conduit configured to carry flowing fluid, the conduit being configured with a gas inlet via which the air compressor apparatus and conduit are fluidly interconnected, such that a

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vacuum is applied to the air compressor apparatus by the flowing fluid.

24. An apparatus according to claim 23, comprising a siphon defining the conduit.

5 25. An apparatus according to claim 24, wherein an intake of the siphon is submerged in a liquid supply reservoir which is naturally occurring.

26. An apparatus according to claim 25, wherein the liquid supply reservoir is defined by a river, stream, lake or the like.

10

27. An apparatus according to claim 24, wherein an intake of the siphon is submerged in a liquid supply reservoir which is manmade.

15 28. An apparatus according to claim 26, wherein the liquid supply reservoir is defined by a dam, water tank or the like.

29. An apparatus according to any one of claims 24 to 28, wherein the siphon has an output which is submerged in liquid in a liquid collection reservoir.

20 30. An apparatus according to claim 23, wherein the conduit comprises a venturi having a constriction at which the gas inlet is located, whereby the fluid flow applies suction to the air compressor apparatus.

25 31. An apparatus according to any one of claims 22 to 30, wherein the conduit is pre-existing.

32. An apparatus according to any one of claims 23 to 31, wherein the conduit is one which supplies water to a remote community.

30 33. An apparatus according to any one of claims 23 to 35, wherein the conduit is arranged in an environment in which there is a pre-existing liquid flow.

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34. An apparatus according to claim 33, wherein the conduit is arranged in a watercourse or a location where there is tidal flow.

5 35. An apparatus according to any one of claims 23 to 34, wherein the conduit comprises a pipe.

36. An apparatus according to any one of claims 22 to 35, comprising, in addition to said concentrator ("the first concentrator"), a further said concentrator ("the second
10 concentrator") the air compressor apparatus of which is fluidly connected to the suction source to be drivable thereby, wherein the output of the concentrating apparatus includes the outputting means of the second concentrator.

37. An apparatus according to any one of claims 22 to 36, wherein the or each air
15 compressor apparatus comprises an air compressor according to any one of claims 1 to 12.

38. An apparatus according to any one of claims 22 to 37, including a gas accumulator downstream of the outputting means of the or each concentrator whereby to receive, from the or each concentrator, the concentrated constituent-rich gas, such that the concentrating
20 apparatus can output at a pressure which is substantially uniform or which fluctuates to a reduced extent.

39. An apparatus according to any one of claims 22 to 38, being an oxygen concentrator apparatus.
25

40. An apparatus according to claim 39, being a therapeutic oxygen concentrator apparatus.

41. An apparatus according to claim 40, including a mask via which oxygen-rich gas
30 output by the gas-extracting means can be inhaled.

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42. An apparatus according to claim 39, being a liquid oxygenating apparatus configured to deliver the constituent-rich gas to a liquid.

43. An apparatus according to any one of claims 22 to 38, being a nitrogen
5 concentrator apparatus.

44. An apparatus according to claim 43, being a food-preserving apparatus.

45. An apparatus according to claim 43, being a welding apparatus.
10

46. A method of concentrating a gas constituent of atmospheric air, comprising operation of an apparatus according to any one of claims 22 to 45.

47. A method of concentrating a gas constituent of atmospheric air, comprising
15 operation of an apparatus according to any one of claims 22 to 42, wherein said gas constituent comprises oxygen .

48. A method of administering oxygen-rich gas, comprising operation of a concentrating apparatus according to any one of claims 22 to 41 to produce said gas,
20 wherein said gas is inhaled.

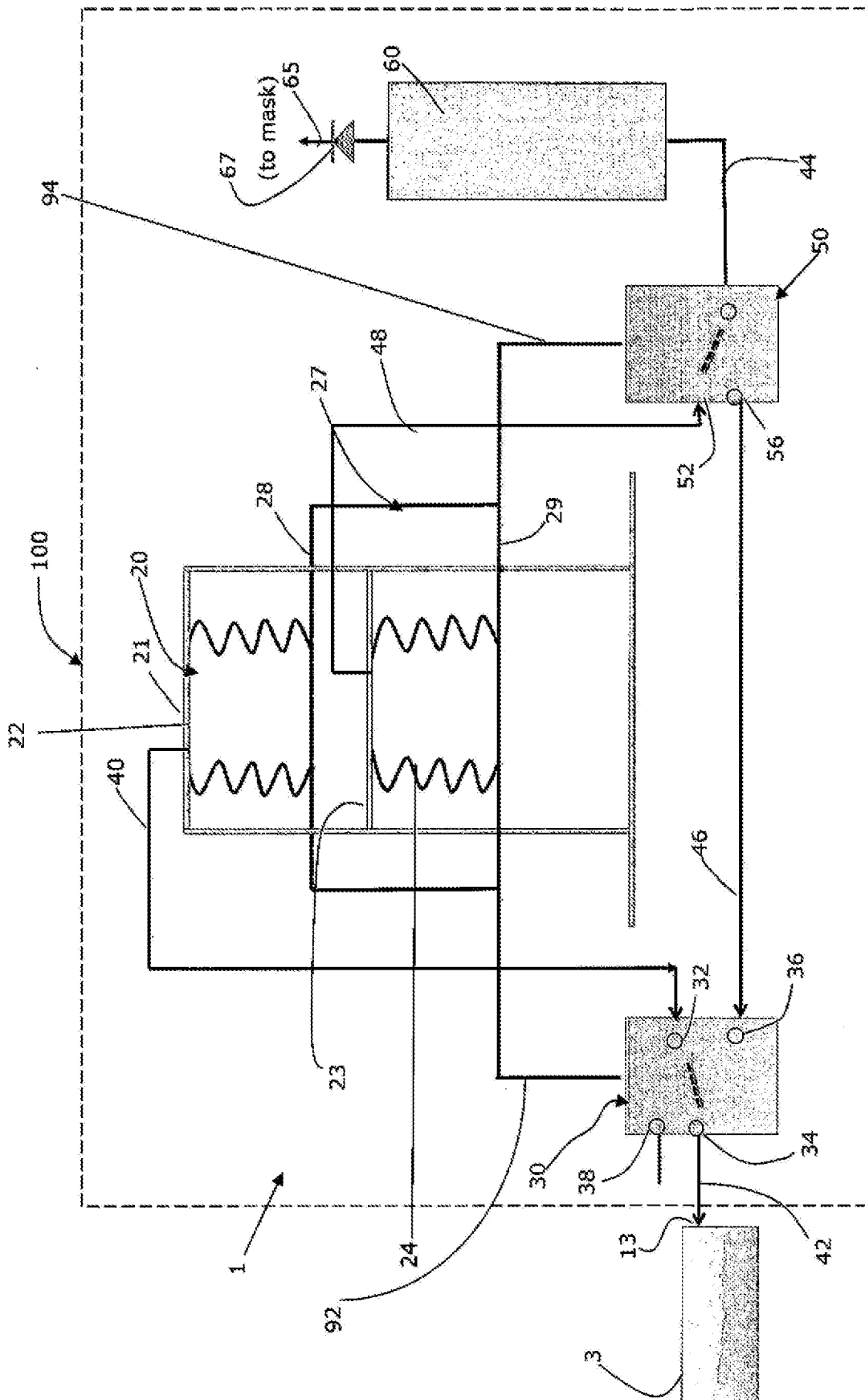


FIG. 1

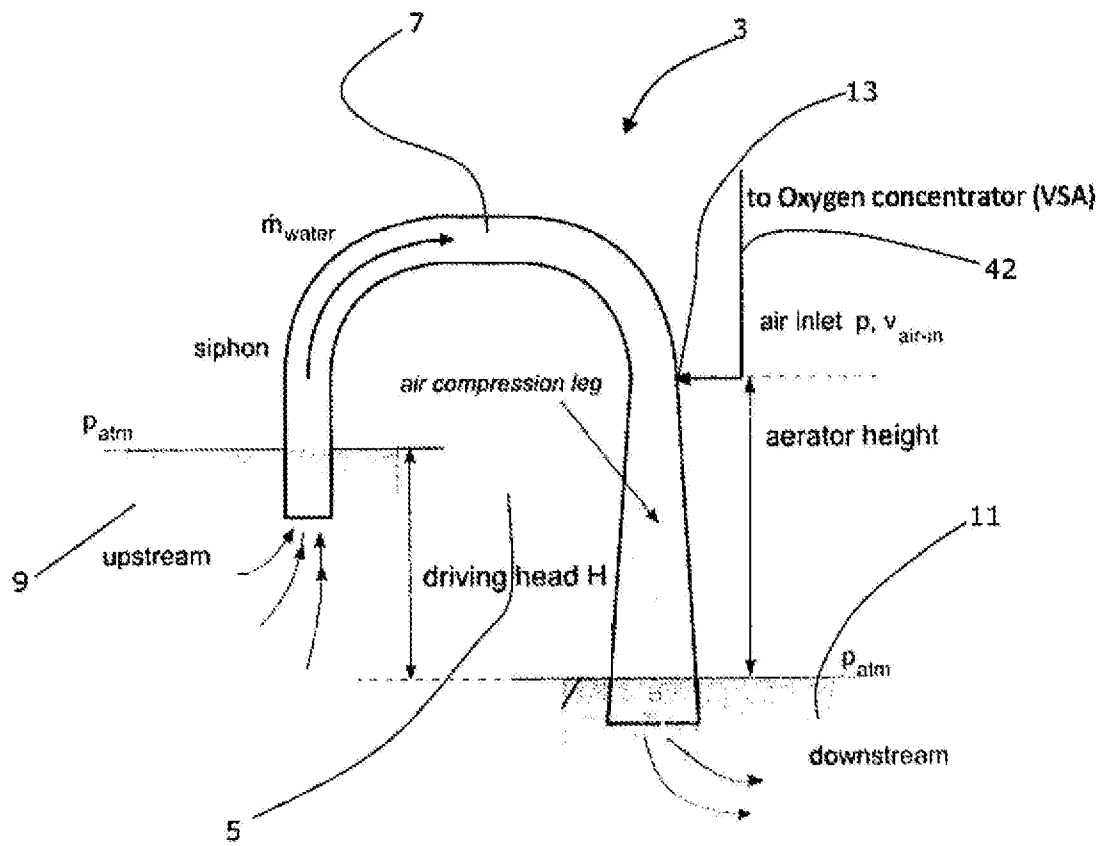
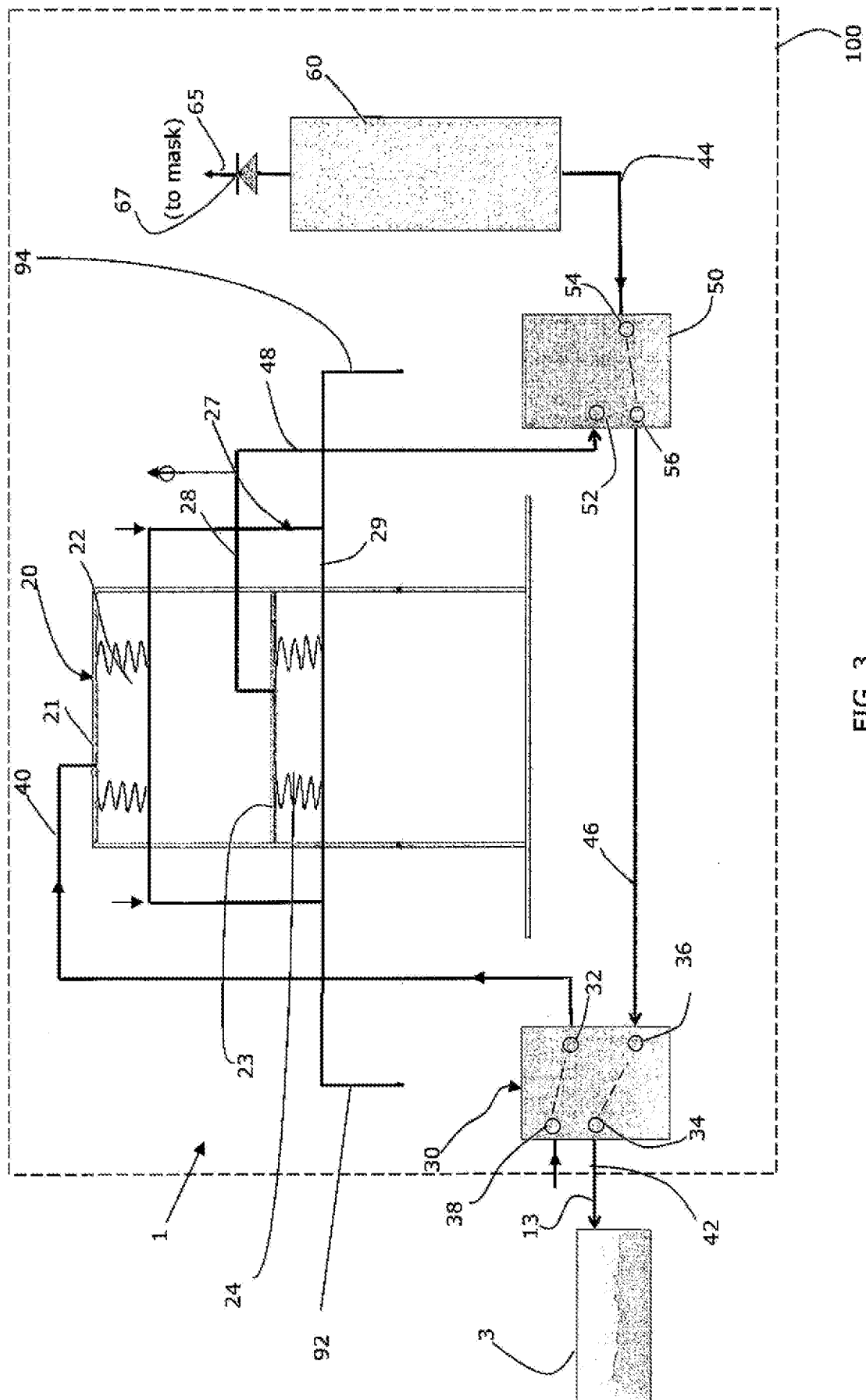


FIG. 2



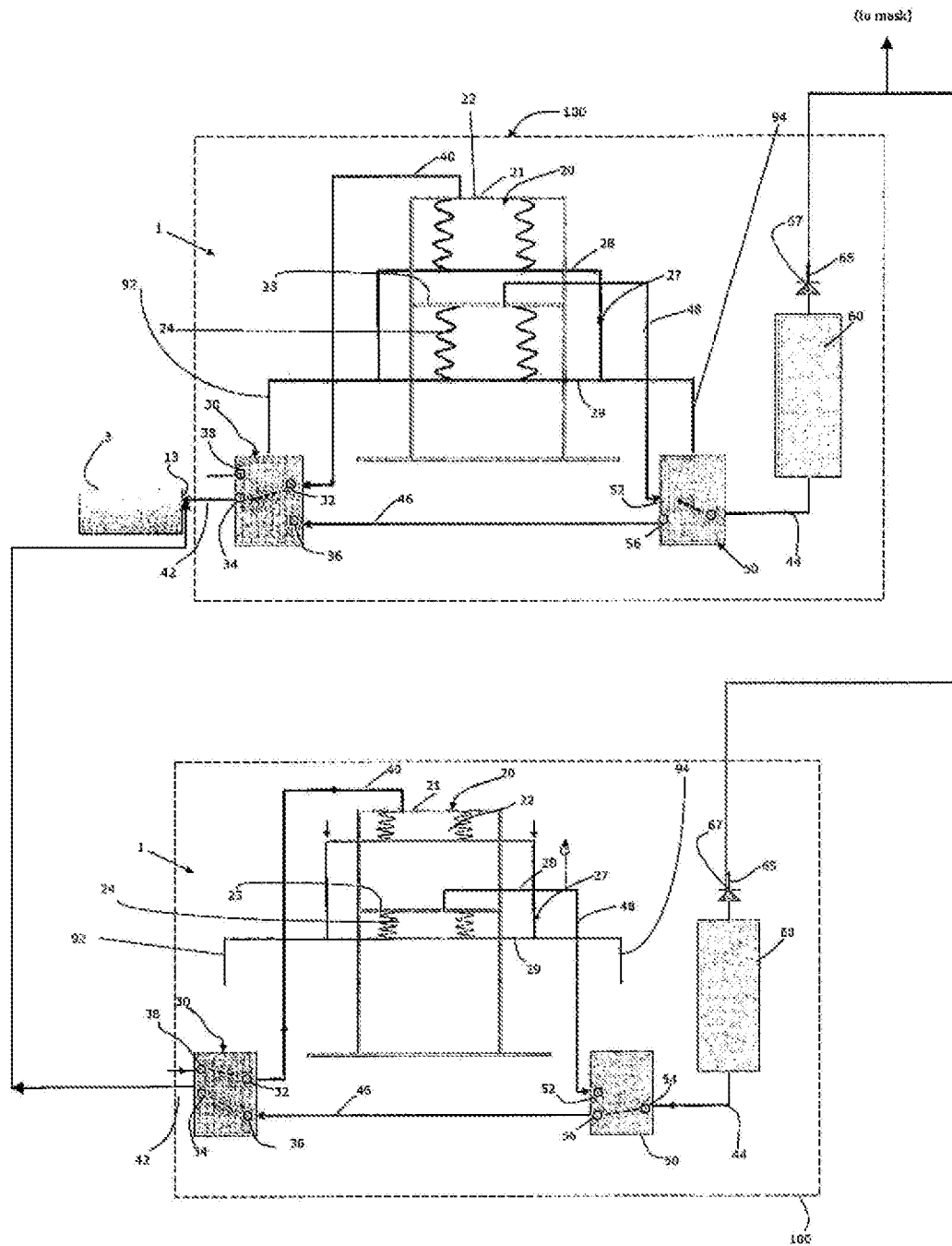


FIG. 4

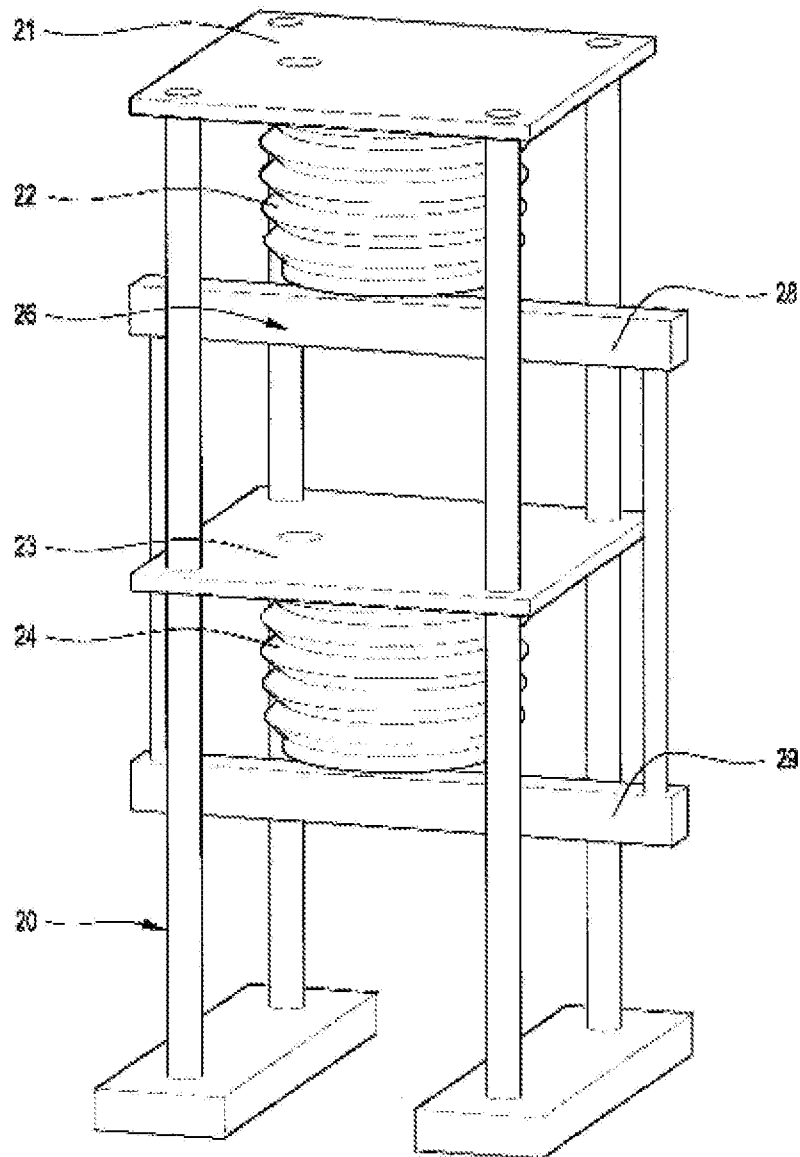


FIG. 5

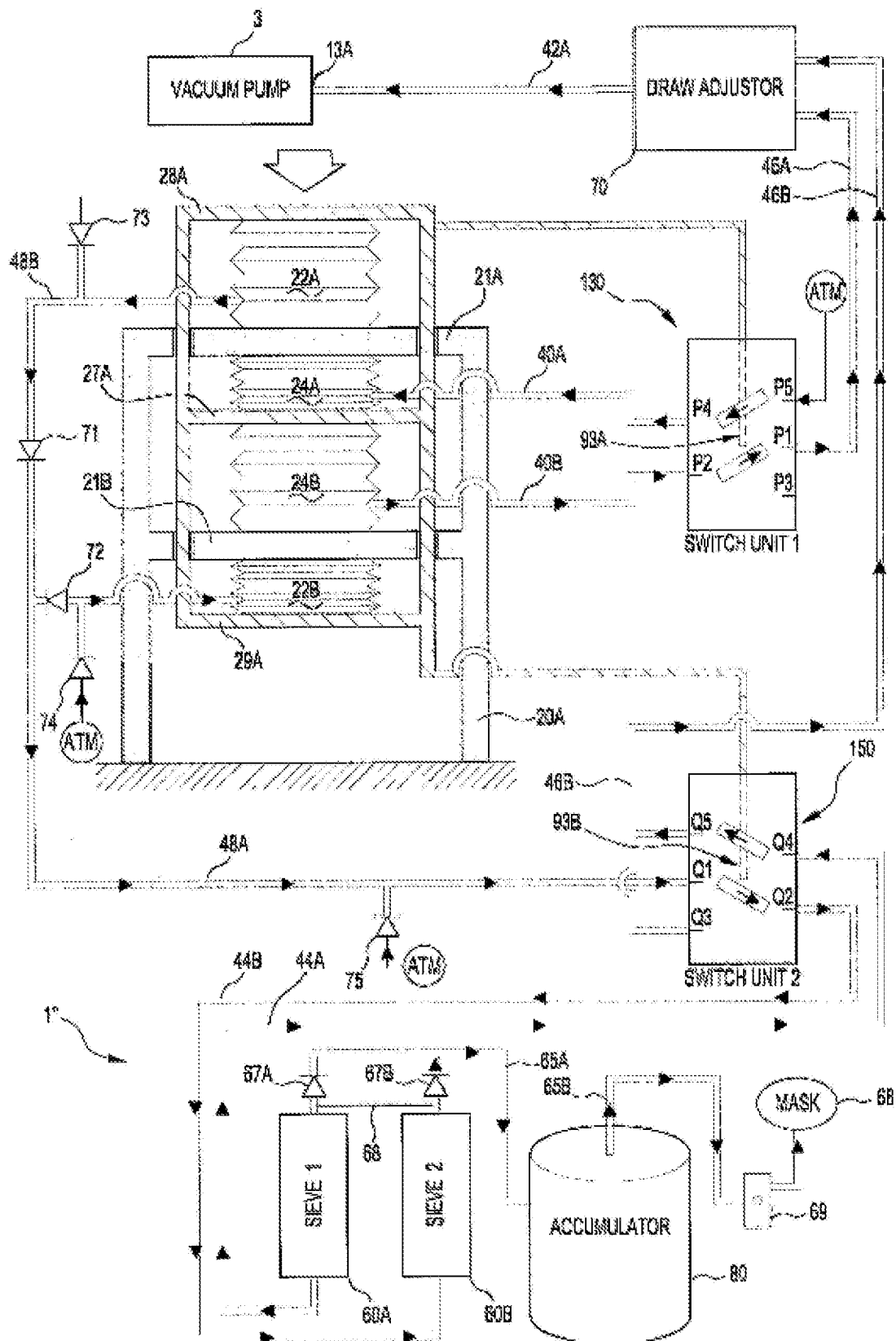


FIG. 6

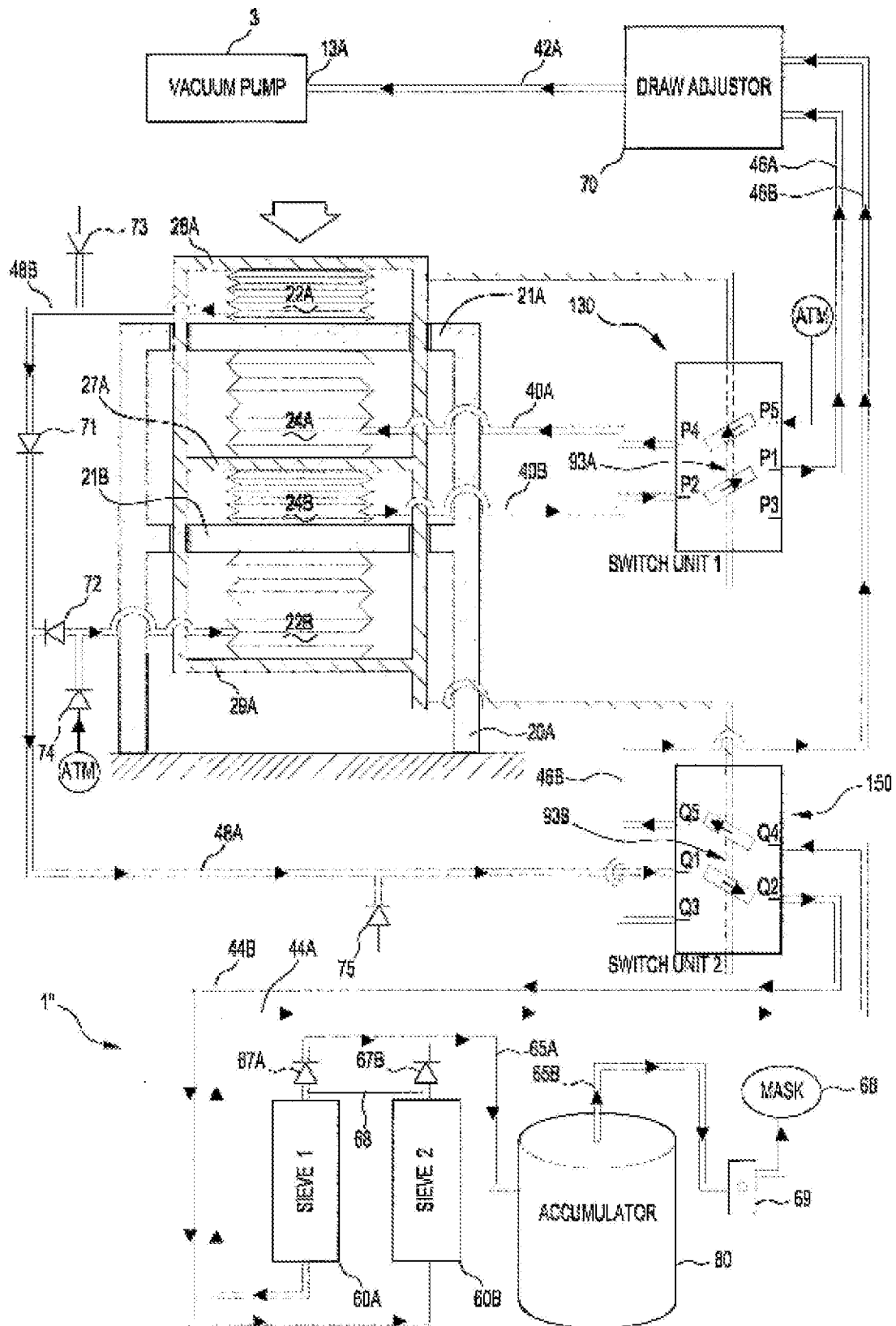


FIG. 7

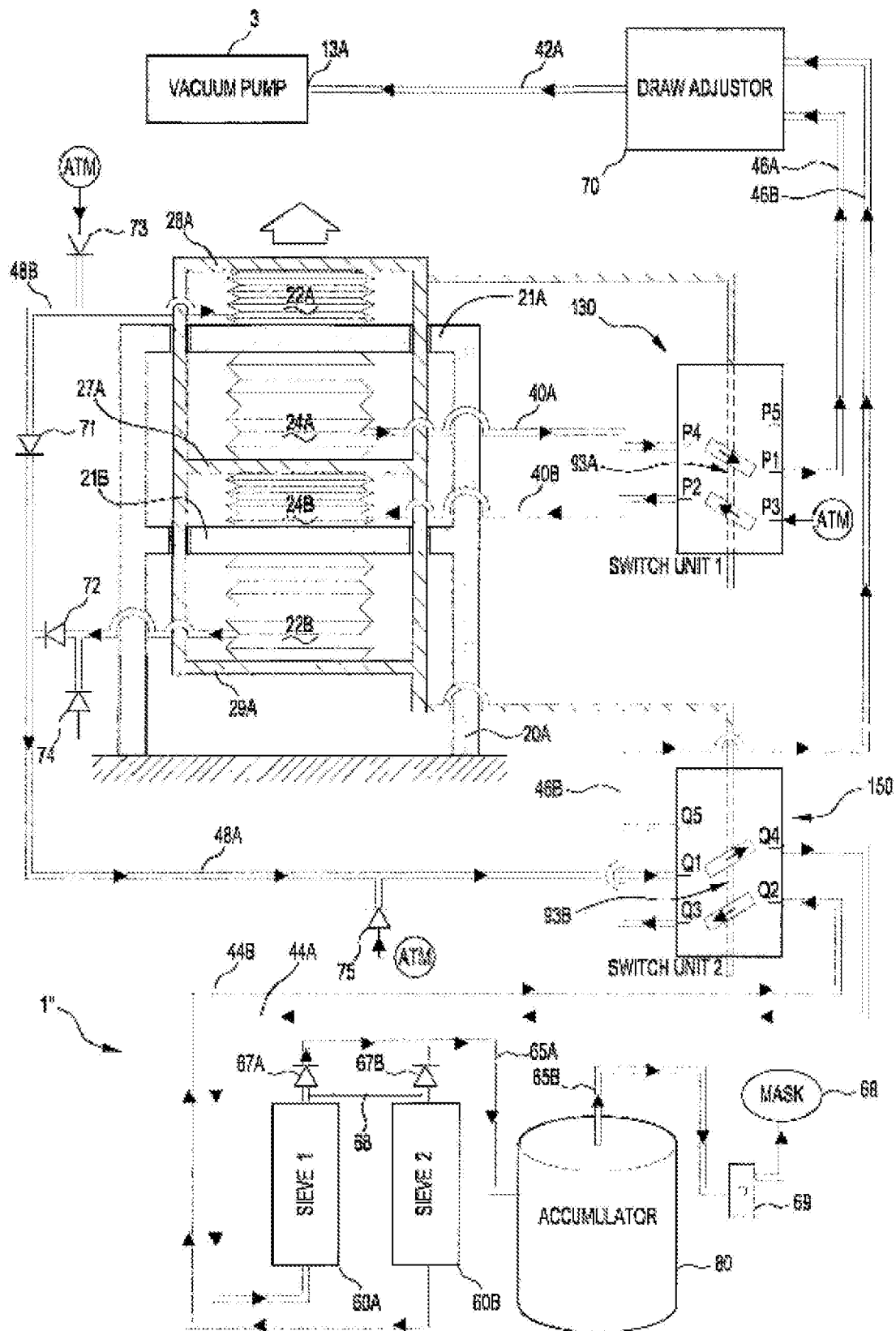


FIG. 8

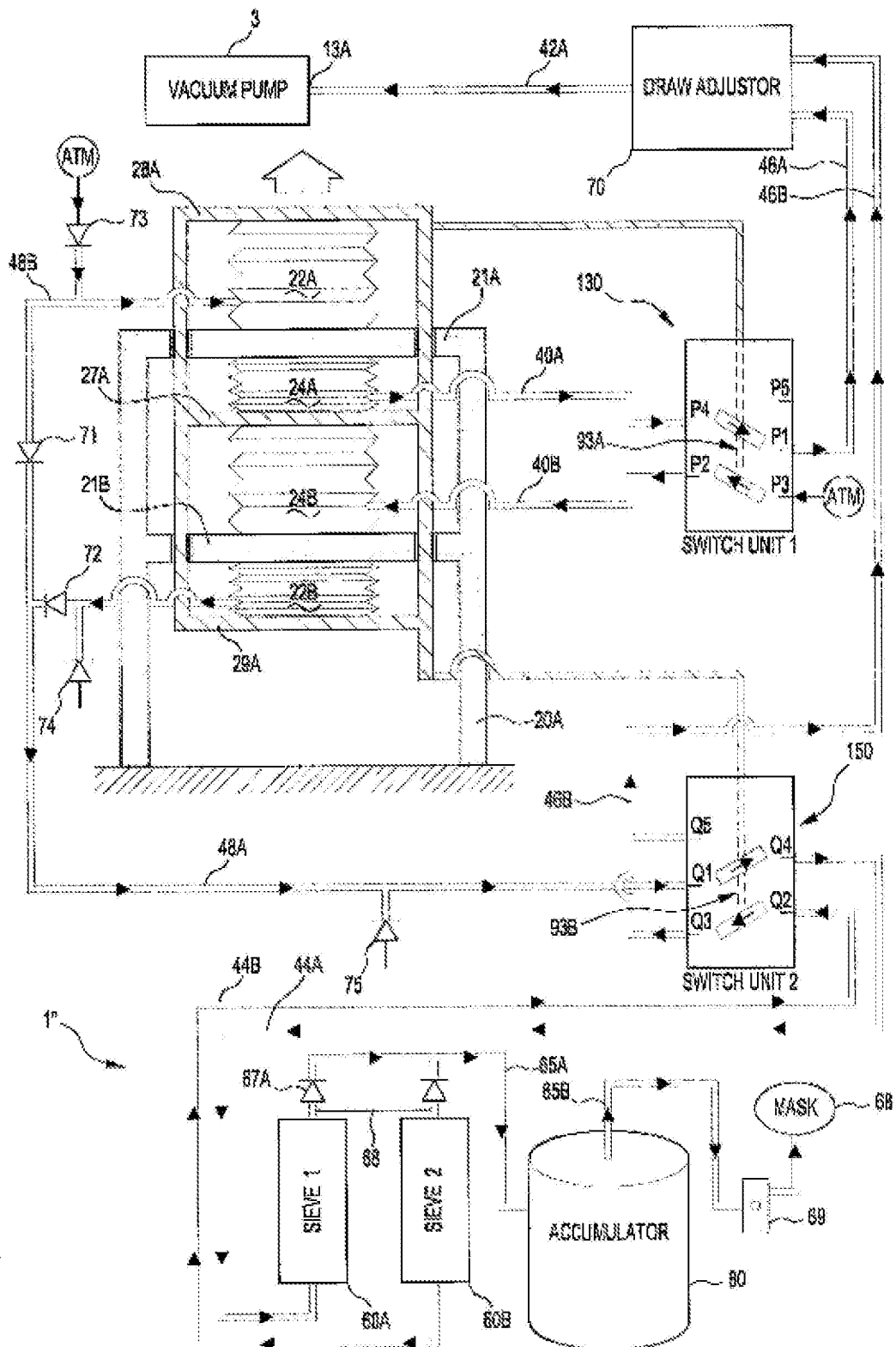


FIG. 9

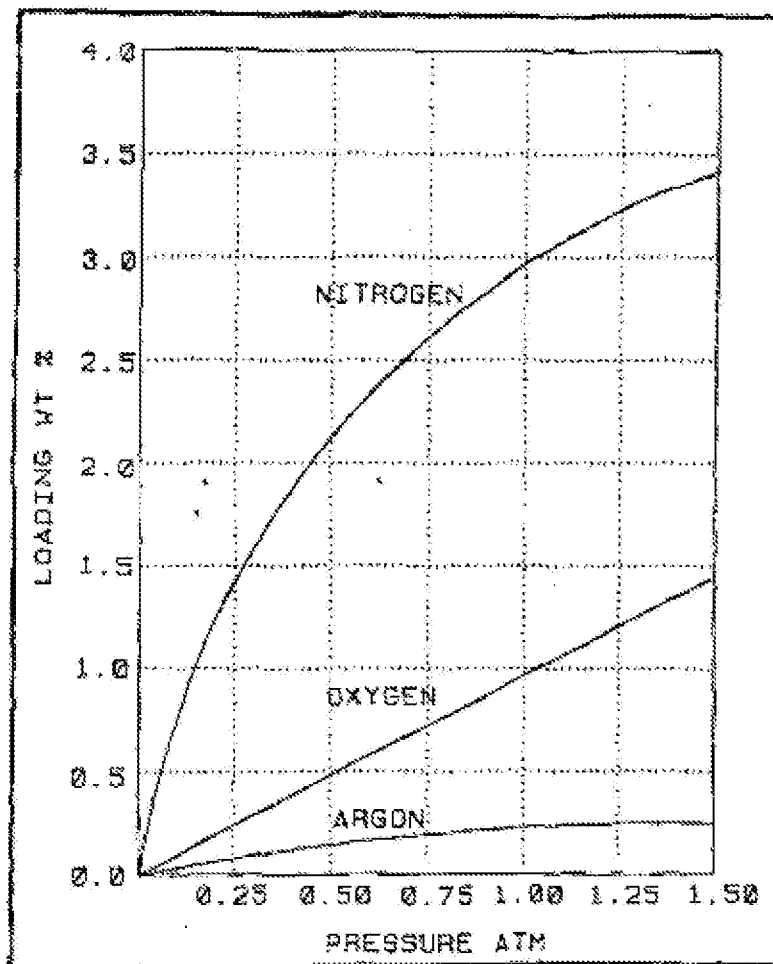


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2014/050152

A. CLASSIFICATION OF SUBJECT MATTER

F04B 45/033 (2006.01) A61H 31/00 (2006.01) A61M 16/10 (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)

WPI, EPODOC, Google Patents: IPC, CPC: F04B45/033, F04B45/02

Keywords: suction, vacuum, siphon, negative, low, pressure, dual, two, second, auxiliary, additional, multi, bellow, chamber, reservoir, diaphragm, compressor, air, pump, driven, drivable, operate, power, and the like.

Auspat, Espacenet: Applicant/Inventor name search: University of Melbourne; Peak, David Joseph

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
25 September 2014Date of mailing of the international search report
25 September 2014

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Telephone No. 0262832954

INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/AU2014/050152
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4329123 A (KAWABATA ET AL) 11 May 1982 Entire document; specifically Fig. 1 & 2; Col. 3 line 53- Col. 4 line 55; Abstract	1-12
A	US 2009/0324431 A1 (VAN BOEYEN ET AL) 31 December 2009	
A	US 3544239 A (GRAHAM) 01 December 1970	
A	CA 2330063 A1 (LITTON SYSTEMS INC) 18 July 2001	
A	US 3908689 A (WINGATE) 30 September 1975	
A	US 2006/0048644 A1 (DOLENSKY AT AL) 09 March 2006	
A	US 2006/0230939 A1 (BLISS ET AL) 19 October 2006	
A	US 8236095 B1 (BASSINE) 07 August 2012	

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

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:
the subject matter listed in Rule 39 on which, under Article 17(2)(a)(i), an international search is not required to be carried out, including
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.:
1-12

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.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2014/050152**Supplemental Box**

Therefore in the light of this document this common feature cannot be a special technical feature. 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 posteriori*.

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 1-12 are directed to an air compressor, reciprocatingly drivable by suction, for pressurising atmospheric air and outputting the pressurised air. The feature of the air compressor comprising: interengaged first and second air reservoirs, each of which is configured to assume an expanded condition and a contracted condition; an output; a first switching means configured such that, in a first condition thereof, it provides fluid communication between the first air reservoir and a source of said suction and, in a second condition thereof, precludes that fluid communication and provides fluid communication between the first air reservoir and atmosphere; and a second switching means configured such that, in a first condition thereof, it provides fluid communication between the second air reservoir and the output and, in a second condition thereof, it precludes that fluid communication and provides fluid communication between the second air reservoir and atmosphere, the apparatus being operable such that: during an air delivery stroke thereof, said switching means assume their first conditions whereby the fluid communication between the first air reservoir and suction source results in withdrawal of air from the first air reservoir and thus movement of the first air reservoir from an expanded condition into a contracted condition, and, owing to the interengagement between the first and second air reservoirs and the fluid communication between the second air reservoir and the output, movement of the second air reservoir from an expanded condition into a contracted condition and thus compression of air in the second air reservoir and delivery of the compressed air to the output; during an air intake stroke thereof, said switching means assume their second conditions whereby the first and second air reservoirs are permitted to revert to their expanded conditions and, owing to the fluid communication between the first and second air reservoirs and atmosphere, air is thus drawn into the first and second air reservoirs from atmosphere; and when the air intake stroke is complete, the switches reassume their first conditions, whereby driving of the apparatus is continuous is specific to this group of claims.
- Claims 13-21, 22-45, and 46-48 are directed to a concentrator operable to concentrate a gas constituent of atmospheric air, an apparatus for concentrating a gas constituent of atmospheric air comprising a concentrator, and a method of concentrating a gas constituent of atmospheric air comprising operation of an apparatus comprising a concentrator, respectively. The concentrator comprising: an air compressor apparatus drivable by a suction source. The feature of gas-extracting means arranged to receive flowing pressurised air output from the air compressor apparatus whereby to extract selectively from the air at least one gas constituent other than the constituent to be concentrated; and outputting means, downstream of the gas-extracting means, configured to deliver a flow of gas rich in the concentrated constituent from the gas extracting means 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. The only feature common to all of the claimed inventions and which provides a technical relationship among them is an air compressor apparatus drivable by suction.

However this feature does not make a contribution over the prior art because it is disclosed in:

US 4329123 A (KAWABATA ET AL) 11 May 1982

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2014/050152	
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	
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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)			