Oct. 7, 1958 C. B. ANDREASEN 2,855,144

DRIVING APPARATUS FOR LUNG VENTILATORS

Filed Nov. 7, 1955 2 Sheets-Sheet 1

Fig. 1.

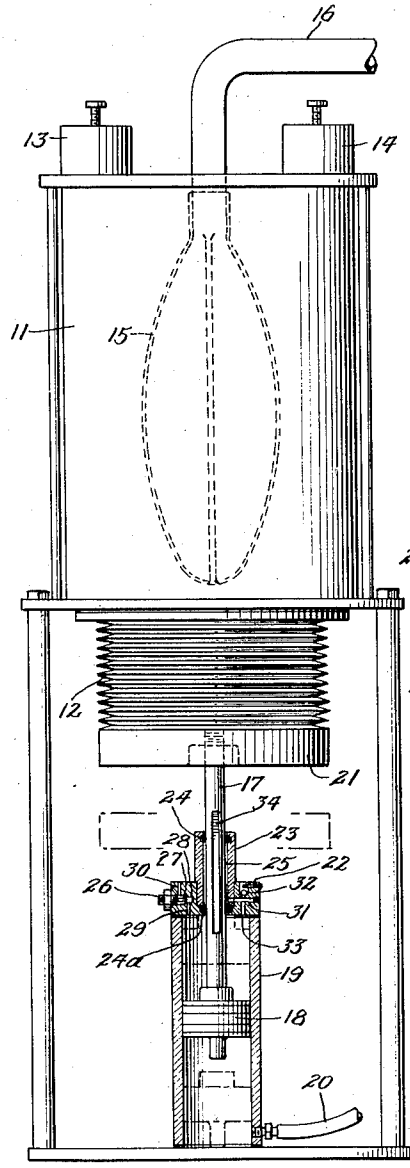


Fig. 2.

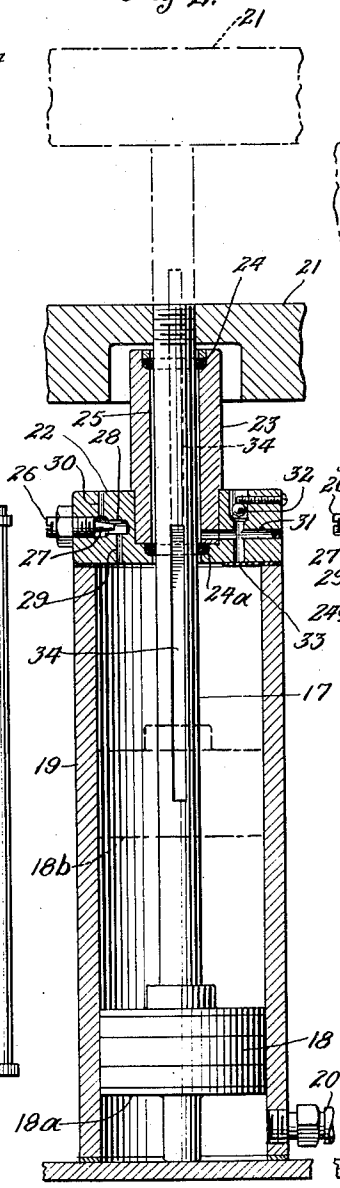
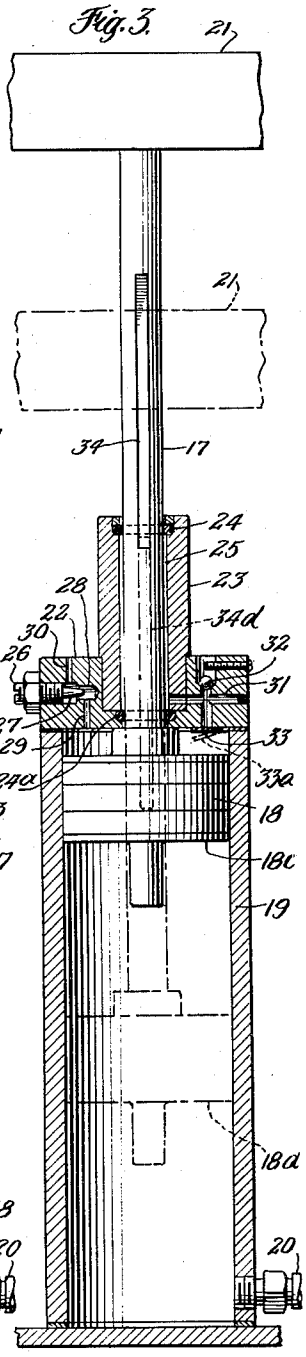


Fig. 3.



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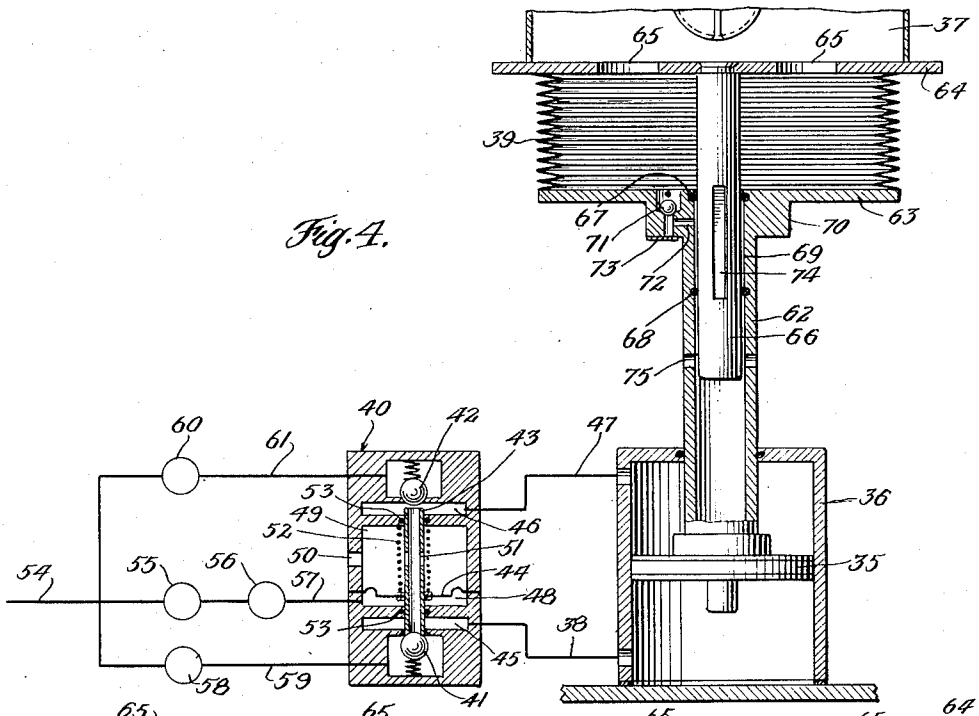


Fig. 4.

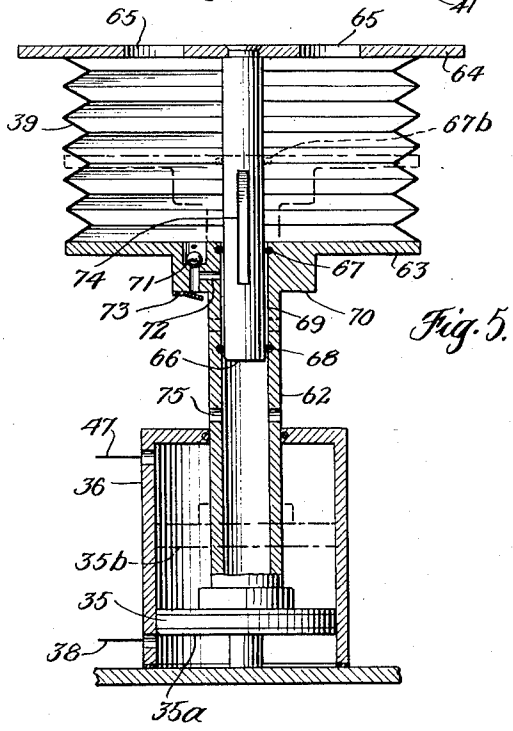


Fig. 5.

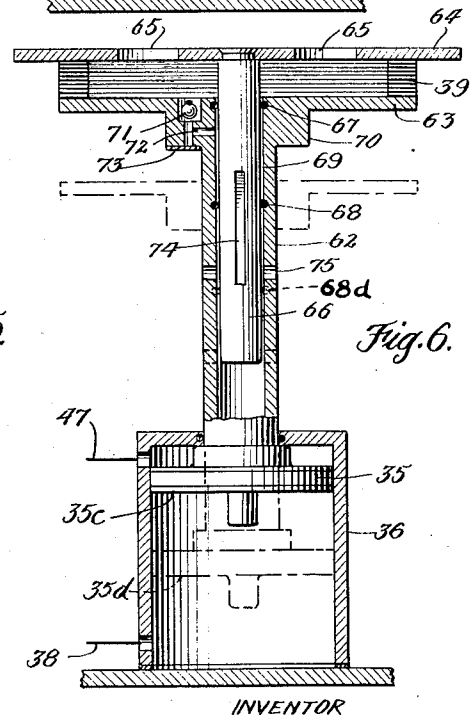


Fig. 6.

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DRIVING APPARATUS FOR LUNG VENTILATORS

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Application November 7, 1955, Serial No. 545,192

10 Claims. (Cl. 230—162)

This invention relates to lung ventilating apparatus and is particularly concerned with improvements in the driving mechanism therefor.

Lung ventilators of the type to which the present improvements apply are especially valuable when used with anesthesia machines. The ventilator construction to which the present invention applies produces both a positive pressure phase and a negative pressure phase in the operating cycle. The energy required during the positive phase is usually different from the energy used during the negative phase.

As a result of this difference in phase energy requirements, when a free piston device is used to operate the apparatus, a longer piston travel is normally needed in the direction requiring the greater power absorption. Since the return stroke of the piston absorbs less energy the piston will travel only part of the way back. As a result after several strokes the piston will be operating near one end of the cylinder and there will be insufficient distance to give the length of stroke needed to handle the higher energy phase.

The primary object of the present invention is the provision of simple and effective means for solving this problem of shift in the operating position of the piston. To accomplish the desired results the present invention provides pressure relief devices which serve to allow relatively free movement of the piston at the start of the stroke in each direction. The effective power for each phase is then developed in the second portion of each stroke. In this manner the piston is always in position to maintain the required movement to produce the pressure desired for an adequate interval.

Another object of the invention is to provide an improved timing and control system for producing the positive and negative phases in the pressure chamber of the ventilating device. The improved system eliminates the relief valves in the pressure chamber for controlling the lung pressures and provides proper control through pressure regulators which supply the gas for the double acting driving piston. With this system, when a bellows is used as the variable pressure chamber, there is definite relationship between the stroke of the bellows and the amount of gas which reaches the patient. Thus there is an indication of the amount of ventilation being provided.

How these and other more specific objects and advantages of the invention are attained will be clear from the following description of the drawings, in which—

Figure 1 is an elevation view with certain parts in section showing the driving piston and variable pressure chamber of a ventilating system.

Figure 2 is a sectional elevation of the driving portion showing the piston at the lower end of its stroke.

Figure 3 is a sectional view similar to Figure 2 showing the piston at the upper end of its stroke.

Figure 4 shows a sectional view of another form of piston drive with the variable pressure chamber together with a schematic arrangement showing the supply system for the actuating gas.

Figure 5 is a sectional elevation of the moving parts of the drive system of Figure 5 showing the piston at the lower end of the stroke.

Figure 6 is a view similar to Figure 5 with the piston at the upper end of the stroke.

In Figure 1 there is illustrated a variable pressure chamber **11** to which it attached a bellows unit **12**, the actuation of which produces the variations in pressure in the chamber **11**. Relief valve unit **13** controls the degree of positive pressure in chamber **11** and relief valve unit **14** controls the value of the negative pressure in the chamber. Breathing bag **15** is connected by duct **16** with the lungs of the patient through the anesthesia machine system. Chamber **11** is preferably transparent so that the action of bag **15** may be observed.

Bellows**12** is actuated by piston rod **17** which is connected to piston **18** supported in cylinder **19**. At the lower end of the cylinder, tube **20** is connected to deliver air for operating the piston. Timing mechanism (not shown) is used to control air delivered through **20** which moves the piston in the upwardly direction for the positive pressure portion of the cycle. For the downward or negative stroke of the piston the air supply is closed off by the timing mechanism and the tube **20** is connected to atmospheric pressure. The downward stroke of the piston occurs due to the weight of the piston **18** and the weight **21** attached to the lower end of the bellows unit. Weight **21** is capable of producing the desired negative pressure in chamber **11**. The air supply portion of the system mentioned above may be similar to that shown in my co-pending application 485,229, filed January 31, 1955.

In the form of apparatus shown in Figures 1, 2, and 3 the mechanism which provides for proper utilization of the piston stroke is located at the upper end of the cylinder where it supports piston rod **17**. The upper end of cylinder **19** is provided with thickened portion **22** which in turn supports an upwardly extending tubular member **23** surrounding piston rod **17**. Seals **24** and **24*a*** are provided at the upper and lower ends of the piston supporting structure. The inside of tubular member **23** is larger in diameter than piston rod **17** thereby providing an annular space **25** surrounding the piston rod between upper seal **24** and lower seal **24*a***. In the upper portion **22** of cylinder **19** various valve and channel structures are incorporated. An adjustable valve **26** having tapered portion **27** extends into horizontal bore **28**. Channel **29** extends from the inside of the cylinder to bore **28** and another channel **30** extends from the outer end of bore **28** to the outside air. Thus by adjusting valve **26** inwardly or outwardly the flow through channel **28** may be restricted to give the desired resistance.

A channel **31** connects into annular space **25** and extends through thickened portion **22** of the cylinder to connect with certain check valves. A ball check valve **32** is shown mounted between channel **31** and the outside air while flap check valve **33** controls flow between channel **31** and the upper end of cylinder **19** above piston **18**.

A longitudinal slot **34** is provided in piston rod **17**. The length of slot **34** and the distance between seals **24** and **24*a*** are so related to the stroke of piston that the desired load released over a portion of each piston stroke is provided.

In Figure 2 piston **18** is shown at the bottom of the stroke ready to move upwardly through the positive phase of the cycle. During the portion of the stroke from piston position **18*a*** to dotted line piston position **18*b***, slot **34** bypasses seal **24*a*** and connects the interior of the cylinder above the piston **18** to annular space **25**. Thus release of air is permitted from the upper portion

of the cylinder through relief valve 32. In this way no appreciable resistance to the motion of the piston is developed by compression effect above the piston. However after the piston reaches position 18*b*, the lower end of slot 34 is above lower seal 24*a* so that there is no open channel between the cylinder and annular space 25. Flapper valve 33 remains closed due to pressure developed in the cylinder. The only release channel for the remainder of the up stroke is through restricted channel 29, 28, 30. Thus a resistance is developed during the last part of the stroke from position 18*b* to the top end of the cylinder, position 18*c* in Figure 3. During this second portion of the upward stroke the speed of piston travel is reduced.

Throughout this upward or pressure stroke the pressure in chamber 11 remains at the value permitted by the setting of positive pressure relief valve 13. During the first portion of the upward stroke considerable excess air is passed through relief valve 13. During the portion of the stroke between position 18*b* and 18*c* the reduced velocity of the piston reduces the flow through valve 13. However sufficient displacement occurs to maintain pressure on bag 15 to provide the collapsing action throughout the complete positive pressure interval as determined by the timing mechanism.

The downward stroke giving the negative portion of the cycle is controlled in generally similar fashion to that for the positive pressure portion of the cycle. Referring to Figure 3, as piston 18 moves from top position 18*c* downwardly toward position 18*d* a negative pressure is induced in the chamber 11. The magnitude of the negative pressure is controlled by relief valve 14 which admits outside air to chamber 11 when the value of the negative pressure reaches the setting of relief valve 14. During the first part of the downward stroke of piston 18 air is admitted from the outside atmosphere through groove or channel 34 past the seal 24 to the small fixed volume chamber formed by annular space 25 and thence through channel 31 and flapper relief valve 33 (position 33*a*) which admits air to the upper portion of the cylinder above the piston. Thus during the portion of piston travel from 18*c* position to 18*d* position the motion is relatively fast because of the free flow of the air into the upper portion of the cylinder. It should be noted that during this portion of the stroke tube 20 is relieved to atmospheric pressure by the timing mechanism so that there is no resisting pressure in the lower portion of the cylinder 19 below the piston. Thus there is no compression effect which would reduce the velocity of the piston motion.

When the piston reaches position 18*d* the upper end of slot or channel 34 (see position 34*d*) has reached upper seal 24. As soon as the end of slot 34 passes inside seal 24 air can no longer be admitted from the outside to annular chamber 25. As a result there is no further free flow from the atmosphere to the part of the cylinder above the piston. The only passage for airflow to the cylinder is through restricted channel 30, 28, 29. Thus for the remainder of the stroke from 18*d* to the bottom position of ths piston the rate of travel is materially reduced because of the restraining effect of the negative pressure above the piston induced by the restricting action of the air flow through the channel 29. During the complete downward stroke of the piston the negative pressure in the chamber 11 has been maintained at constant value by the action of relief valve 14.

With this valve arrangement the piston is always positioned to provide a fully effective stroke in either direction. Thus the first part of the positive pressure stroke from position 18*a* to position 18*b* occurs in a short period of time. The restricted portion of the positive pressure stroke from position 18*b* to top position 18*c* requires a much longer period of time. Therefore the piston will always be above position 18*b* before the timing device calls for the negative phase of the cycle. Likewise during the negative phase the piston travels from 18*c* to 18*d* in a very short interval while its travel from position 18*d* to the bottom of the stroke occurs in a relatively longer interval. Thus the major portion of the negative cycle occurs during the last part of the downward stroke. The piston will always be lower than position 18*d* before the timing device calls for the positive pressure phase of the cycle. In this way the piston is always re-positioned to give an adequate positive pressure stroke even though the negative phase of the cycle may be of shorter duration than the positive phase. Thus the stroke from 18*d* to 18*c* is always available for the positive pressure phase even though this full distance is not usually needed. Also the stroke from 18*b* to 18*a* is always available for the negative phase even though only a portion of this is normally used.

Figures 4, 5 and 6 shows a somewhat different form of operating mechanism for producing the stroke utilization action. In Figure 4 the control system for the driving air is shown in diagrammatic form. It will be seen that piston 35 which operates in cylinder 36 is double-acting. In this form of the apparatus there are no relief valves associated with chamber 37. Thus the positive pressure in variable pressure chamber 37 is determined directly by the pressure applied to the piston 35 on the up-stroke. The positive pressure is applied by means of air delivered to the lower part of cylinder 36 through line 38. During the up-stroke of piston 35 the bellows 39 is collapsing and developing the positive pressure in chamber 37 thus giving the positive pressure phase of the cycle.

Similarly the negative pressure phase of the cycle is developed during the down-stroke of piston 35 and the pressure value in chamber 37 is determined by the degree of pressure applied to the upper side of piston 35. A switching valve unit 40 controls the application of pressure to the lower side and the upper side of piston 35 and determines the timing for each phase. Switching valve 40 incorporates valve 41 for controlling the air supply to the lower end of the cylinder and valve 42 for controlling the air supply to the upper end of the cylinder. A hollow rod 43 which is attached to the diaphragm 44 controls the opening and closing of valves 41 and 42. Chamber 45 connects with the lower end of cylinder 36 through line 38 and chamber 46 connects with the upper end of cyinder 36 through line 47. A closed chamber 48 is provided on the lower side of diaphragm 44 and atmospheric pressure chamber 49 is provided above diaphragm 44. Openings 50 lead from chamber 49 to the atmosphere. Also an opening 51 in hollow rod or tube 43 provides for flow of air from the inside of tube 43 to atmosphere. Seals 53 prevent leakage from chambers 45 or 46 around rod 43.

Air is supplied to the system through line 54. Regulator 55 controls the flow of air through timer 56 which in turn controls the air through line 57 to chamber 48. Another regulator 58 controls the flow of air to line 59 leading to valve 41. Similarly regulator 60 controls the flow of air through line 61 leading to upper valve 42 of the switching valve unit 40.

Timing device 56 is constructed to admit air under pressure from the regulator 55 to the diaphragm chamber 48 at predetermined intervals for a predetermined time after which it releases the pressure from chamber 48 for a predetermined interval before repeating the cycle. By means of adjustments in the timing device the length of the pressure applied period and the pressure released period may be varied to provide the desired time for the positive phase and the negative phase of the operating cycle. With the timer in position so that the pressure in chamber 48 is released, diaphragm 44 will be forced downwardly by spring 52 so that the end of tube 43 pushes against valve 41 to hold it in the open position. While holding valve 41 it will be noted that the end of tube 43 against valve 41 is sealed. However in this posi-

tion the upper end of tube 43 is removed from upper valve 42 and thus valve 42 closes and the upper end of tube 43 opens into upper chamber 46. With this setting the air in pipe 59 can flow through valve 41 into chamber 45 and through line 38 to the lower side of piston 35 to develop pressure in the lower portion of the cylinder. During the time pressure is being transmitted through valve 41 air may flow from the upper portion of cylinder 36 through line 47 to chamber 46 and through the inside of tube 43 out through opening 51 to the atmosphere. Thus while pressure is being developed under piston 35 the trapped air at the upper side of piston 35 is released to the atmosphere.

This condition continues until the timer operates to supply air under pressure to chamber 48 and move diaphragm 44 to its upper position against the action of spring 52. The diaphragm then carries tube 43 upwardly so that it permits the valve 41 to close and causes the valve 42 to open. At the same time the upper end of tube 43 is closed and the lower end is opened to connect with chamber 45. Under this condition the flow is such that air under pressure is supplied through valve 42, chamber 46 and line 47 to the upper side of piston 35 and causes piston 35 to move downwardly. At the same time cylinder 36 under the piston 35 relieves to the atmosphere through line 38, chamber 45 and through tube 43 with its opening 51. This condition continues until the timer again moves to cut off the supply of air to chamber 48 and relieve it to atmospheric to permit the diaphragm to shift the position of tube 43 again.

The timing action may be changed by adjusting regulator 55. The pressure applied to the lower side of piston 35 during the positive phase action may be regulated by adjusting regulator 58 thus controlling the magnitude of the pressure developed in chamber 37 during the positive phase. Likewise the negative pressure developed in chamber 37 is regulated by adjusting regulator 60 to control the negative phase action of the device.

In this construction as in the previously described construction of Figures 1, 2 and 3, the free piston 35 operates bellows 39 by means of a piston rod which is in the form of tube 62. Thus if one phase of the cycle is longer in duration than the other, there is a tendency for the piston to change its neutral position and gradually the stroke will be toward the end of the piston having the shorter duration. The effective working action of the piston will become insufficient for developing the complete phase. To prevent this, relief valve mechanism is provided to relieve the pressure in the bellows during a portion of each stroke.

Piston tube 62 is connected to the lower surface 63 of the bellows 39. At the bottom of chamber 37 is a diaphragm 64 having openings 65 to the bellows. Downwardly projecting rod 66 is connected to the diaphragm 64 and extends into the inside of piston tube 62. Seals 67 and 68 are provided in piston tube 62 at suitably spaced intervals. These seals engage rod 66 and provide a fixed volume chamber in the form of annular space 69 between rod 66 and piston tube 62. In the upper end of tube 62 enlarged portion 70 supports a pair of relief valves. Relief valve 71 permits flow from annular space 69 through channel 72 to the inside of the bellows 39. Flapper valve 73 permits flow from annular space 69 through channel 72 outwardly through the valve to the atmosphere. Thus positive pressure in bellows chamber 39 closes valve 71 while positive pressure in channel 72 causes opening of valve 73. An elongated slot 74 is provided in rod 66 which is positioned with respect to the seals 67 and 68 to give the desired relief action for piston 35 during a portion of the travel of each stroke. It should further be noted that openings 75 in piston tube 62 provide access to atmospheric pressure from the inside of piston tube 62 below seal 68.

In Figure 5 the piston is shown in position 35*a* at the

bottom of the stroke ready to start the pressure phase of the cycle. As the piston 35 moves upwardly from position 35*a* under the influence of pressure applied to the lower end of the cylinder, bellows 39 proceeds to collapse and air flows through slot 74 from bellows chamber 39 past seal 67 to annular space 69 and thence through channel 72 and relief valve 73 to atmospheric. Thus during the portion of the stroke from piston position 35*a* to piston position 35*b* there is little or no resistance developed in the bellows chamber and as a result piston 35 moves very quickly from one position to the other. However as soon as the piston reaches position 35*b* upper seal 67 has reached position 67*b* where it is at the top of slot 74. At this position air can no longer flow from bellows chamber 39 into slot 74 and since valve 71 is closed due to the pressure in chamber 39 the pressure therefore immediately develops to the amount determined by the pressure applied to the lower end of cylinder 36. The portion of the stroke from position 35*b* upwardly to the top of the piston stroke at 35*c* (Figure 6) is therefore the effective portion of the pressure stroke. During this time the desired positive pressure is developed in bellows chamber 39 and chamber 37 which contains the breathing bag. During this portion of the stroke, piston 35 travels relatively slowly. The time of application of pressure is controlled by the switching valve. The travel above position 35*b* is governed by the volume of air delivered to the patient's lungs.

For the down stroke, that is, the negative pressure phase of the cycle, pressure is applied to the cylinder above piston 35 beginning at its top position 35*c*—see Figure 6. At this position any downward movement of bellows 39 causes opening of valve 71 so that air at atmospheric pressure is admitted, travelling through opening 75 and slot 74 to annular space 69 and then through channel 72 and valve 71 into the bellows chamber 39. Thus during the first part of the downward stroke, since no negative pressure can be developed in the bellows 39, piston 35 moves very rapidly from position 35*c* to position 35*d*.

When the piston has reached the position 35*d* lower seal 68 has reached position 68*d* at bottom end of slot 74 and as a result no further air can pass from the outside atmosphere through slot 74 into the bellows chamber. The bellows chamber is therefore effectively sealed and immediately the negative pressure determined by the pressure applied to piston 35 is developed in the bellows chamber and chamber 37. The development of this negative pressure immediately causes slowing down of the movement of piston 35 so that the remainder of the stroke from position 35*d* to the bottom end is at a greatly reduced rate and encompasses the major portion of the time required for the negative phase of the cycle. The volume of air withdrawn from the lungs determines the piston travel below 35*d*.

With this arrangement of valves to control the piston action, the main working portion of each piston stroke is toward the end of the stroke. Thus regardless of how much or how little of the working stroke is actually used during the effective portion of any piston action, the piston is always in position to provide full effectiveness for the next active stroke in the reverse direction.

From the foregoing it will be seen that I have provided suitable valve structure for assuring full effectiveness of every stroke of the free piston whether or not the lengths of the phase cycles are equal. By the use of the neutral chamber between the seals and the cooperative slotted channel a simple mechanism is provided for producing rapid travel during the initial portion of the stroke in either direction of travel. By this means proper repositioning of the piston is assured so that no faulty functioning can be experienced because of displacement of the neutral position of the stroke. With apparatus of the type disclosed it is also possible to combine effective

cycling control both as to adjustable timing of phases and as to effective pressure control for both positive and negative phases. With the second form of equipment shown in which the bellows chamber is sealed during the effective portions of both the positive phase and the negative phase action, an indication of the amount of ventilation being provided to the lungs during anesthesia is provided. This indication is given by the position to which the bellows travels upwardly during the positive phase and the position to which it travels downwardly during the negative phase. This relationship indicates therefore the amount of gas which reaches a patient and provides a ready means of checking the action of the anesthesia machine.

I claim:

1. For lung ventilator apparatus and the like having two cycle phases wherein one phase may have different duration and energy requirements than the other phase, actuating mechanism having a cylinder and piston forming a variable volume chamber, a second variable volume chamber having a movable wall, a driving connection between said variable volume chambers, a fixed volume chamber, channel structure leading from said fixed volume chamber to one of said variable volume chambers and to the outside atmosphere, control means to close off the portion of said channel structure to said last mentioned one of said variable volume chambers during a predetermined portion of the stroke of said piston and a check valve in the portion of said channel structure to the outside atmosphere.

2. Driving mechanism for lung ventilator apparatus and the like including a cylinder and piston forming a variable volume chamber, means including a fixed wall and a movable wall forming a second variable volume chamber, a rod member, a tubular member around a portion of said rod member with an annular clearance space therebetween, one of said members forming a connection between said piston and said movable wall, the other of said members being supported in fixed relationship thereto, said tubular member supporting a pair of spaced seals which engage said rod member to form the ends of a fixed volume chamber produced by the annular space, channel structure extending from said clearance space to the outside atmosphere including a check valve, additional channel structure leading from said clearance space to one of said variable volume chambers including a second check valve, a further channel structure positioned to extend from said clearance space to one of said variable volume chambers during a portion of the stroke of said piston.

3. Driving mechanism for apparatus such as a lung ventilator having two cycle phases, one of which may have different duration and energy requirements than the other, said mechanism incorporating a cylinder and piston, a cylindrical rod member, a tubular member positioned around said rod member to form an annular clearance space therebetween, one of said members being connected to said piston and the other of said members being supported in fixed relationship with respect to the piston-connected member, said tubular member supporting a pair of spaced seals which also engage said rod member, channel means extending longitudinally in said rod member to provide a connection from said clearance space to one side of said seals during one portion of the piston stroke and from said space to the other side of said seals during another portion of the stroke.

4. Actuating mechanism for lung ventilating apparatus and the like including a cylinder and piston forming a variable volume chamber, a bellows device forming a second variable volume chamber, a rod member extending between said piston and said bellows device, a neutral chamber located intermediate said variable volume chambers, channel and valve means between said neutral chamber and one of said variable volume chambers, channel and valve means between said neutral chamber and the outside atmosphere, an air supply system for driving said piston in said cylinder, an air supply switching valve in said system, an air line extending from said switching valve to each end of said cylinder, said switching valve incorporating a check valve device at each end thereof, one of said check valve devices controlling the flow of air to one end of said piston and the other of said check valve devices controlling the flow of air to the other end of said cylinder, a tubular member extending between said check valve devices, a diaphragm attached to said tubular member, a chamber in said switching valve having one of its walls formed by said diaphragm, an air line leading to said last mentioned chamber to supply pressure for periodically shifting said tubular member for alternately opening one or the other of said check valve devices.

5. Actuating mechanism for lung ventilating apparatus and the like including a cylinder and piston forming a variable volume chamber, a bellows device forming a second variable volume chamber, a tubular piston rod member extending between said piston and said bellows device, an elongated rod fixed to a wall of said bellows device and extending into said tubular piston rod member, said elongated rod being of smaller diameter than the inside of said tubular piston rod member to form a clearance space therebetween, a pair of seals mounted in spaced relationship in said tubular piston rod member and engaging the surface of said elongated rod, said elongated rod having a longitudinal channel therein, channel and check valve means permitting flow from the annular space between said seals to the bellows chamber and from the annular space to the outside atmosphere, said check valve means preventing flow either from the bellows chamber or from the outside atmosphere into said annular chamber.

6. Driving mechanism in accordance with claim 3 in which another channel means connects said clearance space with the outside atmosphere, a check valve to control flow to the outside atmosphere through said other channel means.

7. Driving mechanism for a lung ventilator or the like, said ventilator having two cycles phases, one of said phases having different duration and energy requirements than the other, said mechanism incorporating a cylinder and piston, a piston rod extending from said piston through one end of said cylinder, piston rod supporting structure at the end of said cylinder having clearance space between it and said rod, a pair of seals mounted in spaced relationship in said supporting structure and engaging said rod, channel and valve means connected to said clearance space, said rod having a channel extending longitudinally along it, a bleed channel structure extending from the inside of the piston rod end of the cylinder to the outside atmosphere, said bleed channel structure incorporating a valve to adjust the bleed rate.

8. Driving mechanism for a lung ventilator or the like, said ventilator having two cycle phases, one of said phases having different duration and energy requirements than the other, said mechanism incorporating a cylinder and piston, a piston rod extending from said piston through one end of said cylinder, piston rod supporting structure at the end of said cylinder having clearance space between it and said rod, a pair of seals mounted in spaced relationship in said supporting structure and engaging said rod, said rod having a channel extending longitudinally along it, another channel to the end of said cylinder connected to said clearance space and a third channel to the outside atmosphere connected to said clearance space, both the second and third channels incorporating valve means to control the flow of gas therethrough.

9. Driving mechanism for a lung ventilator or the like, said ventilator having two cycle phases, one of said phases having different duration and energy requirements than the other, said mechanism incorporating a cylinder

and piston, a piston rod extending from said piston through one end of said cylinder, piston rod supporting structure at the end of said cylinder having clearance space between said supporting structure and said piston rod, a pair of seals mounted in spaced relationship, a channel structure leading from said clearance space to the inside of the cylinder, a check valve in said channel structure to control the flow of gas between said clearance space and said cylinder.

10. Driving mechanism for a lung ventilator or the like, said ventilator having two cycle phases, one of said phases having different duration and energy requirements than the other, said mechanism incorporating a cylinder and piston, a piston rod extending from said piston through one end of said cylinder, piston rod supporting

structure at the end of said cylinder having clearance space between said supporting structure and said piston rod, a pair of seals mounted in spaced relationship in said supporting structure and engaging said rod, said rod having a channel extending longitudinally along it, a channel structure leading from said clearance space to the outside atmosphere, a check valve supported in said channel structure to control the flow of gas therethrough.

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