Jan. 11, 1955 CARL-GUNNAR D. ENGSTRÖM 2,699,163

RESPIRATOR

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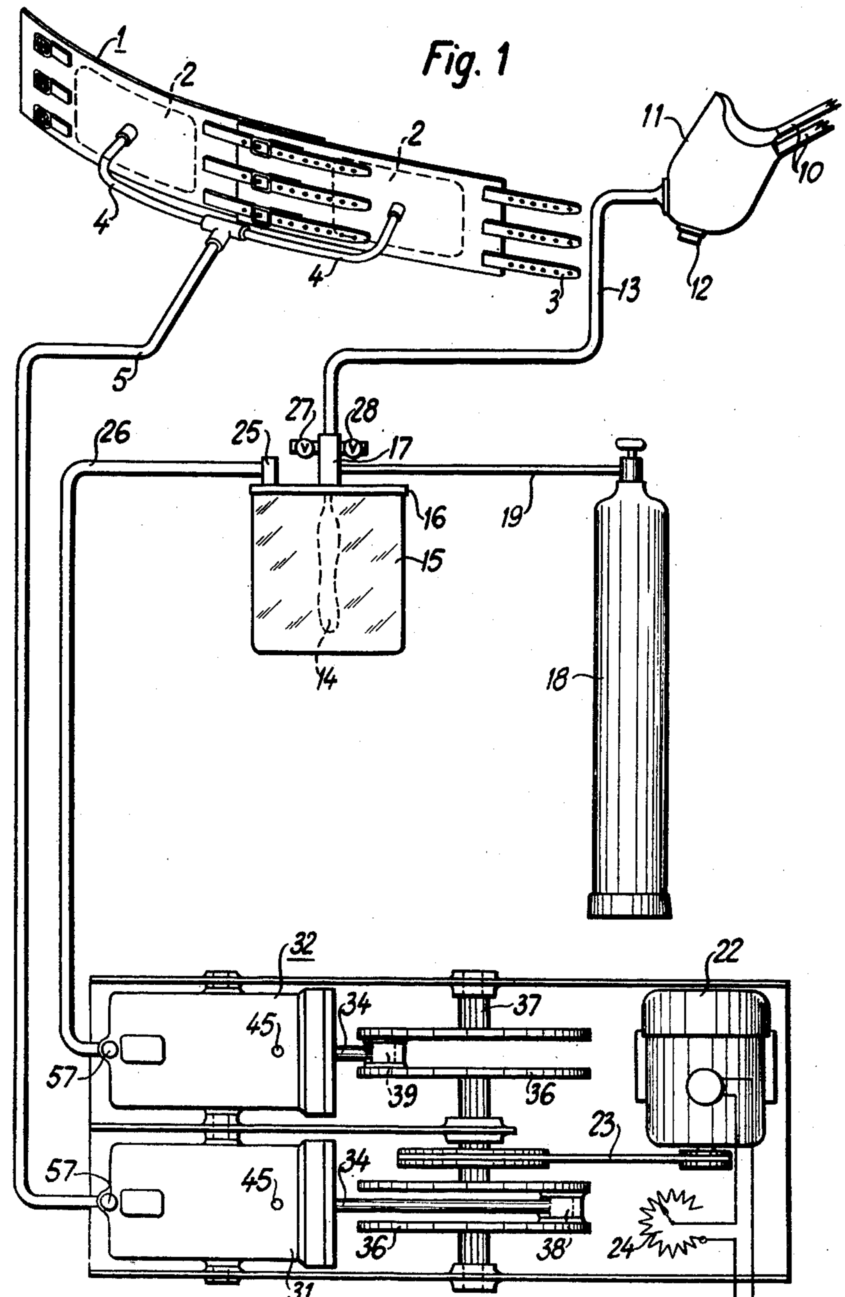
Fig. 1




Inventor:
Carl-Gunnar Daniel Engström,
By: Pierce, Scheffler & Parker,
Attorneys.

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Fig. 2

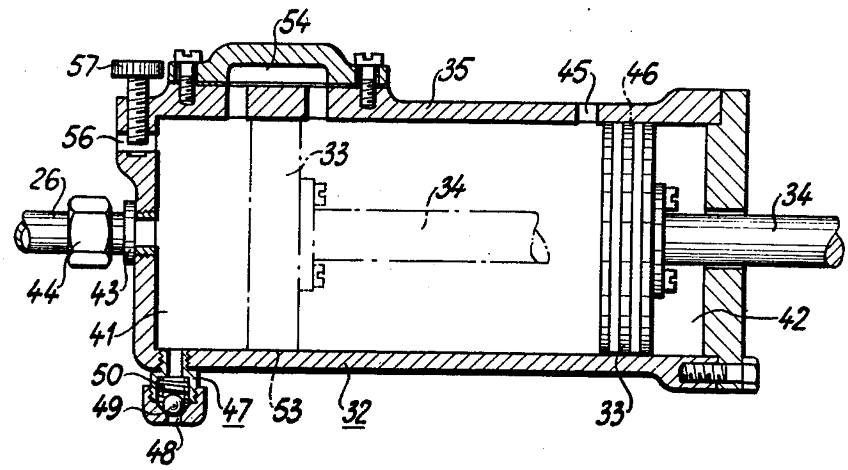
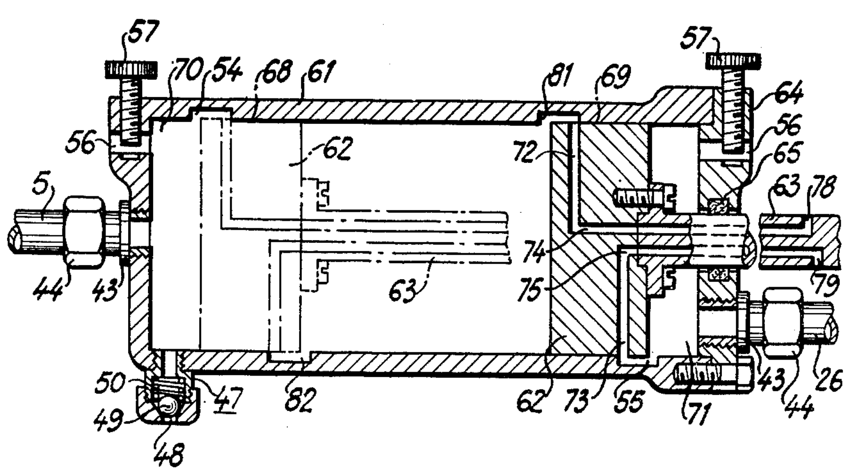



Fig. 3

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Carl-Gunnar Daniel Engström,
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Fig. 4

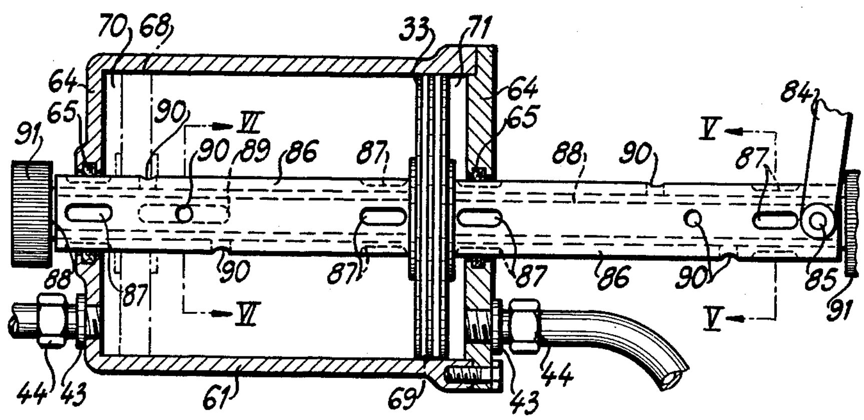



Fig. 5

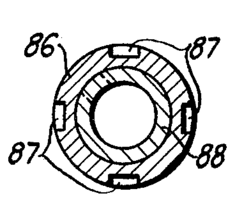
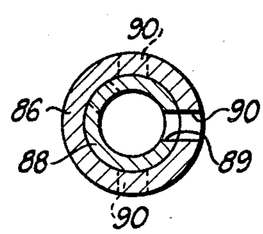



Fig. 6




Inventor:
Carl-Gunnar Daniel Engström,
By: Pierce, Scheffler & Parker,
Attorneys.

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2,699,163

## RESPIRATOR

Carl-Gunnar D. Engström, Stora Essingen, Stockholm, Sweden

Application June 25, 1951, Serial No. 233,275

Claims priority, application Sweden June 26, 1950

17 Claims. (Cl. 128—29)

The present invention relates to a respirator arrangement and is more particularly concerned with respirators having a positive action in the inhalation phase as well as in the exhalation phase of a patient. Artificial respiration is usually brought about either by introducing a suitable gas mixture, such as air or oxygen or a mixture thereof, with or without a percentage of carbon dioxide, into the lungs of the patient by the aid of a face mask or a cannula, or by applying an intermittent vacuum around the body of the patient (so-called tank respirators) or by compressing the chest as by an inflatable girdle strapped about the chest of the patient. In the first case, an active inhalation (or respiration) is obtained and the exhalation or expiration takes place as a result of the elasticity of the lungs and chest which in their expanded state have a tendency to recover their normal state. In the case of compressing the chest an active expiration is effected followed by an inhalation action when the compressed chest expands to its normal state, also as a result of its elasticity. Both methods can be employed at the same time to bring about alternating active inhalation and expiration periods.

It is the primary object of the invention to provide a respirator arrangement performing active inhalation and active exhalation phases alternating with certainty at predetermined intervals and at a controllable rhythm so that the phases become absolutely synchronized. Another object is to provide means for controlling the rate of compressing the chest and of filling the lungs with inhalation gas independently of one another. A further object is to provide means for compulsory pressing an inhalation gas into the lungs by the aid and control of air periodically obtained from a compressor.

To obtain these and other objects which will be readily understood by those familiar with the present art the invention consists in chest compressing means including an inflatable bag and inhalation means including a trachael attachment, such as a face mask or a canula, and a pressure chamber connected thereto, separate air conduits connecting each of said bag and pressure chambers with separate compressor chambers having mechanical means for compressing the gas contained in said chambers, said mechanical means being so interconnected as to act in dependency of each other.

The invention will now be described with reference to the accompanying drawings illustrating embodiments of the invention, but it will be understood that the invention is not limited to these embodiments.

In the drawings:

Fig. 1 illustrates a complete respirator arrangement according to the invention, comprising two separate compressors.

Fig. 2 is a cross-sectional view of one of the compressors of Fig. 1.

Figs. 3 and 4 illustrate two types of a double-acting compressor to be used instead of the two compressors shown in Fig. 1.

Figs. 5 and 6 are cross-sectional views of a piston rod shown in Fig. 4.

The belt **1** is provided with inflatable bags **2** on the one side and has straps **3** so as to enable the belt to be strapped round the chest portion of the body of a patient to be subjected to artificial respiration with the bags against the chest. The bags **2** are connected to a hose **5** by branch hoses **4**. On the other hand, the inhalation or face mask **11** of any common type having head bands **10** and provided with a pressure balanced exhalation



valve **12**, is provided with a hose **13** connecting it with the inflatable bladder **14** placed within the pressure chamber of an air tight flask **15** through an air tight connection box **17** mounted on the cover **16** of the flask. The hose **13** is provided with a safety valve **27** of any convenient type limiting the pressure of the gas admitted to the patient's lungs to some convenient value, such as 12 to 18 centimeters water column. The hose is also provided with a suction valve **28**. The box **17** is also connected, through a tube **19** to a pressure flask **18** containing the gas mixture to be used as inhalation gas. The flask **18** has a conventional pressure reduction valve for reducing the pressure of the gas and is set to supply the requisite quantity of gas per unit of time.

The cover **16** of the flask has a nipple **25** to air hose **26** through which air can be introduced into the flask **15**.

The air hose **5** is connected to a compressor **31** and the air hose **26** is connected to another compressor **32**. Each compressor has a piston **33** and a piston rod **34** secured thereto. The piston rods are secured to crank discs **36** of a crank shaft **37** by pins **38** and **39**, respectively, in such way that when, for instance, pin **38** is in its remotest position relative to the compressor **31** pin **39** is in its nearest position, at least approximately. Shaft **37** is driven by any convenient source of power, such as by a motor **22** and belt **23**. The speed should be adjustable as by a resistance **24** in the current supply. Alternatively conical pulleys could be used for the driving belt.

Each compressor has a cylindric wall **35** and a bottom wall and, as illustrated in Fig. 2, a top wall, which is not essential, said walls forming a volume divided by piston **33** into two chambers, the compressor chamber **41** and the rear chamber or space **42**. A nipple **43** at the bottom of the compressor chamber **41** connects one of the air hoses **5** and **26** with the compressor chamber. Near the top of the cylinder there is an air opening **45** so located as to connect the compressor chamber **41** with the atmosphere when the piston is about to turn at its end position **46**. The compressor chamber is thus filled with air and takes the pressure of the surrounding atmosphere. A one-way inlet valve **47** for air is arranged near the bottom of the compressor chamber. The valve, which is preferably controllable, has an inlet opening **48** in its wall forming there a seat for a ball **49** pressed against said seat by a spring **50** so as to prevent air from entering the chamber except when a sub-pressure prevails therein. At and about the bottom turning position **53** of piston **33** a passage or recess **54** is provided in the cylindric wall **35** for connecting the compressor chamber **41** with the rear chamber **42**, which communicates through opening **45** with the atmosphere.

In order to make feasible a regulation of the quantity of air and the pressure delivered by the compressor at constant speed of the piston **33** a vent **56** is provided in the bottom portion of the cylinder so as to permit air to escape therethrough instead of being pressed into the air bag **2** or the pressure flask **15**, respectively. The vent can be regulated by screw **57** so that the quantity of exhausted air can be controlled by appropriately setting screw **57**. Alternatively the vent can be controlled by a plate that can be brought to cover the vent more or less. Equivalents of this implement will be obvious to those skilled in the art.

When operating the equipment described belt **1** is strapped round the chest of the patient and face mask **11** is applied over the nose and mouth of the patient by means of the bands **10**. Inhalation gas is admitted from the flask **18** to bladder **14** and the driving means for crank shaft **37** is started so that the pistons **33** move reciprocatingly in their respective compressors **31** and **32**. Preferably, the apparatus is started so as to first cause a compression of the chest, that is to say that compressor **31** is first caused to perform its compression stroke so that air bag **2** becomes filled with air and presses the chest, thus compressing the lungs so that a positive expiration takes place through valve **12** of mask **11**. When the piston **33** has reached its bottom turning position **53** the pressure in the air bag **2** is released through hose **5**, compressor chamber **41**, recess **54**, rear chamber **42** and opening **45**. The piston then moves in opposite direction and a vacuum is established in chamber **41** causing the atmospheric air to open valve **47** and enter chamber **41** successively. At its top turning position piston **33** discovers the opening **45** to chamber **41** so that the pressure therein becomes equal to that of the surrounding atmosphere and a new cycle can be started.

During the return stroke of the piston of compressor **31** the piston of a compressor **32** makes its compressing stroke after the compressor chamber **41** of that compressor has been filled with air in the manner just described with reference to compressor **31**. At the compression stroke air is pressed through air hose **26** and nipple **25** into flask **15**. The bladder **14** having been filled automatically by inhalation gas from flask **18** during a pervious suction stroke of the piston, is now compressed by the compressor air and the inhalation gas is pressed through tube **13** to mask **11** and from there into the trachea of the patient thus performing an active inhalation. At the end of the positive stroke of the piston **33** of compressor **32** chamber **41** communicates with the atmosphere through recess **54**, chamber **42** and opening **45**, thus releasing the pressure in flask **15** so that bladder **14** can be filled again with inhalation gas from flask **18** when piston **33** makes its return stroke. The pressure of the gas will usually be sufficient for filling the bladder, but, if desired, the vacuum which may be created in chamber **41** and flask **15** at the return stroke of the piston may facilitate the filling. This vacuum can also be used for filling the bladder wholly or partly with atmospheric air by properly setting the suction valve **28** and/or adequately controlling the vacuum in the chamber **41** by inlet valve **47**. At a predetermined value the vacuum in chamber **41** will cause valve **47** to open and admit air into the chamber, the pressure of which is ultimately equalized when the piston has revealed opening **45**. One cycle of the operation is now completed and a new one is to start.

In Fig. 3 an embodiment is described in which only one compressor cylinder **61** is used to replace the two cylinders **31** and **32** just described. The compressor cylinder **61** contains a piston **62** attached to a piston rod **63** passing through a packing **65** in the end wall **64** of the cylinder. Driving means of any adequate character, such as those described with reference to Figs. 1 and 2, will cause rod **63** and piston **62** to move reciprocatingly in the cylinder of the compressor. At the one end of the cylinder is a nipple **43** which is adapted to be connected by a muffle **44** to the air hose **5** of the inflatable bag **2** and a nipple **43** at the other end of the cylinder is adapted in a similar way to be connected to the air hose **26** of the pressure flask **15**. The piston **62** divides the compressor cylinder into two chambers, the one **70** communicating with the air bag and the other **71** with the pressure flask **15**. Chamber **70** has an inlet valve **47** as described with reference to Fig. 2 for admitting air into the chamber under the suction stroke of the piston. Both chambers have near their bottoms air vents **56** controllable by screws **57** and provided for the purpose described.

For establishing communication between the respective chambers **70**, **71** and the surrounding atmosphere recesses **54**, **81** and **55**, **82**, respectively, are provided at either end of the cylinder near the turning positions of the piston. Recesses **54** and **81** cooperate with a radial boring **72** in the cylindric face of the piston communicating with an axial channel **74** in the piston and the piston rod **63** which leads to an opening **78** to the atmosphere outside the cylinder wall **64** even when the piston is in its innermost position. The recesses **55** and **82** cooperate similarly with boring **73** opening on the cylindric face of the piston at a position radially and preferably also axially spaced from that of boring **72**. Boring **73** communicates with axial channel **75** and opening **79** outside wall **64**.

By this arrangement of the communications with the atmosphere the pressures in the chambers **70** and **71** are completely independently controlled and pressure waves from the one chamber to the other are eliminated.

During operation the piston **62** is moved reciprocatingly in the cylinder **61** by any convenient means acting upon rod **63** making a compression stroke in the one cylinder chamber and a suction stroke in the other cylinder chamber at the same time. It may be presumed that the piston moves first to the left, compressing the air in chamber **70**, so that it will pass through hose **5** into the inflatable bag **2** compressing the chest of the patient and causing expiration to take place, surplus of air escaping through vent **56**. When piston **62** reaches its end position **68**, chamber **70** will communicate with the atmosphere through recess **54**, boring **72**, channel **74** and opening **78** and the pressure in bag **2** is then suddenly released permitting the inhalation to take place, first by the normal expansion of the chest and then through the positive action of the respirator when piston **62** moves to the right. Before starting its return stroke, however, piston **62** has allowed air to enter through opening **79**, channel **75**, boring **73** and recess **82** into chamber **71** so that the pressure therein will be equalized with regard to the atmospheric pressure. During the return stroke air is sucked into chamber **70** through inlet **47** and the air in chamber **71** is compressed and passed through hose **26** into flask **15** to perform an artificial positive inhalation action as described with reference to Fig. 1. The pressure can be regulated by screw **57**. Piston **62** having reached its right end position **69** the borings and channels therein will put chamber **71** into communication with the atmosphere through recess **55**, and at the same time chamber **70** will communicate with the atmosphere through recess **81** so that the pressures in these chambers as well as in flask **15** will be equal to the atmospheric pressure. When moving to the left piston **62** will create a vacuum in chamber **71** and flask **15** which will promote the filling of bladder **14** for next inhalation stage. Simultaneously the air bag **2** is filled with air through the advancing piston **62**.

The embodiment illustrated in Figs. 4 to 6 has also a single compresser cylinder **61** divided into two cylinder chambers **70** and **71** by the piston **33** which is reciprocatingly movable in the cylinder by the action of means indicated by lever **84** pivoted on pins **85** on piston rod **86** which in this case extends on either side of the piston **33** and is passed through both of the cylinder and walls **64** through packings **65** therein. The rod **86** may, if desired, consist of two separate rods, one on each side of the piston and secured thereto by any convenient means. As in the embodiment shown in Fig. 3 nipples **43** are arranged at either end of the cylinder, the one connecting chamber **70** to the inflatable bag **2** through hose **5** and the other connecting chamber **71** with the pressure flask **15** through hose **26** as described above. For establishing communication between each of the chambers **70** and **71** and the surrounding atmosphere in the end positions **68** and **69** of the piston recesses **87** are provided on the surface of the piston rod **86**. The recesses have such an axial length as to extend so far on either side of the end walls **64** when the piston is in its end positions as to establish communication between respective chamber and the surrounding atmosphere.

This respirator, as described so far, may operate principally as described with reference to Fig. 3. Air vents **56** and air inlet **47** may also be provided for the purposes set forth; it being understood that in the embodiments described such vents or inlet may be arranged in the hoses **5** and **26** or at the inflatable bag **2** or flask **15** instead.

An alternative construction for regulating the compression is illustrated in Figs. 4 to 6. The piston rod **86** is made in the form of a pipe which establishes therein a cylindric axial channel and a smaller pipe **88** is introduced therein to fit snugly so as substantially to prevent air from passing between the pipes. Pipe **88** which is open to the atmosphere at its end has a longitudinal slit **89** located inside the cylinder when the piston is in its innermost position. Radial openings **90** are provided in the piston pipe **86** within the cross sectional zone of slit **89**, radially and axially spaced from each other so that slit **89** upon rotation of pipe **88** by means of hand wheel **91** will register with only one of the openings **90** at a time or be closed completely so that the communication with the atmosphere can take place at different positions of the piston. The axial length of these openings should be less than the thickness of the end wall **64** so as not to cause communication between the chamber and the atmosphere when passing the wall.

By this arrangement the active stroke length and stroke volume can be varied and the compression be postponed. The interval between the inhalation and exhalation phases can thus be varied.

It is to be understood that if only one of the active respiration phases described is wanted, the other can be omitted.

Having now particularly described and ascertained the nature of my said invention, I declare that what is claimed is:

1. A double acting respirator comprising chest compressing means including an inflatable bag, tracheal attachment and a pressure chamber connected thereto, compressor means, walls in said compressor means defining two compressor chambers, separate gas conduits connecting said inflatable bag and said pressure-chamber with one each of said compressor chambers so as to form two separate compression gas rooms comprising, on the one hand, said bag and the gas conduit and compressor chamber connected thereto and, on the other hand, said pressure chamber and the gas conduit and compressor chamber connected thereto, a movable wall in each of said chambers adapted at its motion periodically to increase and decrease the volume of each chamber, said movable walls being so interconnected that the volume of the one chamber increases as the volume of the other chamber decreases and vice versa, and a release vent in the walls of at least one of said rooms, said vent being arranged to connect said room to the atmosphere substantially at that position of the movable wall of the compressor chamber of said room where the volume of said compressor chamber is at its minimum.

2. A respirator as claimed in claim 1, in which said compressor means comprises two cylinder chambers, a gas outlet in each chamber leading to said inflatable bag and said pressure chamber, respectively, piston means reciprocatingly movable in each chamber towards and away from the outlet thereof, the piston means of the one of said chambers being arranged to move towards or away from the outlet therein as the piston means of the other of said chambers moves away from or towards the outlet of said other chamber, respectively.

3. A respirator as claimed in claim 2 wherein is included an inflatable inhalation bladder in said pressure chamber, a conduit connecting said pressure chamber with one of said compressor chambers, a conduit connecting said inhalation bladder with said tracheal attachment and a conduit connecting said inhalation bladder with a source for inhalation gas, means in the last mentioned conduit for controlling the inhalation gas supply.

4. A respirator as claimed in claim 2 wherein is included an inflatable inhalation bladder in said pressure chamber, a conduit connecting said pressure chamber with one of said compressor chambers, a conduit connecting said inhalation bladder with said tracheal attachment and a conduit connecting said inhalation bladder with a source for inhalation gas, an air intake in said compressor chamber connected to the pressure chamber, means in said air intake for controlling the development of the vacuum in the compressor chamber as the piston means moves away from said outlet of the compressor chamber.

5. A respirator as claimed in claim 2, in which at least one of said cylinder chambers has a controllable vent.

6. A respirator as claimed in claim 2 comprising cylindric walls forming two separate compressor cylinders and two separate pistons, one piston for each cylinder, a piston rod attached to each piston, and a gas outlet at the one end of each cylinder, driving means for said piston rods arranged to move the pistons in opposite directions relative to the respective gas outlets.

7. A respirator as claimed in claim 6 in which at least one of the cylinders comprises a piston dividing the cylinder into one compressor chamber and one rear chamber, the cylinder having a recess in the cylindric wall near that end of the cylinder where the gas outlet is located, said recess being shaped so as to form a passage connecting along a limited portion of the path of the piston said compressor chamber with said rear chamber.

8. A respirator as claimed in claim 2 comprising a cylindric wall and transverse end walls forming a compressor cylinder, at the one end of said cylinder an outlet connected to said inflatable bag and at the other end of the cylinder an outlet connected to said pressure chamber, a piston movable in said cylinder, a piston rod connected to said piston and passing substantially airtightly through one of said end walls, two separated longitudinal channels in said piston rod opening outside said end wall, two separated radial borings in said piston communicating with one each of said channels and opening at radially spaced points on the peripheral surface of said piston, recesses in said cylindric wall matching said points when the piston is about in each one of said end positions.

9. A respirator as claimed in claim 2 comprising a cylindric wall and transverse end walls forming a compressor cylinder, at the one end of said cylinder an outlet connected to said inflatable bag and at the other end of the cylinder an outlet connected to said pressure chamber, a piston movable reciprocatingly in said cylinder between end positions near each end of said cylinder, a piston rod connected to said piston and passing substantially airtightly through both of said end walls, recesses in said piston rod connecting the interior of said cylinder with the exterior thereof when the piston is substantially in said end positions.

10. A respirator as claimed in claim 2 comprising a cylindric wall and transverse end walls forming a compressor cylinder, at the one end of said cylinder an outlet connected to said inflatable bag and at the other end of the cylinder an outlet connected to said pressure chamber, a piston movable reciprocatingly in said cylinder between end positions near each end of said cylinder, a piston rod connected to said piston and passing, substantially airtightly through one of said end walls, at least one axial channel in said piston, rod, an outside opening connecting said channel to the exterior of said cylinder and at least one inside opening connecting said channel to the interior of said cylinder at a point of the surface of said rod positioned within said cylinder, when the piston is in its remote end position.

11. A respirator as claimed in claim 10 comprising means for closing said channel.

12. A respirator as claimed in claim 10 comprising a plurality of axial channels opening at axially spaced points within said cylinder.

13. A respirator as claimed in claim 10, in which said piston rod has a cylindric axial channel, a pipe snugly fitting and rotatable in said channel, a longitudinal slot in said pipe, radial openings in said rod positioned radially and axially spaced from each other and so arranged as to register one at a time with said slot upon rotation of said pipe.

14. A respirator arrangement comprising pressure actuated respiration means, a compressor, a cylindric wall and a transverse end wall in said compressor forming a compressor cylinder, an outlet near said end wall connected to said respiration means, a piston movable reciprocatingly in said cylinder, a piston rod connected to said piston and passing through said end wall, at least one axial channel in said piston rod, an outside opening connecting said channel to the exterior of said cylinder and at least one inside opening connecting said channel to the interior of said cylinder at a point of the surface of said rod positioned within said cylinder when the piston is in its remote end position.

15. A respirator as claimed in claim 14 comprising means for closing said channel.

16. A respirator as claimed in claim 14 comprising a plurality of axial channels opening at axially spaced points within said cylinder.

17. A respirator as claimed in claim 14 in which said piston rod has a cylindric axial channel, a pipe snugly fitting and rotatable in said channel, a longitudinal slot in said pipe, radial openings in said rod positioned radially and axially spaced from each other and so arranged as to register one at a time with said slot upon rotation of said pipe.

**References Cited** in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 2,071,215 | Petersen | Feb. 16, 1937 |
| 2,169,784 | Andersen | Aug. 15, 1939 |
| 2,263,844 | Hammond | Nov. 25, 1941 |
| 2,436,853 | Coleman | Mar. 2, 1948 |
| 2,490,395 | Wilm | Dec. 6, 1949 |
| 2,582,210 | Stanton | Jan. 8, 1952 |