

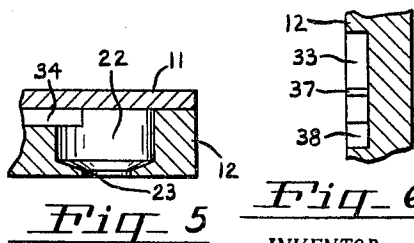
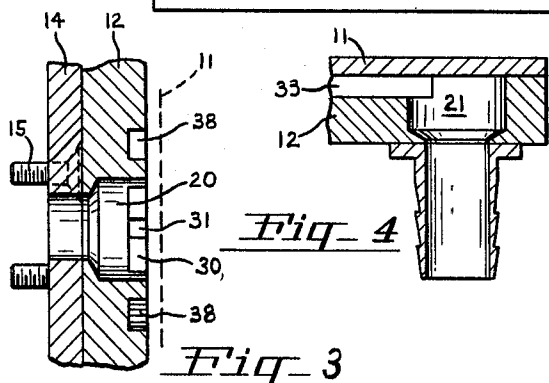
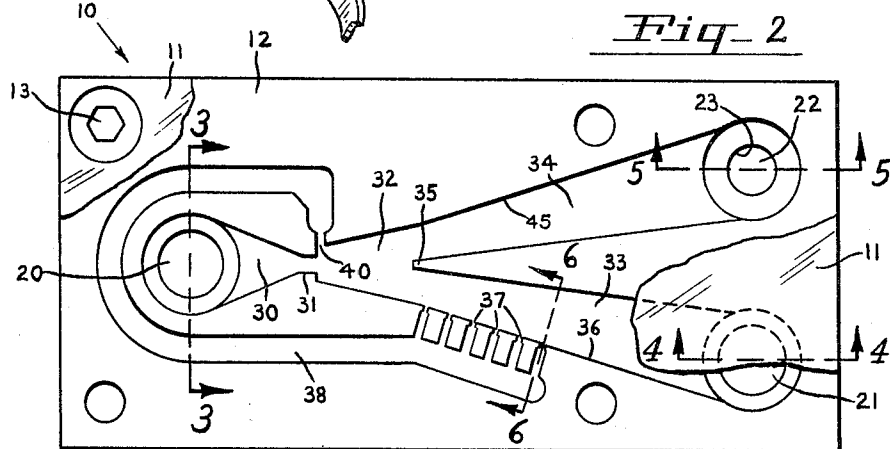
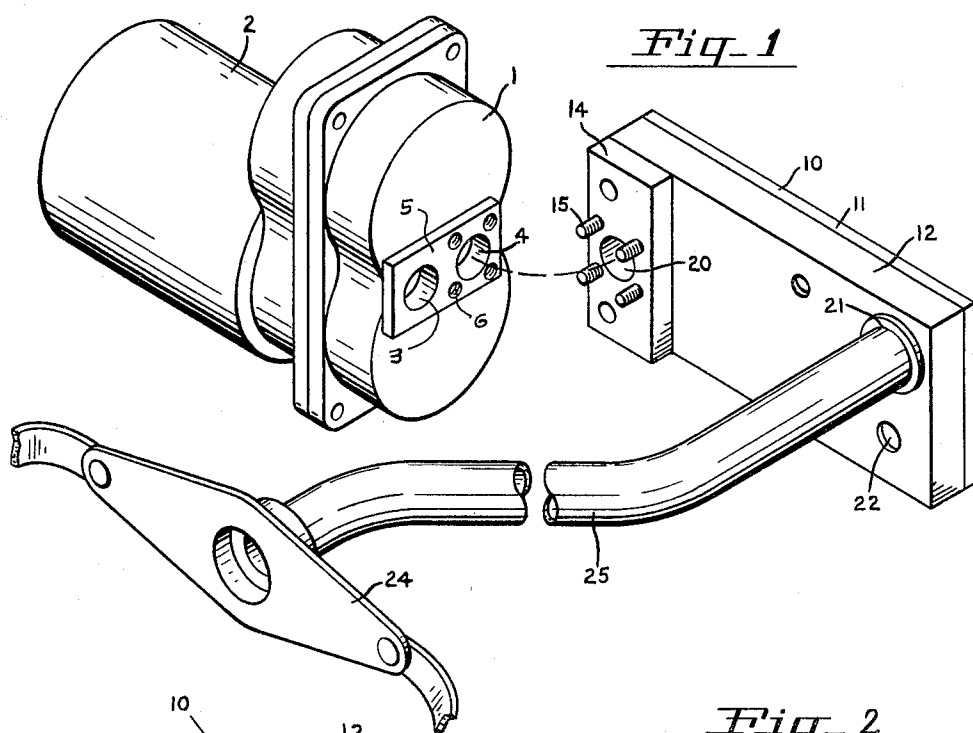
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CYCLING VALVE

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CYCLING VALVE

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This invention relates to a cycling valve without moving parts and has particular reference to a cycling valve for a resuscitator, although the valve is of general application and is not limited to resuscitators.

Resuscitators have two general classes of use. First, they are used to maintain breathing in situations where respiration has been stopped due to suffocation as in drowning, electric shock, poisoning, paralysis, etc. The second field of use is to assist breathing in the therapy of partial paralysis, emphysema, asthma, post operative removal of anesthetic gases, etc.

Resuscitators are normally limited by practical considerations to fire departments, public first aid facilities, public swimming pools, hospitals, hazardous industries, sick room rental agencies, etc. Cost and inconveniences has precluded location of resuscitators in home swimming pools, in utility company service trucks, in home therapy except on a rental basis, and other long range risk situations. Another disadvantage of conventional resuscitators is the existence of rather delicate parts including the cycling valve and parts associated therewith, such as springs, magnets, etc., which are subject to sticking and deterioration in long periods of non-use. However, the very nature of the respiration accidents is such that immediate availability of a resuscitator is highly desirable in the private as well as the public enterprises mentioned above.

Basic components of a resuscitator are: One, a source of gas under controlled pressure; two, a means of applying this gas pressure intermittently, and, three, a means coupling this intermittent gas pressure to the patient's lungs. The usual gas pressure system consists of a high pressure storage cylinder, cylinder shut-off valve, a means of filling or exchanging cylinders, a means of indicating the amount of gas in the cylinder, pressure reduction means and an outlet pressure regulator. The usual intermittent control consists of inhalation and exhalation valves triggered from one mode to the other via some pressure sensitive means. The usual coupling to the patient consists of a breathing tube and an oral-nasal face mask. Various refinements, operator adjustments and performance features, such as suction in the exhalation mode, may be found in the art but the three basic components of gas supply, cycling means and patient coupling are a requirement of all automatic and semi-automatic resuscitators.

The key component of a resuscitator is the cycling valve, both from the standpoint of performance and from the standpoint of total cost of the system. But a simple, inexpensive cycling valve may not reduce the overall cost and convenience if the gas supply system must still be made up of cylinders, gauges, valves and high performance pressure regulators.

The general object of the present invention is to provide a cycling valve for resuscitators and other purposes which has no moving parts. Other objects are to provide a resuscitator which is simple in construction, requires no maintenance, has maximum reliability, is easy to use and inexpensive to manufacture. A more particular object is to provide a new and improved cycling valve which obviates the necessity for gas cylinders, gauges, manual valves and pressure regulators normally required to operate conventional resuscitators.

The key component of the present invention is a cycling valve which is simple in construction and which

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allows the use of a directly connected gas blower in place of the usual storage cylinder and array of control devices associated therewith. This cycling valve has no moving parts other than the stream of air which flows through it. Use of an inexpensive electric gas pressure blower for the gas supply of a resuscitator has not been commercially successful heretofore because the intermittent off-on action of the conventional cycling valves create wide pressure fluctuation in the blower output which must be levelled out by the same expensive regulating and accumulator components of the compressed gas cylinder system.

The invention will be better understood and additional objects and advantages will be appreciated from the following detailed description of the preferred embodiment illustrated on the accompanying drawing. Various changes may be made, however, in the details of construction and arrangement of parts and, as previously stated, the cycling valve may be used for other purposes. All such modifications within the scope of the appended claims are included in the invention.

In the drawing:

FIGURE 1 is a perspective view of a resuscitator embodying the invention, the cycling valve being removed from the blower;

FIGURE 2 shows the construction of the cycling valve;

FIGURE 3 is a fragmentary sectional view taken on the line 3-3 of FIGURE 2;

FIGURE 4 is a fragmentary sectional view taken on the line 4-4 of FIGURE 2;

FIGURE 5 is a fragmentary sectional view taken on the line 5-5 of FIGURE 2; and

FIGURE 6 is a fragmentary sectional view taken on the line 6-6 of FIGURE 2.

Referring first to FIGURE 1, numeral 1 designates a positive displacement blower driven by an electric motor 2. The blower draws in air from the atmosphere through intake 3 and discharges it in continuous flow through outlet 4. These inlet and outlet ports are incorporated in a mounting plate 5 having screw holes 6 for mounting the cycling valve 10.

The valve 10 comprises two flat plates 11 and 12 secured together by screws 13 or other suitable means. On the inlet end of the valve a standoff plate 14 is secured to the plate 12 and screws 15 are provided to engage the holes 6 for securing plate 14 and the valve plates to mounting plate 5. When the valve is thus mounted on the motor and blower unit, the valve inlet port 20 is in registering communication with blower outlet port 4, and standoff plate 14 holds the valve plate 12 spaced from the blower inlet port 3 so that the latter is not obstructed. The valve 10 has two discharge ports 21 and 22, the former being connected with a flexible tube 25 leading to an oral mask 24 and the latter being open to atmosphere. Outlet 22 is restricted at 23.

The details of construction of valve 10 are shown in FIGURE 2. Plate 12 is a thick plate having grooves recessed into one surface, all the grooves being of uniform depth with square sides and flat bottoms to form air passageways of rectangular cross section. Plate 11 is a flat plate which is attached to plate 12 over the grooves, converting them to enclosed airways. It is the pattern of these airways that determines the functioning properties of the cycling valve.

Air enters the valve in continuous steady flow through the inlet 20 and proceeds through a converging airway 30 to a restricted rectangular nozzle orifice 31. Downstream from nozzle 31 the airway widens at 32 between divergent side walls and separates into a mask branch 33 and an outlet branch 34. These two airway branches diverge from each other on opposite sides of a wedge-shaped divider 35 which is aligned with the center line of nozzle 31. The walls of the branches 33 and 34 pre-

erably diverge slightly as they approach the outlets 21 and 22. Branch 33 and outlet 21 provide free and unrestricted flow to the mask.

In the mask branch 33 the side wall 36 farthest from the outlet branch 34 is provided with a longitudinal series of narrow slot openings 37 beginning just downstream from the apex of divider 35. These slots vent the surface 36 into a feed back airway 38 which passes around to a biasing jet opening 40 immediately at the outlet of nozzle 31 on its opposite side and at right angles to the nozzle center line.

Air entering at 20 is converted from a predominantly pressure state to a velocity state via the converging airway 30 approaching nozzle 31. As the air stream injects from the nozzle into the widened downstream area, a relative vacuum is created at the biasing jet opening 40 thereby establishing a flow of air from openings 37 through passageway 38 and jet opening 40 to impinge on the air stream from nozzle 31. The effect of this air jet from opening 40 is to bias the flow from nozzle 31 into the mask airway branch 33. Otherwise, the nozzle flow would tend to divide equally into both branches 33 and 34.

Once the main stream contacts airway side wall 36, boundary layer effects cause all of the flow from nozzle 31 to lock into the mask branch 33. If the mask outlet is a compliant but dead end system, such as a patient's lungs, flow will continue from mask outlet 21 until the elastic resistance of the lungs equals the available flow pressure causing flow through mask branch 33 to diminish and force the nozzle airstream to switch into outlet branch 34 where the boundary layer phenomenon on wall 45 causes the air stream to lock into the outlet branch 34. This relieves the air pressure in the patient's lungs allowing the elasticity of the rib cage structure to start exhalation.

As long as exhalation flow continues from the mask connection 21 back down airway 33, its impingement on the nozzle air stream will enhance the outlet mode and overpower the biasing effect of flow from opening 40. Relatively free flow through the outlet branch 34 plus boundary layer effects of flow on wall 45 plus such aid from the mask branch 33 backflow tends to hold flow in the outlet mode even to the extent of creating a partial vacuum at the mask connection 21. Outlet restriction 23 brings this mask vacuum producing tendency under control by limiting air velocities through outlet branch 34 and, in this resuscitator application, a terminal pressure of atmosphere or very slight vacuum is the optimum point at which to switch the nozzle air stream into the mask branch 33 to complete the cycle. When exhalation backflow through mask branch 33 ceases, or almost ceases, this backflow can no longer overpower the biasing effect of flow from opening 40 and the biasing jet then switches the main flow from nozzle 31 back into the mask branch to start the next inhalation phase or mode.

In order to achieve maximum efficiency conversion of inlet supply pressure to the build-up of mask pressure at switch-over point, the boundary layer lock-up on wall 36 is further enhanced by turbulence attenuating flow into slots 37. The diverging walls of branches 33 and 34 produce efficient conversion of velocity pressure into static pressure. The interconnection of bias jet 40 and holding slots 37 has a diminished effect during the outlet or exhalation flow mode since the vacuum tendency in the mask branch 33 also tends to attenuate the bias jet flow which, if acting unrestricted, would cause switching from outlet to mask before the desired zero or slight vacuum was attained.

A typical pressure flow cycle attainable with the present cycling valve is as follows: Starting with the onset of the inhalation mode, unrestricted flow exits from the mask connection 21 and, as the lungs expand elastically, produces an increasing back pressure until boundary layer effects and biasing jet can no longer lock the gas flow

into the mask branch 33. For resuscitation this should occur at five to six inches water column mask pressure (one inch water equal 0.036 p.s.i. or 1.87 mm. mercury).

After switching to the exhalation mode, the inlet nozzle air stream plus exhaled gases flow out the outlet branch 34 until exhalation flow has diminished to zero or near zero when the biasing jet can switch the nozzle air into the mask branch 33 to start a new cycle. This should occur when mask pressure is between zero and minus one-half inch water column. To maintain these cycling pressures an inlet pressure between 9 and 10 inches water column is used. It will be noted that the cycling valve is predominantly flow sensitive. Inlet pressure from a one cubic foot per minute constant displacement flow has less than ten percent variations during both phases of the cycle except for a very short pressure spike at the instant of switch-over from inhalation to exhalation.

Known fluid switching devices used predominantly in fluid powered amplifiers and computing equipment, and particularly those designed for sonic flow velocities and high energy jets, are not suitable for the present purpose. An attempt to apply these known principles directly, as well as many of the published variations of oscillator and feed-back systems, resulted in entirely unsatisfactory performance as a resuscitator. With the computer configurations, the best inlet pressure to maximum mask pressure ratio obtained was thirty inches water inlet to six inches at the mask; this is undesirable and dangerous. Exhalation pressures lower than one inch above atmospheric were unattainable and switching action from inhalation to exhalation even then was not positive. Applicant's new arrangement has produced gross changes in performance. The turbulence reducing holding slots 37 in communication with biasing jet 40 are a novel and essential feature of the present cycling valve which impart the desired characteristics, particularly for a resuscitation application.

The stable and relatively low inlet pressure requirement (nine to ten inches water) makes use of a simple positive displacement gas blower feasible as an inexpensive part of the resuscitator assembly. Such a low inlet pressure is achieved by minimizing pressure drop through mask branch 33, the turbulence reducing slots 37 being an important contributing factor. The cycling pressure flow pattern matches the generally accepted ideal for resuscitators and produces a desired breathing rhythm when the patient is not breathing. The unit sensitivity to flow allows the patient to set the breathing rhythm with a minimum effort when he is breathing. A blocked airway to the patient's lungs will cause rapid cycling providing a clue to the operator that the lungs are not being ventilated and that appropriate action must be taken. A steady non-cycling mode would indicate to the operator that there is an excessive leak in the face mask.

In summary the following important features are emphasized.

(1) The cycling valve performance characteristics are such that a simple direct connected gas blower may be used.

(2) The cycling valve has only two parts, both stationary—a grooved plate and a cover plate which can be produced by inexpensive manufacturing techniques.

(3) The cycling valve has no moving parts thereby assuring long life and maximum reliability. There are no valve seats to develop leaks, no sliding or pivoting parts to freeze up, no pressure sensing diaphragms to deteriorate, no springs to maintain in adjustment.

(4) Performance characteristics meet the ideal intermittent pressure specifications for resuscitators and, if future clinical study should show greater suction pressures are desirable, the cycling valve has these capabilities also (by enlarging outlet orifice restriction 23).

The cycling valve is useful wherever a repeating fill and dump fluid cycle is desired in connection with a fluid capacitance. For example, the valve may be used as a

liquid volume indicator in a closed tank, the cycle frequency being a measure of the volume which is not occupied by liquid. When the gas or vapor capacitance is small (tank nearly full of liquid), the valve will cycle rapidly and, as the gas or vapor capacitance increases (as liquid is withdrawn from the tank), the valve will cycle more slowly.

For such other applications, it may be noted that stable and uniform cycling can be obtained with pressures lower than 0.1 inch water column and flows well within the laminar region. In the lower pressure ranges a centrifugal blower may be used instead of a positive displacement type.

Having now described my invention and in what manner the same may be used, what I claim as new and desire to protect by Letters Patent is:

1. A reversing valve for coupling with an external fill and dump fluid capacitance of substantially limited capacity comprising an inlet nozzle, a flow divider in front of said nozzle, a pair of diverging branch passageways on opposite sides of said divider, one of said branches terminating in an outlet and the other branch terminating in a connection for said capacitance, a constantly operative, unidirectional biasing jet orifice adjacent said inlet nozzle arranged to divert the nozzle flow into said capacitance branch, and an opening in the wall of said capacitance branch opposite said divider supplying said biasing jet orifice with fluid from said capacitance branch, said inlet nozzle constituting the only functional source of fluid to said valve and said biasing jet orifice being the only biasing jet orifice in the valve.

2. A reversing valve as defined in claim 1, said opening comprising a series of slots in said wall arranged to sustain boundary layer flow over the slots.

3. A reversing valve as defined in claim 2, said series of slots extending downstream from a point approximately opposite the apex of said divider.

4. A valve comprising an inlet nozzle, a pair of outlets, a flow divider in front of said nozzle, a pair of diverging branch passageways on opposite sides of said divider leading to said outlets, a single biasing jet orifice on one side of said nozzle, and slot openings in the wall of said branch opposite said orifice for supplying said orifice with fluid from said branch, said slot openings being arranged to sustain boundary layer flow over the slots, and said inlet nozzle constituting the only functional source of fluid to said valve.

5. A reversing valve for an external fill and dump fluid capacitance comprising an inlet nozzle, a flow divider in front of said nozzle, a pair of branch passageways on opposite sides of said divider, one of said passageways being a capacitance branch for connection with the capacitance and the other passageway being an outlet branch for said capacitance and for the inlet nozzle flow, and a unidirectional constantly operative biasing jet orifice adjacent said nozzle and supplied from said capacitance branch to divert the nozzle flow into said capacitance branch until the capacitance is filled, said capacitance branch being subject to reverse flow from the capacitance and arranged relative of said jet orifice to direct said reverse flow in opposition to the biasing jet and render the biasing jet ineffective though constantly operative during the interval of reverse flow.

6. A fill and dump fluid capacitance system comprising a reversing valve having an inlet nozzle, a flow divider in front of said nozzle, a pair of diverging branch passageways on opposite sides of said divider, one of said branches terminating in an outlet, a receiver of substantially limited capacity connected with the terminal end of the other branch, a constantly operative, unidirectional biasing jet orifice adjacent said nozzle and arranged to divert the nozzle flow into said receiver branch, and an opening in the wall of said receiver branch opposite said divider supplying said biasing jet orifice with fluid from said receiver branch.

7. A fill and dump fluid capacitance system comprising a reversing valve having an inlet for connection to a constant flow gas source, an outlet in said valve, a receiver of substantially limited capacity connected to said valve, branching passageways in said valve arranged to convey gas flow from said inlet to said outlet and receiver, unidirectional, constantly operative means adjacent said inlet to bias said flow into said receiver branch until the receiver is filled, cessation of flow through said receiver branch when the capacitance is filled creating a back pressure and switching said inlet flow from said source through said outlet branch permitting said receiver to discharge through said outlet branch along with said inlet flow from said source, said discharge creating a reverse flow in said receiver branch, said receiver branch being arranged to direct said reverse flow so as to overcome the effect of said biasing means, cessation of said reverse flow rendering said biasing means again effective to start a new receiver filling mode.

8. In a resuscitator, a reversing valve having an inlet, an air supply connected to said valve inlet, an outlet to atmosphere in said valve, a patient face mask connection in said valve, branching airways in said valve arranged to convey air flow from said inlet to said outlet and said mask connection, unidirectional biasing jet means supplied from said mask connection and adjacent said inlet for continuously biasing said flow into said mask branch to start an inhalation mode, cessation of flow through said mask branch when the patient's lungs are filled with air creating a back pressure switching said inlet flow from said supply through said outlet branch and permitting exhalation through said outlet branch along with said inlet flow from said source, said exhalation creating a reverse flow in said mask branch, said mask branch being arranged to direct said reverse flow so as to overcome the effect of said biasing means, cessation of said exhalation reverse flow rendering said biasing means again effective to start a new inhalation mode.

9. In a resuscitator, a reversing valve having an inlet nozzle, a constant flow air pump having an outlet connected to said valve inlet, a flow divider in front of said nozzle, an outlet to atmosphere in said valve, a patient face mask connection in said valve, divergent branching airways on opposite sides of said divider arranged to convey air flow from said inlet to said outlet and said mask connection, a constantly operative, unidirectional biasing jet orifice arranged to divert said flow into said mask branch to start an inhalation mode, and slots in the wall of said mask branch opposite said divider supplying said biasing jet orifice, cessation of flow through said mask branch when the patient's lungs are filled with air creating a back pressure switching said inlet flow from said pump through said outlet branch and permitting exhalation through said outlet branch along with said inlet flow from said pump, said exhalation creating a reverse flow in said mask branch, said mask branch being arranged relative to said jet orifice to direct said reverse flow in opposition to said biasing jet, cessation of said exhalation reverse flow rendering said biasing jet again effective to start a new inhalation mode.

10. A resuscitator as defined in claim 9 including means to control the minimum exhalation pressure, said means comprising a restriction in said outlet.

11. A reversing valve having an inlet, an outlet, and a fluid capacitance connection for an external fill and dump fluid capacitance of substantially limited capacity branching passageways comprising an outlet branch and a capacitance branch arranged to convey a fluid flow from said inlet to said outlet and to said capacitance connection, respectively, and effectively unidirectional biasing means adjacent said inlet and acting continuously to bias said flow into said capacitance branch, attainment of the limit of capacity acting to overcome the effect of said biasing

means and switch said inflow through said outlet branch to evacuate said capacitance branch.

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