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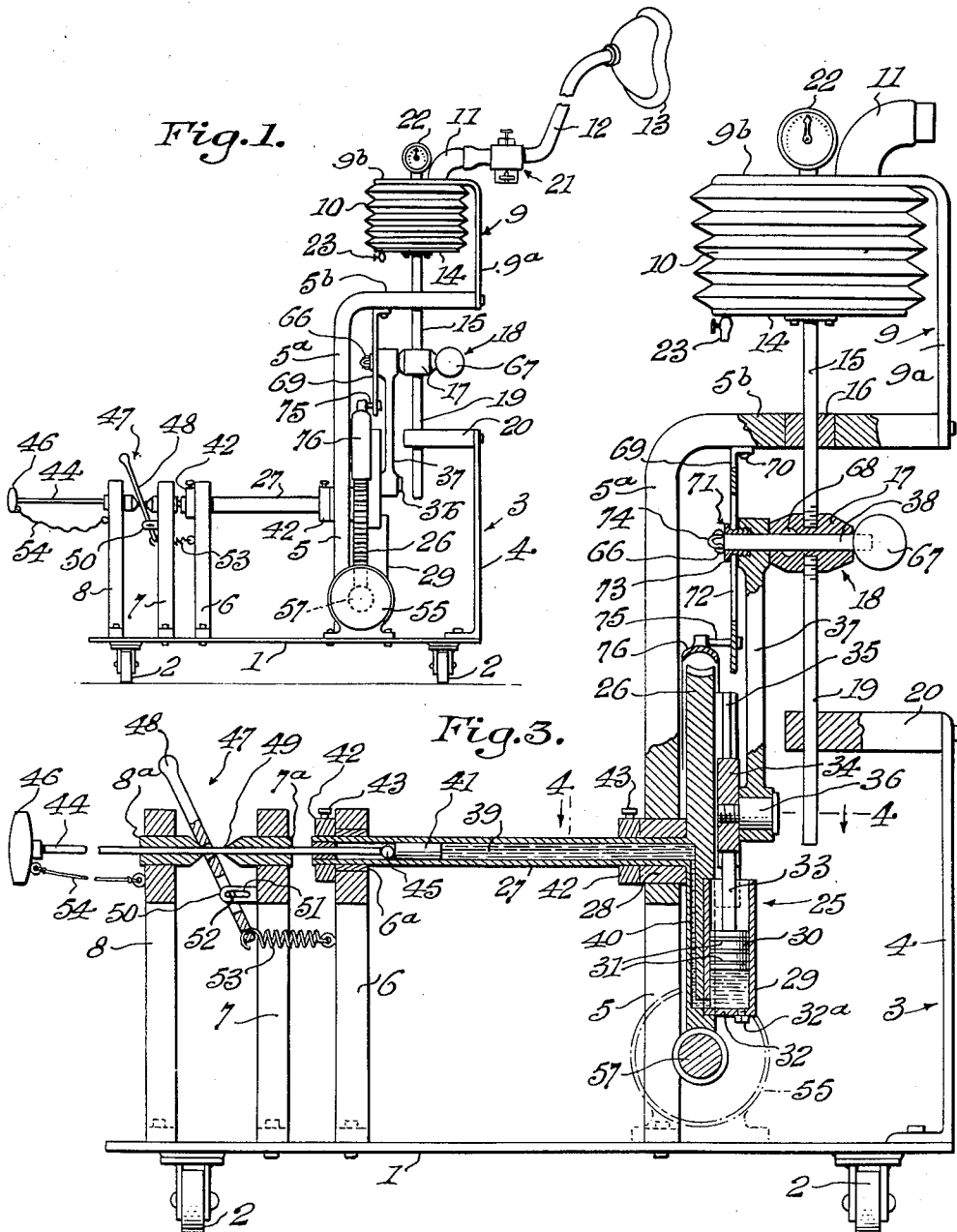
L. C. BLAIR

2,946,330

RESPIRATOR APPARATUS

Filed July 31, 1956

2 Sheets-Sheet 1



INVENTOR

Lyman C. Blair

BY *Baldwin & Wright*
his ATTORNEYS

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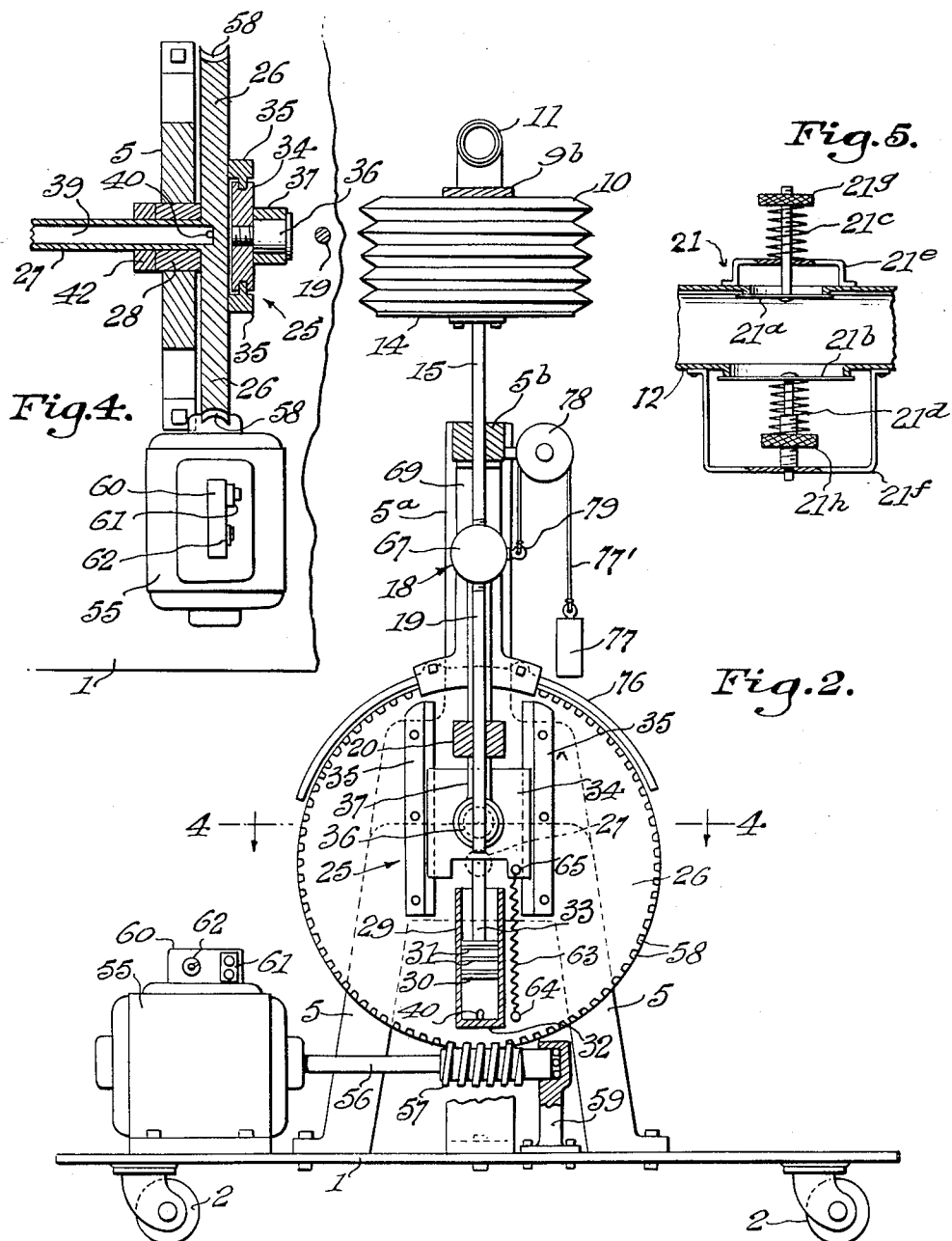
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INVENTOR

Lyman C. Blair

BY *Baldwin & Wright*
 his ATTORNEYS

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RESPIRATOR APPARATUS

Lyman C. Blair, 1212 Rothwell St., Houston, Tex.

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11 Claims. (Cl. 128—29)

This invention relates to respirator apparatus intended for use primarily in the treatment of humans, and more particularly to respirator apparatus for effecting adequate pulmonary ventilation of the respiratory system of a human patient in those situations where it is desirable that respiration of the patient be accomplished independently of the patient's respiratory muscles as, for example, in a case where the patient is undergoing intrathoracic surgery or in a case where the patient is suffering from poliomyelitis.

When utilizing a respirator or ventilating machine it frequently becomes necessary to vary the pressures created in the patient's respiratory system, or to vary the rate of respiration of the patient, or both. It even becomes necessary sometimes, such as in the event of power failure or when, in the opinion of the attending physician or surgeon it is desirable, to disconnect the respirator apparatus from the patient and resort to manual ventilation of his respiratory system. Not infrequently, these changes or adjustments must be made quickly. A satisfactory ventilating machine, therefore, must be capable of having its cycle of operation changed rapidly, it must be able to produce a wide range of pressures in the respiratory system and be capable of rapid adjustment throughout its range, and it must be quickly convertible from automatic to manual operation.

An object of this invention is to provide apparatus for producing effective pulmonary ventilation of a patient through a wide range of pressures and which is quickly and easily adjusted during operation to vary the pressures created in the patient's respiratory system.

Another object of the invention is to provide apparatus of the class referred to which may be readily and simply converted from automatic to manual operation so as to enable the patient's respiratory system to be ventilated manually.

A further object of the invention is to provide cyclically operable ventilating apparatus of the kind described which is capable of rapid and simple adjustment so as to vary its frequency.

Other objects and advantages of the invention will be pointed out specifically or will become apparent from the following description of the invention when read in conjunction with the appended claims and the accompanying drawings, in which :

Figure 1 is a side elevation of apparatus constructed in accordance with the invention;

Figure 2 is an end view, partly in elevation and partly in section, of the apparatus;

Figure 3 is a view similar to Figure 1, but on an enlarged scale and showing certain of the parts in cross-section;

Figure 4 is a view, partly in plan and partly in section, taken on the lines 4—4 of Figures 2 and 3; and

Figure 5 is an enlarged view of a detail shown in Figure 1.

Apparatus constructed in accordance with the disclosed embodiment of the invention comprises a platform 1,

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preferably provided with casters 2, and on which is mounted a frame 3 composed of a plurality of elements 4, 5, 6, 7, and 8. The frame element 5 includes a vertical section 5^a and an upper, horizontal section 5^b to the end of which is secured an angular frame member 9 having a vertical section 9^a and a horizontal section 9^b overhanging the horizontal section 5^b of the frame element 5.

To the under surface of the horizontal frame section 9^b is secured one end of a bellows or pump 10. The frame section 9^b is apertured for reception of a tubular connecting piece 11 which provides communication between the pump chamber and the respiratory system of a patient through the intermediary of a hose 12. The hose 12 may be fitted at its free end with either a face mask 13 or an endotracheal tube (not shown). The lower end of the bellows chamber is closed by a plate 14 to which is secured one end of a rod 15, the rod passing through a bearing 16 (Fig. 3) in the horizontal frame section 5^b and having its other end secured in a block 17 forming part of a coupling device 18. From the block 17 extends another rod 19 which passes through an opening formed in a horizontal shelf or flange 20 and serves as a guide for insuring vertical reciprocation of the bellows, the flange 20 being secured to the frame section 4.

The construction and arrangement of the parts described thus far are such that vertical reciprocation of the rod 15 will cause fluid alternately to be discharged from and drawn into the bellows chamber through the conduit provided by the connecting piece 11 and the tube 12, the discharge and intake of fluid being accompanied by the creation of pump induced relatively positive and negative pressures, respectively, in the respiratory system of the patient in simulation of natural breathing. The apparatus may be used either with or without an anaesthesia machine of known construction. When used in conjunction with an anaesthesia machine, the fluid discharged from and drawn into the bellows chamber will be regulated by the valves forming a part of the anaesthesia machine and when the apparatus is used alone the ingress and egress of fluid to and from the bellows chamber may be regulated by valve equipment incorporated in a housing in the hose structure 12 and indicated in Fig. 1 of the drawings by the numeral 21. Such valve equipment may be of the kind shown in Fig. 5 in which the wall of the tube 12 is provided with openings normally maintained closed by inlet and outlet valves 21^a and 21^b, respectively, under the influence of springs 21^c and 21^d which react against their respective valves and their supporting brackets 21^e and 21^f, the latter being bonded or otherwise suitably secured to the tube wall. As shown, the tension imposed by the springs upon each valve is capable of being adjusted by means such as knurled nuts 21^g and 21^h so as to enable the operator to control the opening and closing of the valves in accordance with the pressures desired to be created in the respiratory system of the patient. To enable the operator of the apparatus to ascertain the intensity of the relative positive and negative pressures created in the respiratory system of the patient, the bellows structure may include a pressure gauge 22, and to enable condensation to be drained from the bellows chamber, the plate 12 may be apertured for reception of a drain cock 23.

The invention includes mechanism generally indicated by the reference numeral 25 for reciprocating the pump 10 automatically and in the disclosed embodiment this mechanism comprises a driving member or rotor 26 and driving connections interconnecting the rotor and the pump. The driving member includes a shaft 27 journaled for rotation in the frame element 5 by means of a suitable

bearing 28. To one face of the rotor 26 is fixed a radially extending cylinder element 29 in which is mounted a reciprocable piston element 30 having the usual piston rings 31 associated therewith. Alternatively, a known form of cup-like sealing device of rubber, neoprene, or the like may be used in association with the piston and cylinder, instead of piston rings. One end of the cylinder is open. Through the open end of the cylinder extends a piston rod 33, one end of which is connected to the piston 30 and the other end of which is connected to a cross-head or part 34 mounted on a pair of parallel guideways 35, fixed to the outer face of the rotor, so as to permit the part 34 to be slidably shiftable radially with respect to the axis of rotation of the rotor 26. The cross-head 34 is provided with a threaded opening for reception of a pin 36 on which is journaled one end of a connecting rod 37. The other end of the connecting rod 37 is apertured for reception of a connecting or coupling pin 38 which forms a part of the coupling device 18 and which will be described in greater detail subsequently.

The rotor shaft 27 preferably is hollow, as is shown in Fig. 3, so as to enable it to serve as a reservoir 39 for hydraulic fluid, e.g. hydraulic brake fluid, which may be admitted to the hydraulic system through a port in the cylinder head 32 and which is closed by means of a plug 32^a. One end of the reservoir 39 communicates with the interior of the cylinder 29 through a passage 40 formed in the driving rotor 26, whereas the other end of the reservoir 39 is sealed by a movable piston 41 which may be equipped with a rubber, neoprene, or like sealing cup. The free end of the rotor shaft 27 is journaled in a suitable bearing 6^a in the frame element 6, the shaft being secured against longitudinal displacement in one direction by engagement of the rotor 26 with the bearing 28 and in the other direction by engagement of collars 42, secured to the shaft by set screws 43, with the bearings in the frame elements 5 and 6.

The position of the movable piston 41 is controlled by a rod 44 which is mounted for longitudinal movement in the frame elements 7 and 8 by bearings 7^a and 8^a, the rod being equipped at one end with a piston engaging part 45. The part 45 preferably is spherical, desirably being a steel ball or thrust bearing so that engagement between the part 45 and the piston 41 during rotation of the latter with the rotor shaft 27 will not impart rotation to the rod 44. At its other end the rod 44 preferably is provided with a hand grip 46 by means of which the position of the rod 44 may be adjusted. In the disclosed arrangement of parts, the rod 44 constitutes operating means for the part 34 and is operatively connected to the latter by the hydraulic fluid, the cylinder 29 and the piston 30, and their associated parts.

To hold the rod 44 in any one of its several adjusted positions, clamping means 47 is provided, which, in the disclosed form of the invention, comprises a manually operable bar 48 having an opening 49 through which the rod 44 passes. The bar 48 is mounted on the frame element 7 by means of a bracket 50 having a slot 51 therein for reception of a pin 52 carried by the bar 48. The arrangement is such that the bar is capable of limited rocking and sliding movement relative to the bracket 50 so as to cause the edges of the opening 49 to bind on the rod 44 and restrain it against movement to the left as viewed in Figure 3. The rod 48 normally is held in clamping engagement on the rod 44 by a spring 53 connected between the lower end of the bar and the frame element 6, but the effect of the spring easily may be overcome by the operator when it is desired to shift the piston 41. To prevent inadvertent withdrawal of the rod 44 from the rotor shaft 27, a cord 54 may be connected between the handle 46 and the adjacent frame element 8.

Apparatus constructed in accordance with the invention includes means for driving the driving member 26. One convenient means for driving the rotor comprises an electric motor 55 which may be mounted on the frame 1 or

elsewhere, in which case transmission means may be included from the motor to the rotor to drive the latter. In the disclosed embodiment the motor shaft 56 is equipped with transmission means comprising a worm 57, the teeth of which mesh with teeth 58 formed on the periphery of the rotor 26 as is best shown in Figure 2. The free end of the shaft may be supported in any suitable manner, e.g., by means of bearings mounted in a bearing support 59.

It is preferred that the motor 55 be capable of variable speed operation in order that the operating cycle of the bellows 10 may be varied at will so as to control the rate of respiration of the patient. Variable speed electric motors are readily available and need not be described in detail, but it is preferred that the motor be operable on direct current and have a control panel 60 including a start-stop switch 61 and a rheostat 62 connected to a source of electric energy (not shown) for varying the motor speed steplessly. Speed varying means consisting of belts and variable diameter sheaves or gear trains or the like also may be used to vary the speed of the motor.

When using the apparatus in conjunction with an anaesthesia machine, the parts of the latter may be mounted on the frame 1 so as to have all parts conveniently close at hand. The endotracheal tube (not shown) or the mask 13, whichever is being used, may be positioned in communication with the respiratory system of the patient and the motor 55 started and adjusted to the speed required to induce respiration of the patient at the desired rate. The flow of gases which are to be inspired and exhausted will be adjusted by the anaesthetist in the usual manner by manipulation of the valves incorporated in the anaesthesia machine. The depth of breathing of the patient, however, will be regulated or controlled by adjustment of the respirator apparatus.

The depth of breathing of the patient is controlled by regulating the stroke length of the bellows or pump 10. The longer the exhaust stroke of the pump, the more fluid will be exhausted from the bellows chamber and the greater will be the intensity of the relatively positive pressure created in the lungs of the patient. Also, the longer the intake stroke of the bellows, the more fluid will be withdrawn from the lungs of the patient and the pressure created in the lungs will be relatively more negative than for a shorter stroke. As has been pointed out previously, the bellows 10 is reciprocated by means of the rod 15 which is connected to the driving member 26 by means of the pin 36, the connecting rod 37, the pin 36 and the cross-head 34. The length of the stroke of the bellows 10, and consequently the intensity of the pressures created in the respiratory system of the patient, will depend on the eccentricity of the part 34 relative to the axis of rotation of the rotor 26. In the positions of the parts shown in Figure 3, the cross-head 34 is slightly eccentric to the axis of the rotor 26, so the length of the bellows strokes will be relatively short. If it is desired to increase the length of the bellows stroke, the rod 44 is pushed to the right, as viewed in Figure 3, whereupon the piston 41 will force hydraulic fluid from the reservoir 39 in the hollow shaft 27 through the passage 40 and into the cylinder 29 so as to displace the piston 30 and the piston rod 33 radially inwardly and cause radially outward movement of the part 34 relative to the rotor 26, since the part 34 is on the opposite side of the axis of rotation of the rotor from the piston 30. Radially outward movement of the part 34 relative to the rotor increases the eccentricity of the part 34 to the shaft 27, thereby increasing the stroke length of the bellows and the intensity of the relatively positive and negative pressures created in the respiratory system of the patient. The position to which the part 34 may be adjusted relatively to the axis of rotation of the rotor 26 will depend solely on the length of continuous sweep movement of the piston 41 under the influence of the rod 44 and it will be clear that the part

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34 may be adjusted uninterruptedly substantially instantaneously and steplessly independently of operation of the driving member 26 to any one of a plurality of positions radially of the rotor 26. When the part 34 has been adjusted to its selected position, the bar 48 will be rocked by the spring 53 to the position shown in Figure 3 so as to clamp the rod 44 against horizontal movement relative to the shaft 27.

If it should be desired to decrease the length of the stroke of the bellows 10, the operator may rock the bar 48 clockwise, as viewed in Figure 3, so as to enable the rod 44 to be moved to the left. The rotation of the rotor 26 would tend to cause the piston 30 to move radially outwardly due to centrifugal force, thereby tending to move the part 34 radially inwardly to decrease the eccentricity of the part 34, but to insure that the decrease in eccentricity of the part 34 will follow immediately the movement of the rod 44 to the left, a spring 63 is connected to a stud 64 on the rotor 26 and to a stud 65 on the part 34. The spring should be of such capacity as to enable the piston 30 to displace hydraulic fluid from the cylinder 29 into the reservoir 39, but should not exert such a force as to make it unduly difficult to move the piston 30 and the part 34 in the reverse direction. As is the case when the eccentricity of the part 34 is increased, the part 34 may be moved radially inwardly to any one of a plurality of positions so as to decrease the length of the bellows stroke as desired.

As is best shown in Figure 3, the connecting rod 37 is coupled to the bellows operating rod 15 by means of a pin 38 which extends through a bore in the coupling block 17 and through an opening in the end of the connecting rod 37. One end of the pin 38 projects beyond the connecting rod 37 and is provided with yieldable spring strips 66 which normally are bowed outwardly beyond the surface of the pin 38 to prevent inadvertent withdrawal of the pin 38 from the connecting rod 37. The other end of the pin 38 is equipped with a knob 67 so as to facilitate lateral movement of the pin 38 to the right, as viewed in Figure 3, and to prevent movement of the pin 38 to the left beyond the position shown in Figure 3. The bore through the block 17 preferably is provided with an enlarged portion 68 into which the spring strips 66 may expand upon movement of the pin 38 to the right, thereby providing a releasable securing means for preventing the pin 38 from becoming separated from the block 17. When the pin connector 38 is in the position shown in Figure 3 it engages both elements of the pair of coupling elements 37 and 17 and operatively couples the pump rod 15 to the driving member 26. When the connector 38 is displaced to the right as viewed in Figure 3 and is thus disengaged from the connecting rod or coupling element 37 it remains engaged with the coupling element 17. With the connector 38 so displaced, the bellows no longer will be reciprocable with the driving member 26, but will remain stationary unless it is manipulated manually, using the knob 67 as a handle. It is preferred that the apparatus include a counterbalance or the like for the bellows, and such a device is shown in Figure 2 as comprising a weight 77 suspended from one end of a cord 77' which is trained around a pulley 78 mounted on the horizontal frame section 5^b, the other end of the cord being secured to an eye bolt 79 threaded into the coupling block 17.

When the bellows has been conditioned for manual operation by separation of the connecting rod 37 and the pin 38, it is not necessary that rotation of the driving member 26 cease. If the driving member continues to rotate, the connecting rod 37, unless restrained, will fall to one side or the other and possibly damage other parts of the apparatus or equipment used in conjunction therewith. To prevent such an occurrence, a metal plate 69 preferably is secured to the horizontal frame section 5^b by means of screws 70 and extends downwardly paral-

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lel to the rods 15 and 19. A hollow, threaded part 71 is received in the opening of the connecting rod 37 and projects beyond the face of the latter so as to be received in a slot 72 formed in the plate 69. The part 71 preferably includes a peripheral flange 73 having a diameter larger than the transverse dimension of the slot 72 so as to prevent withdrawal of the part 71 from the slot. With this arrangement of parts, reciprocating movement of the connecting rod 37 by rotation of the driving member 26 will be guided by cooperation between the part 71 and the slot 72 which will prevent the connecting rod 37 from being thrown about when it is disconnected from the bellows operating rod 15.

When it is desired to reconnect the driving member to the bellows, the coupling block 17 may be moved manually to a position where the pin 38 is aligned with the opening in the connecting rod 37 and the pin then may be moved toward the left, as viewed in Figure 3. To facilitate the reconnecting of the parts, the nose of the pin 38 may be rounded as at 74.

The lower end of the plate 69 may, if desired, be provided with supports, one of which is shown at 75, for mounting a fender or guard 76 over the driving rotor 26.

The disclosed apparatus provides means for continuously ventilating the respiratory system of a patient and may be so adjusted as to provide any amount of both positive and negative pressure which may be useful and safe in the treatment of humans. The volume of fluid delivered to and exhausted from, and consequently the intensity of the relatively positive and negative pressures created in the patient's respiratory system may be varied substantially instantaneously and steplessly during operation of the apparatus and the rate of ventilation of the patient may be varied substantially instantaneously and steplessly by adjustment of the speed of the driving motor 55. Moreover, the apparatus may be instantaneously converted from automatic operation to manual operation by disconnecting the bellows from the connecting rod 37. Using apparatus constructed in accordance with the invention in conjunction with a circular filter arrangement on a conventional anaesthesia machine, perfect control of respiration, together with perfect control of anaesthetic agents should be possible. For use with poliomyelitis patients, where oxygen is not being administered, a simple arrangement of two one-way valves, such as are incorporated in tubes connected to masks or tracheotomy tubes and disclosed in Figure 5, will be sufficient to insure adequate ventilation of the respiratory system.

The disclosed embodiment is intended to be illustrative, but not definitive, of the invention. The invention is defined in the claims.

I claim:

1. Apparatus for effecting pulmonary ventilation of a patient undergoing treatment, said apparatus comprising a pump having a chamber from which fluid may be discharged on one stroke of the pump and into which fluid may be drawn on the other stroke; means for connecting said chamber to the respiratory system of the patient so as to create alternating relatively positive and negative pressures in the respiratory system of the patient in simulation of natural breathing; a driving member; means for driving said driving member; and means coupling said driving member to said pump and including a pair of adjacent elements, and a connector normally operatively engaging both elements of said pair for operatively connecting said pump to said driving member to be driven thereby, said connector being mounted for displacement to be disengaged from the element of said pair on the driving member side of said coupling means while remaining engaged with the element of said pair on the pump side of said coupling means, and said connector when so displaced providing a handle for operating said pump manually.

2. Apparatus for effecting pulmonary ventilation of a patient undergoing treatment, said apparatus comprising a pump having a chamber from which fluid may be discharged on one stroke of said pump and into which fluid may be drawn on the other stroke; means for connecting said chamber to the respiratory system of the patient so as to create alternating relatively positive and negative pressures in the respiratory system of the patient in simulation of natural breathing; a driving member; means for driving said driving member; means for varying the speed of said driving means whereby the rate of respiration may be varied; and means coupling said driving member to said pump and including a pair of adjacent elements, and a connector normally operatively engaging both elements of said pair for operatively connecting said pump to said driving member to be driven thereby, said connector being mounted for displacement to be disengaged from the element of said pair on the driving member side of said coupling means while remaining engaged with the element of said pair on the pump side of said coupling means, and said connector when so displaced providing a handle for operating said pump manually.

3. Respirator apparatus for effecting pulmonary ventilation of a patient undergoing treatment, said apparatus comprising a pump having a chamber from which fluid may be discharged on one stroke of said pump and into which fluid may be drawn on another stroke of said pump; means communicating with said chamber for connecting the latter to the respiratory system of the patient so as to create alternating positive and negative pressures in the respiratory system in simulation of natural breathing; a driving member; a cylinder fixed on said driving member; a reciprocable piston in said cylinder; a cross-head slidably mounted on said driving member and connected to said piston for movement therewith; means connecting said cross-head to said pump; means operatively connected to said piston for steplessly moving the latter and the cross-head relatively to said driving member so as to steplessly vary the stroke length of said pump, thereby steplessly to vary the intensity of the pressures created in the respiratory system of the patient; and means for driving said driving member.

4. Respirator apparatus for effecting pulmonary ventilation of a patient undergoing treatment, said apparatus comprising a pump having a chamber from which fluid may be discharged on one stroke of said pump and into which fluid may be drawn on another stroke of said pump; means communicating with said chamber for connecting the latter to the respiratory system of the patient so as to create alternating positive and negative pressures in the respiratory system in simulation of natural breathing; a driving member; a cylinder radially mounted on said driving member; a reciprocable piston in said cylinder; a cross-head mounted for radial movement on said driving member and connected to said piston for movement therewith; means connecting said cross-head to said pump; means operatively connected to said piston for steplessly moving the latter and the cross-head relatively to said driving member so as to steplessly vary the stroke length of said pump, thereby steplessly to vary the intensity of the pressures created in the respiratory system of the patient; and means for driving said driving member.

5. Respirator apparatus for effecting pulmonary ventilation of a patient undergoing treatment, said apparatus comprising a pump having a chamber from which fluid may be discharged on one stroke of said pump and into which fluid may be drawn on another stroke of said pump; means communicating with said chamber for connecting the latter to the respiratory system of the patient so as to create alternating positive and negative pressures in the respiratory system in simulation of natural breathing; a driving member; a cylinder fixed on said driving member; a reciprocable piston in said cylinder; a cross-head slidably mounted on said driving member and con-

nected to said piston for movement therewith; means connecting said cross-head to said pump, said connecting means including a separable coupling device operable to disconnect said pump from said cross-head; means operatively connected to said piston for steplessly moving the latter and the cross-head relatively to said driving member so as to steplessly vary the stroke length of said pump, thereby steplessly to vary the intensity of the pressures created in the respiratory system of the patient; and means for driving said driving member.

6. Respirator apparatus for effecting pulmonary ventilation of a patient undergoing treatment, said apparatus comprising a pump having a chamber from which fluid may be discharged on one stroke of said pump and into which fluid may be drawn on another stroke of said pump; means communicating with said chamber for connecting the latter to the respiratory system of the patient so as to create alternating positive and negative pressures in the respiratory system in simulation of natural breathing; a rotatable driving member; a cylinder radially mounted on said driving member; a reciprocable piston in said cylinder; a cross-head mounted for radial movement on said driving member and connected to said piston for movement therewith; means connecting said cross-head to said pump, said connecting means including a separable coupling device operable to disconnect said pump from said cross-head; means operatively connected to said piston for steplessly moving the latter and the cross-head relatively to said driving member so as to steplessly vary the stroke length of said pump, thereby steplessly to vary the intensity of the pressures created in the respiratory system of the patient; and means for driving said driving member.

7. Respirator apparatus for effecting pulmonary ventilation of a patient undergoing treatment, said apparatus comprising a pump having a chamber from which fluid may be discharged on one stroke of said pump and into which fluid may be drawn on another stroke of said pump; means communicating with said chamber for connecting the latter to the respiratory system of the patient so as to create alternating positive and negative pressures in the respiratory system in simulation of natural breathing; a driving member; a cylinder fixed on said driving member; a reciprocable piston in said cylinder; a cross-head slidably mounted on said driving member and connected to said piston for movement therewith; means connecting said cross-head to said pump; means operatively connected to said piston for steplessly moving the latter and the cross-head relatively to said driving member so as to steplessly vary the stroke length of said pump, thereby steplessly to vary the intensity of the pressures created in the respiratory system of the patient; means for driving said driving member; and means for varying the speed of said driving means whereby the rate of respiration of the patient may be varied.

8. Respirator apparatus for effecting pulmonary ventilation of a patient undergoing treatment, said apparatus comprising a pump having a chamber from which fluid may be discharged on one stroke of said pump and into which fluid may be drawn on another stroke of said pump; means communicating with said chamber for connecting the latter to the respiratory system of the patient so as to create alternating positive and negative pressures in the respiratory system in simulation of natural breathing; a rotatable driving member; a cylinder radially mounted on said driving member; a reciprocable piston in said cylinder; a cross-head mounted for radial movement on said driving member and connected to said piston for movement therewith; means connecting said cross-head to said pump; means operatively connected to said piston for steplessly moving the latter and the cross-head relatively to said driving member so as to steplessly vary the stroke length of said pump, thereby steplessly to vary the intensity of the pressures created in the respiratory system of the patient; means for driving said driving member; and means for varying the speed of

said driving means whereby the rate of respiration of the patient may be varied.

9. Respirator apparatus for effecting pulmonary ventilation of a patient undergoing treatment, said apparatus comprising a pump having a chamber from which fluid may be discharged on one stroke of said pump and into which fluid may be drawn on another stroke of said pump; means communicating with said chamber for connecting the latter to the respiratory system of the patient so as to create alternating positive and negative pressures in the respiratory system in simulation of natural breathing; a driving member; a cylinder element; a piston element relatively reciprocable in said cylinder element, one of said elements being fixed with respect to and carried by said driving member; a cross-head slidably mounted on said driving member and connected to the other of said elements for movement therewith; means connecting said cross-head to said pump; means for applying fluid pressure within said cylinder element to act on said piston element for steplessly moving said other of said elements and the cross-head relatively to said driving member so as to steplessly vary the stroke length of said pump, thereby steplessly to vary the intensity of the pressures created in the respiratory system of the patient; and means for driving said driving member.

10. Respirator apparatus for effecting pulmonary ventilation of a patient undergoing treatment, said apparatus comprising a pump having a chamber from which fluid may be discharged on one stroke of said pump and into which fluid may be drawn on another stroke of said pump; means communicating with said chamber for connecting the latter to the respiratory system of the patient so as to create alternating positive and negative pressures in the respiratory system in simulation of natural breathing; a driving member; a cylinder element; a piston element relatively reciprocable in said cylinder element, said elements extending radially with respect to said driving member and one of said elements being fixed with respect to said driving member; a cross-head mounted for radial movement on said driving member and connected to the other of said elements for movement therewith; means connecting said cross-head to said pump; means for applying fluid pressure within said cylinder element to act on said piston element for steplessly moving said

other of said elements and the cross-head relatively to said driving member so as to steplessly vary the stroke length of said pump, thereby steplessly to vary the intensity of the pressures created in the respiratory system of the patient; and means for driving said driving member.

11. Respirator apparatus for effecting pulmonary ventilation of a patient undergoing treatment, said apparatus comprising a pump having a chamber from which fluid may be discharged on one stroke of said pump and into which fluid may be drawn on another stroke of said pump; means communicating with said chamber for connecting the latter to the respiratory system of the patient so as to create alternating positive and negative pressures in the respiratory system in simulation of natural breathing; a rotatable driving member; a cylinder element; a piston element relatively reciprocable in said cylinder element, said elements extending radially with respect to said driving member and one of said elements being fixed with respect to said driving member; a cross-head mounted for radial movement on said driving member and connected to the other of said elements for movement therewith; means connecting said cross-head to said pump; means for applying fluid pressure within said cylinder element to act on said piston element for steplessly moving said other of said elements and the cross-head relatively to said driving member so as to steplessly vary the stroke length of said pump, thereby steplessly to vary the intensity of the pressures created in the respiratory system of the patient; means for driving said driving member; and means for varying the speed of said driving means whereby the rate of respiration of the patient may be varied.

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