Aug. 21, 1945. H. E. ENSLIN ET AL 2,383,181

APPARATUS FOR INDUCING RESPIRATION

Filed Jan. 29, 1943 2 Sheets-Sheet 1

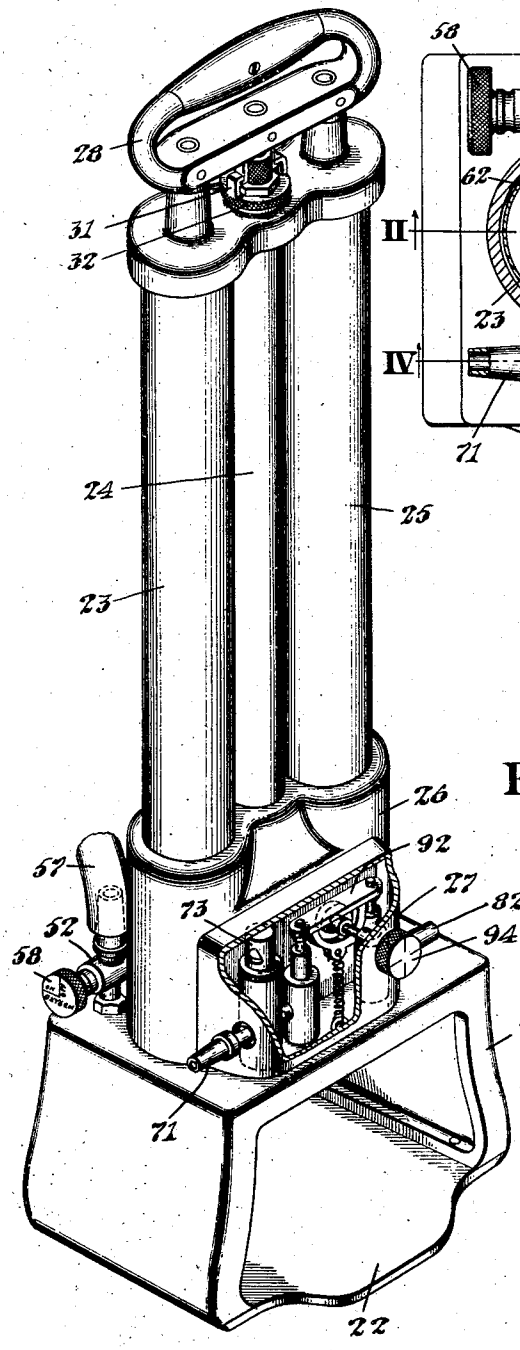


Fig. 1.

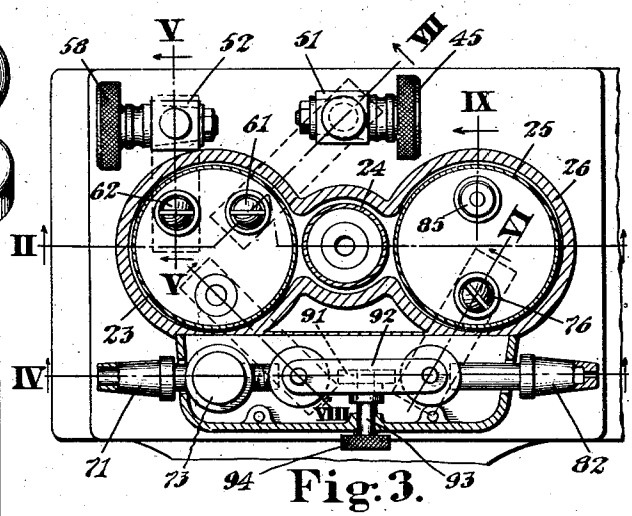


Fig. 3.

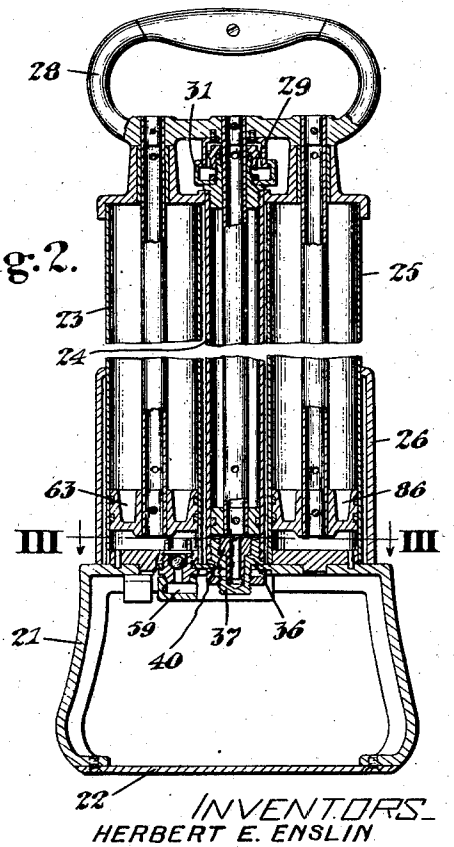


Fig. 2.

INVENTORS
HERBERT E. ENSLIN
EDGREN C. WALLACE
BY Thomson & Thomson
ATTORNEYS

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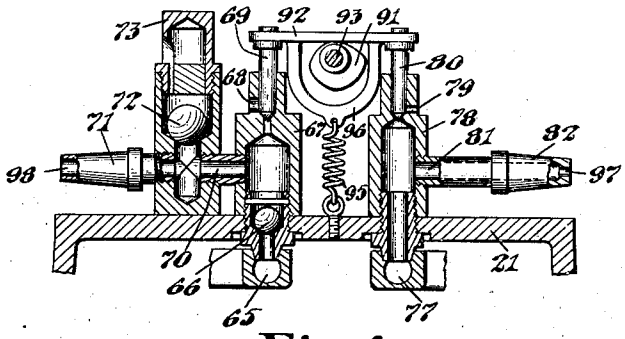


Fig.4.

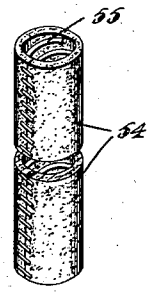


Fig.12.

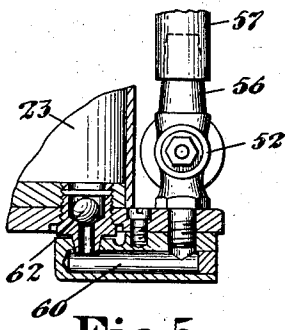


Fig.5.

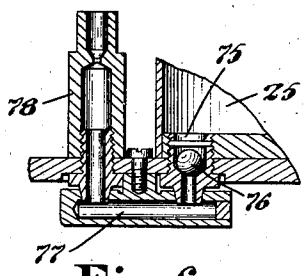


Fig.6.

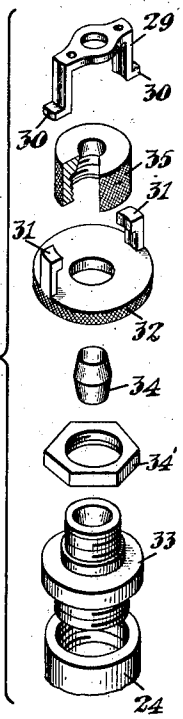


Fig.10.

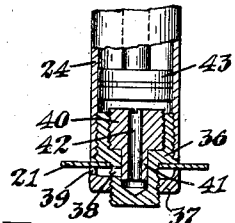


Fig.11.

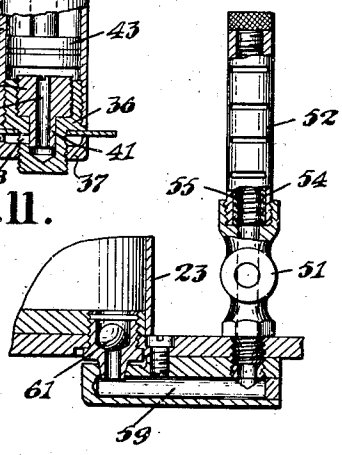


Fig.7.

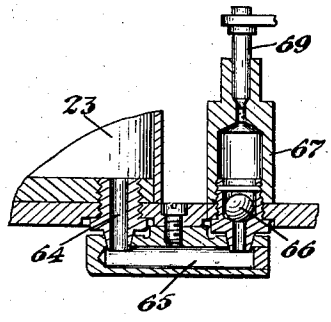


Fig.8.

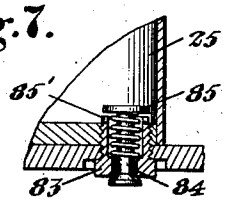


Fig.9.

INVENTORS.
HERBERT E. ENSLIN
EDGREN C. WALLACE
BY Thomson & Thomson
ATTORNEYS.

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UNITED STATES PATENT OFFICE

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APPARATUS FOR INDUCING RESPIRATION

Herbert E. Enslin, Beverly, Mass., and Edgren C. Wallace, Miami, Fla., assignors to Revair Corporation, Boston, Mass., a corporation of Massachusetts

Application January 29, 1943, Serial No. 474,020

4 Claims. (Cl. 128—29)

This invention relates to apparatus for administering oxygen-containing or other gases to the lungs for the purpose of restoring normal respiration; and pertains more particularly to improvements in portable, manually-operated, mechanical respirators intended to be used in lieu of or as an adjunct to well known methods of manual resuscitation.

The principal purpose of the invention is to provide a safe, efficient and relatively simple device which may be readily transported and easily operated by a layman, which will supply to the lungs either fresh air, pure oxygen or gaseous mixtures, under controllable conditions of volume and pressure, and which will withdraw relatively smaller proportions of expended gases until the lungs are adequately inflated and natural breathing has been induced.

We are aware that various types of pulmotors, mechanical resuscitators and other respirating devices have heretofore been devised, but it is commonly known that such devices have met with the disapproval of the medical profession for general usage because they could not be regulated or controlled to induce pulmonary ventilation under conditions of time, volume and pressure approximating natural respiration of the individual being treated. It has been found that these prior devices creat abnormal conditions and tend to injure the tissues of the lungs and respiratory tract by overdistention under excessive positive pressures on forced inspiration, and by harmful contraction under excessive negative pressures on forced expiration. A further objection to the pressure-and-suction type of apparatus has been the inability of such devices to afford anadequate exchange of gases because of the too rapid constriction of the alevoli and bronchia.

It is now recognized that resuscitation after asphixia or the restoration of natural respiration after failure for other causes is primarily a chemical action involving a renewed supply of oxygen which stimulates circulation, improves the tonus and elasticity of the diaphragm and thoracic muscles, and induces normal pulmonary ventilation. Hence, satisfactory results may safely be achieved by administering oxygen-containing gases to the lungs under natural conditions of time, volume and pressure, without employing the excessive quantities and pressures which were considered necessary to accomplish the results by mechanical phenomena. It is understood, nevertheless, that the gases administered to the lungs are absorbed or diffused through the tissues according to the mechanical principles applying to inflated bodies having capacities and surface tensions comparable to the lungs.

The improved apparatus which we have devised has been designed after extended research of the physiological conditions affecting artificial respiration and the mechanical requirements necessary to satisfy those conditions; and it is the main object of this invention to obviate the objectionable features and harmful effects of the prior devices, and to provide means for so adjusting and controlling the operation of our machine that its rate of operation, and the volume and pressure of gases delivered to or withdrawn from the lungs, will approach as nearly as practicable to the individual physiologic conditions of natural breathing, even when the machine is manipulated by an inexperienced operator.

This objective is attained by equipping the improved machine with controls which ensure gradual inflation of the lungs with fresh air supplied in safe quantities at harmless pressures and initially withdrawn in substantially smaller quantities at lower pressures, so that a gradually increasing minimal supply remains in the lungs; and which permit expirations of larger amounts at higher pressures after the lungs have been filled to such an extent that muscular reflex expels the exhausted air. Thus, normal respiration is induced and maintained while the machine is being operated and without further adjustment of its controls.

These and other salutary features of the improved apparatus will become apparent from the following description of the construction and operation of the recommended embodiment of the invention shown in the accompanying drawings, in which:

Fig. 1 is a perspective view of our apparatus, with a portion of the control compartment broken away;

Fig. 2 is a vertical section of the machine taken on line II of Fig. 3, with certain parts in elevation;

Fig. 3 is a horizontal section on line III—III of Fig. 2;

Figs. 4 to 9 inclusive are detail section views taken on lines IV, V, VI, VII, VIII and IX, respectively, of Fig. 3;

Fig. 10 is a developed view in perspective of the parts of the bearing and lock mechanism at the top of the central cylinder in Fig. 2;

Fig. 11 is an enlarged sectional detail of an adjustable valve mechanism at the bottom of the central cylinder of Fig. 2; and

Fig. 12 is a perspective view to larger scale of an air filter shown in Fig. 7.

In the particular embodiment chosen for the purpose of illustration, the improved mechanical respirator is of the hand-operated pump type, comprising in general a pressure cylinder, a suction cylinder, an intermediate cushion cylinder acting as a pneumatic brake for controlling the speed of reciprocation of the pistons moving in said cylinders; an operating handle connected to the three pistons; a base on which the cylinders are mounted, having ports and check valves regulating the admission and discharge of air or oxygen-containing gases to and from the cylinders; an adjustable valve for controlling the rate of reciprocation of the piston in the brake cylinder; manual valves controlling the supply of pure air, oxygen or mixtures thereof, to the machine; nozzles associated with the respective pressure and suction cylinders, to which tubes leading to a suitable face mask may be attached, the two nozzles having openings substantially different in diameter for a purpose hereafter explained; and a control chamber having vents disposed in the conduit between the respective nozzles and the corresponding cylinders, and manually controlled valves simultaneously operable to open or close the vent openings and thereby regulate both the volume and pressure of the gas delivered to the lungs or withdrawn therefrom by the operation of the machine.

The base **21** of the machine may be a metal casting providing a bridged opening for receiving the operator's foot which bears upon a bottom plate **22**. The three cylinders **23**, **24** and **25** may be made of metal, preferably plated on the inside to avoid corrosion, or of other suitable material. They are suitably mounted in upright position on the base **21**, and the lower portions of the cylinder are preferably shielded and reinforced by a casing **26** of plastic or the like. The control chamber **27** is mounted on the base against the shield **26**.

In the aligned arrangement shown, **23** is the pressure or inspirating cylinder, **25** is the suction or expirating cylinder, and **24** is the brake or stroke control cylinder; but it will be understood that the cylinders may be disposed in other formations if desired. Each cylinder has a suitable piston and rod as shown in Fig. 2, the pistons having suitable compression rings, the rods being tubular and having vent openings to permit free circulation of air above the pistons as indicated in said figure; and each of the operating cylinders has a cap or head affording a bearing for its piston rod. The brake cylinder **24** has a packer head providing a releasable lock for the operating handle as hereafter described.

The upper ends of the piston rods are connected to a handle **28** for reciprocating the three pistons simultaneously, and the bottom portion of the handle is provided with a bridge-like latch member **29** having flanged legs **30** (Fig. 10) releasably engaged by the inturned lugs **31** of a locking ring **32**, to hold the handle and piston rods in downward or closed position when the apparatus is not in use (Fig. 2). As best indicated in Fig. 10, the locking ring turns about the threaded stem of a packer head **33** which screws into the top of cylinder **24**; a nut **34'** holds the ring against displacement while permitting its rotation by hand; and a tapered bushing **34** and packer head nut **35** threading on the packer head **33** to provide a relatively tight bearing for the piston rod of the stroke control cylinder. Downward movement of the handle is limited by its engagement with the hubs of the caps on cylinders **23** and **25** (Fig. 2).

The base of the stroke control cylinder **24** is fitted with an internal nut **36** (Figs. 2 and 11) having a depending end projecting through the top portion of the base member **21** and secured thereto by a lock nut **37**. Said nut end and locking member have vent openings **38** and **39**, respectively; and an orificed screw **40** having a valve tip **41** threads in the upper end of the nut **36** to open or close the opening **38** and thereby regulate the flow of air through the screw orifice **42** and beneath the brake piston **43**. In Figs. 2 and 11 the adjustable valve is closed, but it will be understood that the screw **40** may be turned to open the port **38** to such extent as may be desired.

It will also be evident that the adjusting valve **40**, **41** must be regulated before the piston **43** is placed in the cylinder **24**, so that the adjustment cannot be changed without dismantling the machine. Hence, the machine may be tested and regulated at the factory until the brake cylinder performs its desired function of affording a pneumatic cushion which prevents abrupt operation of the handle **28** and tends to control the speed of reciprocation to the desired rate of about sixteen to twenty strokes per minute. If desired, a check valve (not shown) may be employed in an obvious manner to close the orifice **42** in the upstroke of piston **43**.

The admission of pure air, oxygen or other gases, or mixtures thereof, to the pressure cylinder **23** is regulated by a pair of valved inlet ports **51** and **52**. Port **51** (Fig. 7) is intended to supply pure air, and is provided with a filter comprising an apertured tube **53** containing a sleeve **54** of felt or other suitable air-filtering material, and a spring **55** for retaining the felt sleeve in proper position within the tube. The valve or cock of this port is regulated by a knob **45** (Fig. 3) which may have suitable indications to designate its setting.

Gas-intake port **52** (Fig. 5) has a hose connector **56** for the attachment of a tube **57** leading from a tank containing oxygen or other gases to be administered to the lungs; and a knob **58** for regulating the valve opening. It will be understood that either port may be used separately, or that both ports may be simultaneously employed to supply any desired mixture of air and oxygen (or other gases); and it will also be apparent that the valves of both ports may be controlled by a single regulating knob, if desired.

These intake ports communicate with cylinder **23** through ducts **59** and **60**, respectively, the openings in the base of the cylinder being equipped with ball check valves **61** and **62**, respectively, which permit the gases to enter the cylinder on the upstroke of pressure piston **63** but seat on the downstroke thereof. The discharge port **64** of the pressure cylinder (Fig. 8) communicates through duct **65** and ball check valve **66** with a pressure regulator chamber **67** located in the control chamber **27**; said regulator having a small vent opening **68** (Fig. 4) controlled by a needle valve or plunger **69**, and a larger outlet port communicating through a nipple **70** with a nozzle **71** to which a tube of the face mask may be fitted.

A safety valve **72** is located in the duct between the regulator **67** and the hose connector **74**, the ball valve **72** being of such weight that it will open under pressures exceeding 25 mm. (Hg) above atmosphere, at the lung. A whistle signal **73** is located above this escape valve so

that the operator is warned when the pressure exceeds the maximum valve for safe operation of the machine.

The base of suction cylinder **25** (Fig. 6) has an inlet port **75** equipped with ball check valve **76** and communicating through duct **77** with a suction regulator chamber **78** located in the control chamber. This regulator has a vent opening **79** regulated by a plunger or needle valve **80** (Fig. 4), and an intake nipple **81** equipped with a hose connector **82** to which the exhaust tube of the face mask is connected. An exhaust port leading to atmosphere and comprising a nipple **83** having a valve seat controlled by a normally closed spring-pressed valve **84**, is located in the bottom of cylinder **25**. The stem of valve **84** has a washer **85** at its inner end to retain the valve spring, and the washer engages the end of the nipple **83** when the valve is fully open. Slots **85'** in the nipple end permit air to pass through the nipple. This discharge port expels air (and also any water or mucous which may be drawn into cylinder **25**) on the downstroke of the suction piston **86** (Fig. 2), when the valve **84** is opened by pressure of the exhausted gas within the cylinder **25**.

The needle valves **69** and **80** (Fig. 4) in the control chamber, are simultaneously actuated in the same direction and to the same degree, by a cam **91** which bears against a plunger bar **92** attached to both valve plungers. The cam shaft **93** is rotated by a regulating knob **94** located outside the chamber **27** (Figs. 1 and 3), and the bar **92** is held against the cam by a spring **95** connected thereto through a yoke **96**, and attached at its other end to the top portion of the base member **21** (Fig. 4). The cam **91** preferably has four rises as indicated in Fig. 4, giving four adjustable positions of the pressure control valves, and these positions may be indicated on the pressure control knob adjuster **94**.

Adjustment of these control valves **69** and **80** enables the user of the apparatus to control both volume and pressure of the gases delivered by the positive pressure cylinder **23** or exhausted by the negative pressure cylinder **25**, by venting to atmosphere a predetermined proportion of the air or gas passing to the lungs through outlet nozzle **71** or withdrawn from the lung through intake nozzle **82**. Such adjustment is necessary to supply the correct volume and pressure for the lung capacity of the patient as determined by his age or physical condition, and the adjustment may obviously be made during operation of the apparatus as well as in advance, merely by turning the regulating knob **94**. The machine and its controls are preferably so constructed and adjusted that the maximum volume of air or gas delivered by the pressure cylinder (with the valve **69** closed) is approximately 500 cc. at a pressure in the vicinity of 25 to 30 mm. (Hg) above atmosphere, at the lungs; and that the minimum volume is approximately 100 cc. at a pressure of about 5 mm. at the lung. Intermediate conditions will depend upon the setting of the regulating knob.

It will be understood that this volume-pressure control operates independently of the stroke control and of the safety valve, but it will be appreciated that excessive positive pressures, caused either by too speedy operation of the machine or by obstructions in the throat, larynx or trachae, will immediately be relieved by the safety valve and the whistle signal will warn the operator to reduce his speed, regulate the control valves, or endeavor to remove any such obstructions. Hence, the three controls upon excessive pressure supplement each other and cooperate in ensuring that the respirator may be efficiently operated at normal speed without injury to the patient due to excessive pressures.

It will be noted that the adjustable control valves **69** and **80** operate simultaneously to reduce both volume and pressure on the expirating stroke as well as on the inspirating stroke of the respirator. For the reasons previously explained, it is very important that the negative pressure created by the suction cylinder **25** be reduced proportionately to any reduction of positive pressure created by the down stroke in cylinder **23**, so that the pressure differential between the positive and negative sides of the apparatus be maintained particularly during the early stages of operation.

Such pressure differential (and complemental volume differential) is influenced by the relative sizes of the openings **97** and **98** in the hose connectors **82** and **71**, respectively, by the provisions of expansion chambers in the regulators **78** and **67** (Fig. 4), and by the drop in pressure within the lungs and tubes of the patient when a collapsed lung is gradually filled on successive inspirating strokes of the machine. It will be apparent from Fig. 4 that the opening in the connector **82** is substantially smaller than that in connector **71**, preferably in the proportion of one to four in cross-sectional area. The differential caused by the relative size of the openings **97** and **98** is, however, overcome after the lungs have been completely expanded, so that the muscular contraction of the diaphragm will thereafter expel a volume of air substantially equal to that delivered by the apparatus, at substantially the same pressure. Thus normal breathing is induced and maintained even though the patient is still unconscious. This condition will normally be reached after thirty to forty strokes of the machine, and thereafter normal tidal exchange of fresh air is uniformly maintained until the patient recovers.

It will be appreciated that optimum results of the use of the improved respirator will depend upon the size of the ducts or conduits between the respective operating cylinders and their hose connectors, and upon the weight of the balls or other valve elements in the safety valves and the check valves, particularly ball valves **72** and **76**. The former should release, as aforesaid, under positive pressure of about 25 to 30 mm. (Hg) above atmosphere, and the latter should unseat at a negative pressure of approximately 6 to 8 mm. Thus, when the pressure cylinder initially delivers about 500 cc. of fresh air (or other gases) to the lungs at 25 mm. pressure, the first upstroke of the piston will withdraw approximately 125 cc. of exhausted air from the lungs at a negative pressure of about 7 mm. Under succeeding inspirating strokes the volume of residual air in the lungs is gradually increased and the quantity withdrawn is also progressively increased under successive expirating strokes, until a normal tidal exchange of the average volume of 500 cc. is induced as aforesaid.

Such gradual filling up of the lungs, coupled with the safety factor afforded by the relief valve **72**, the limitation on the speed of operation and the adjustment permitted by the pressure control regulator **94**, ensures that normal respiration is artificially achieved without injury to the patient, even though the respirator is operated by an in-

experienced person. The device herein described may be manufactured at reasonable cost; it is small, compact and portable; it is easy to operate efficiently under simple instructions which may be packed with the machine; and it may be used confidently and safely in any cases of asphixia, due to poisonous gases, electric shock, water submersion, or the like.

We claim:

1. In respirating apparatus of the character described having a pressure cylinder, a suction cylinder and outlet and intake ducts leading from the respective cylinders to inspirating and expirating hose connectors; pressure control means comprising movable valves operatively disposed in the respective ducts, said ducts having vent openings controlled by said valves to permit the escape of air therefrom when the valves are opened, a bar interconnecting said valves, a cam engaging said bar, and manually operable means for rotating said cam to simultaneously regulate both valves.

2. In respirating apparatus of the character described having a pressure cylinder, a suction cylinder and outlet and intake ducts leading from the respective cylinders to inspirating and expirating hose connectors, a stroke control cylinder having an apertured valve member in its base, and a valve-closing screw threading downwardly into said member, whereby the valve opening may be regulated by turning said screw only when the cylinder is open, each of the three cylinders having pistons and piston rods, and the three rods being connected to an operating handle, so that the rate of movement of the pistons in the pressure and suction cylinders is governed by the rate of movement of the piston in the control cylinder.

3. In respirating apparatus of the character described having a pressure cylinder, a suction cylinder and outlet and intake ducts leading from the respective cylinders to inspirating and expirating hose connectors, a control chamber disposed adjacent the bases of said cylinders and containing a portion of each of said ducts, said ducts having vent openings disposed within said chamber, and pressure control means comprising movable valves operatively disposed in the respective ducts and regulating the escape of air through the respective vent openings, a link interconnecting said valves, and a valve actuator engaging said link, said actuator extending through the compartment wall and having an operable handle accessible outside the compartment, whereby both valves are simultaneously regulated in unison by turning the handle.

4. In respirating apparatus of the character described having a pressure cylinder, a suction cylinder and outlet and intake ducts leading from the respective cylinders to inspirating and expirating hose connectors, a control chamber disposed adjacent the bases of said cylinders and containing a portion of each of said ducts, said ducts having vent openings disposed within said chamber, and pressure control means comprising movable valves operatively disposed in the respective ducts and regulating the escape of air through the respective vent openings, a link interconnecting said valves, a spring connected to the link and tending to move the valves to vent closing position, a cam engaging said link for opening the valves, and a rod extending through the compartment wall and having a knob accessible outside the compartment, whereby both valves are simultaneously regulated in unison by turning the knob.

HERBERT E. ENSLIN.
EDGREN C. WALLACE.