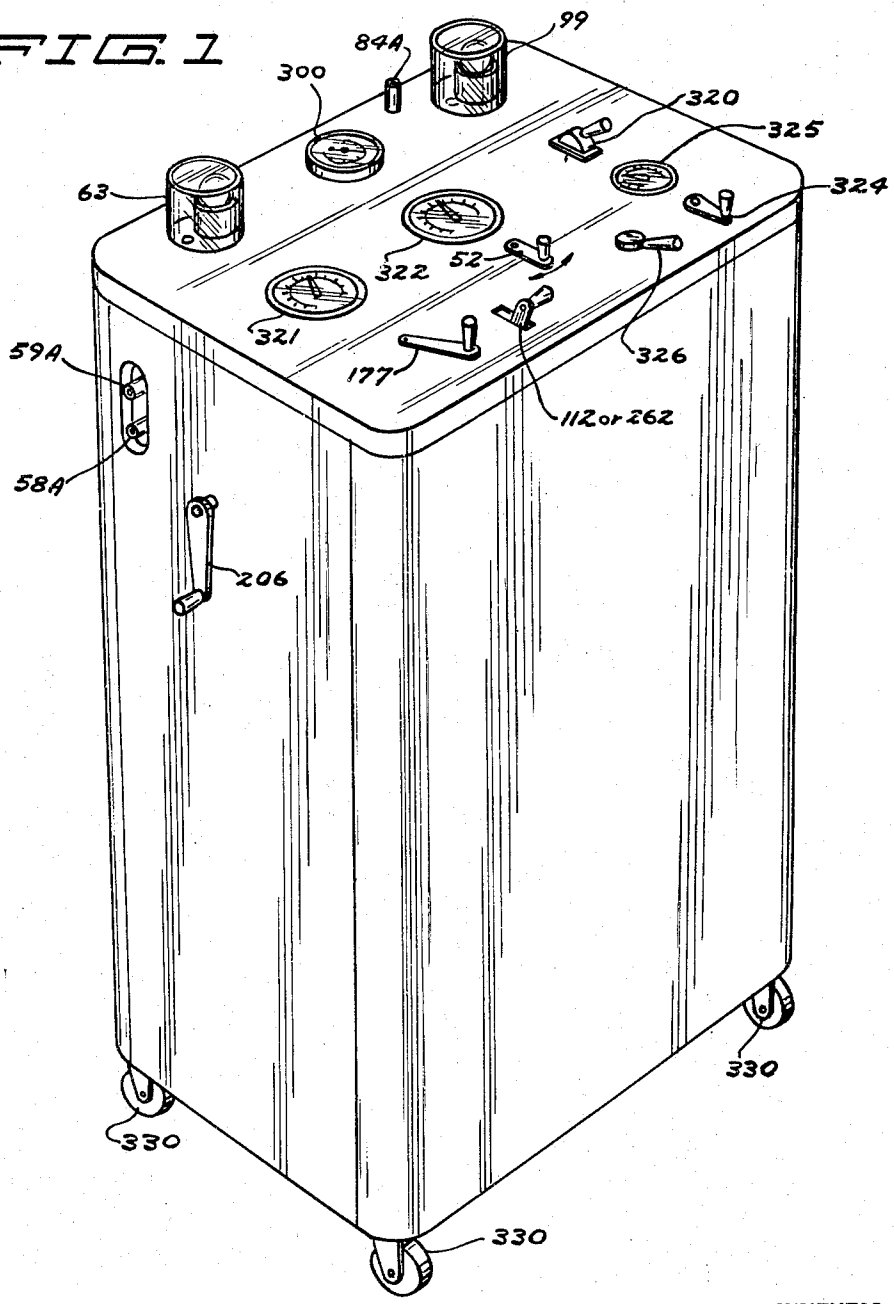
Nov. 13, 1956 T. FALK 2,770,231

RESPIRATOR SYSTEM

Filed Aug. 18, 1954 8 Sheets-Sheet 1

FIG. 1



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RESPIRATOR SYSTEM

Filed Aug. 18, 1954 3 Sheets-Sheet 2

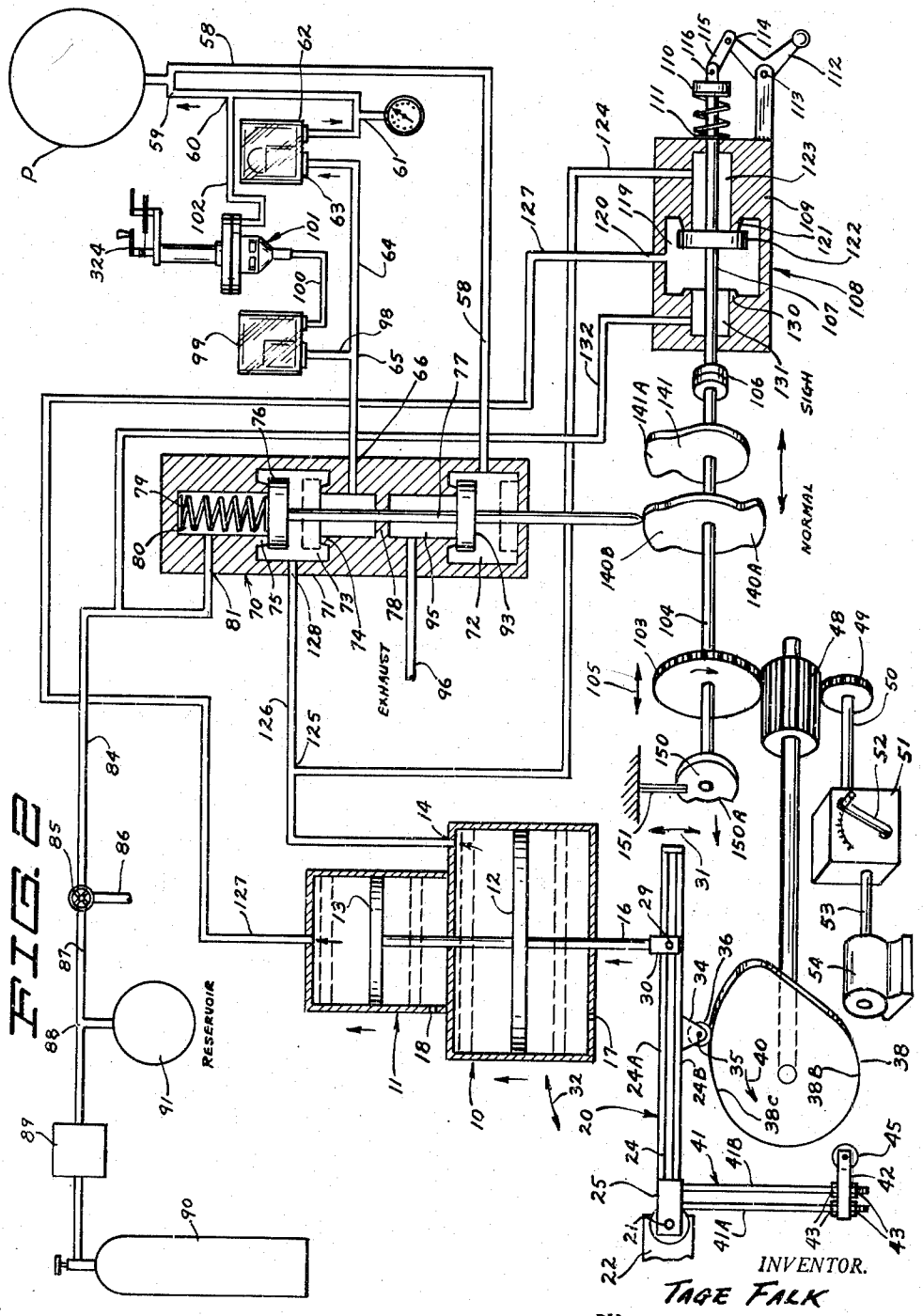


FIG. 2

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RESPIRATOR SYSTEM

Filed Aug. 18, 1954 3 Sheets-Sheet 3

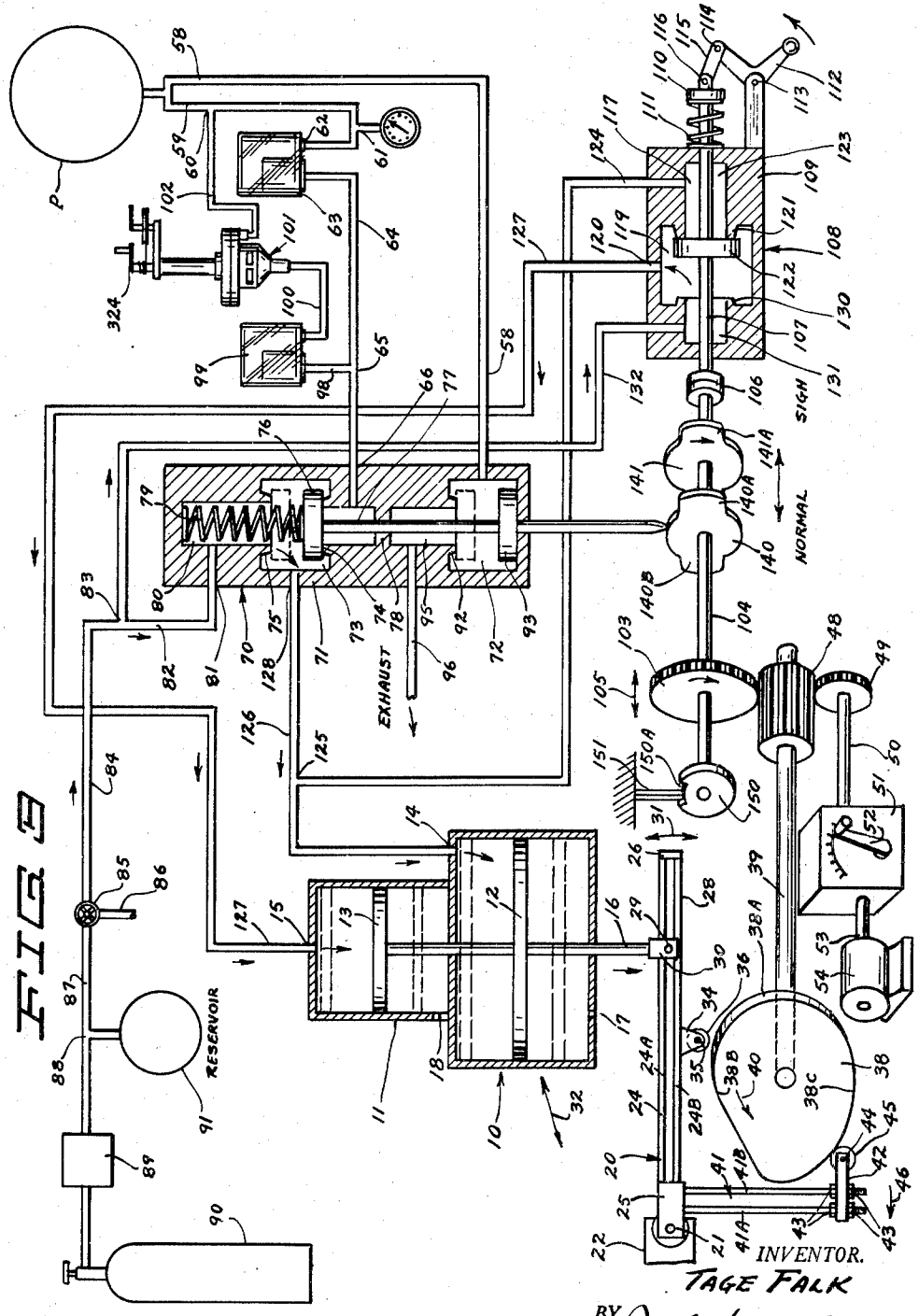


FIG 3

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RESPIRATOR SYSTEM

Filed Aug. 18, 1954 8 Sheets-Sheet 4

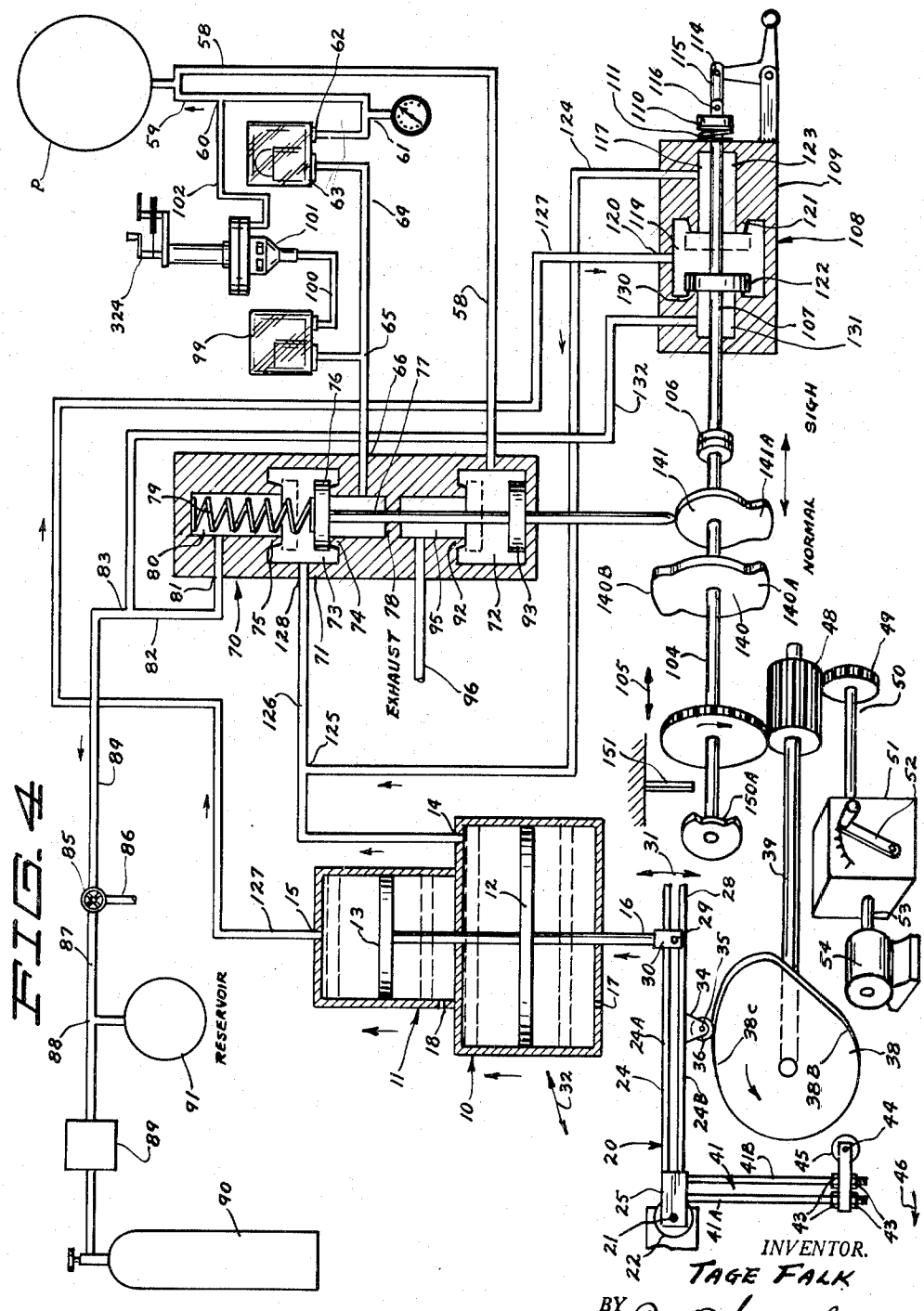


FIG. 4

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Nov. 13, 1956 T. FALK 2,770,231

RESPIRATOR SYSTEM

Filed Aug. 18, 1954 8 Sheets-Sheet 5

FIG. 5

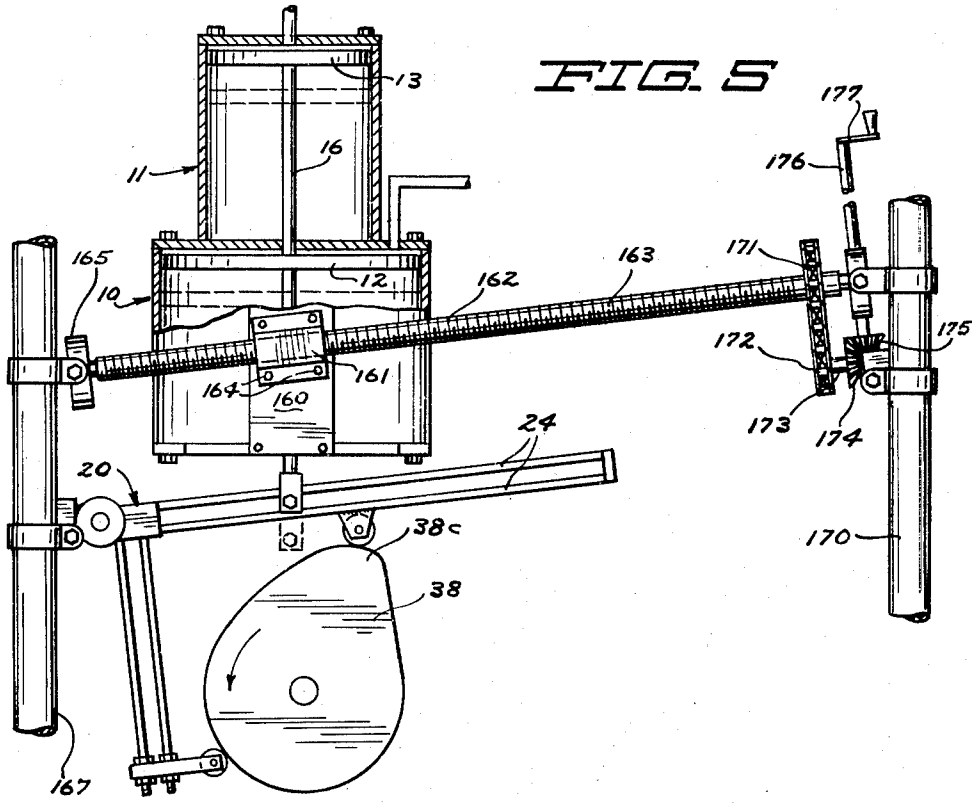
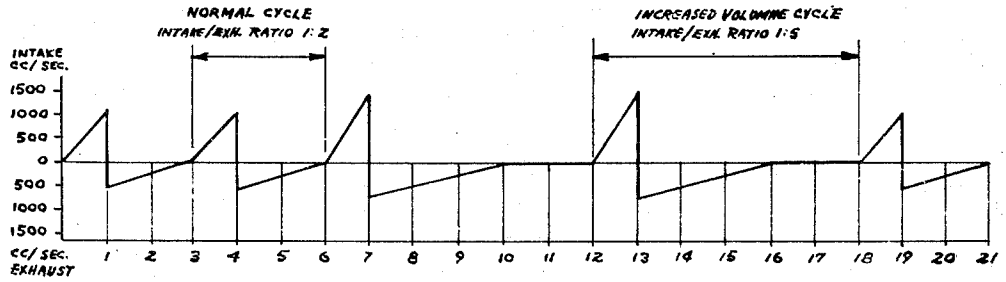


FIG. 8



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Nov. 13, 1956 T. FALK 2,770,231

RESPIRATOR SYSTEM

Filed Aug. 18, 1954 8 Sheets-Sheet 6

FIG. 7

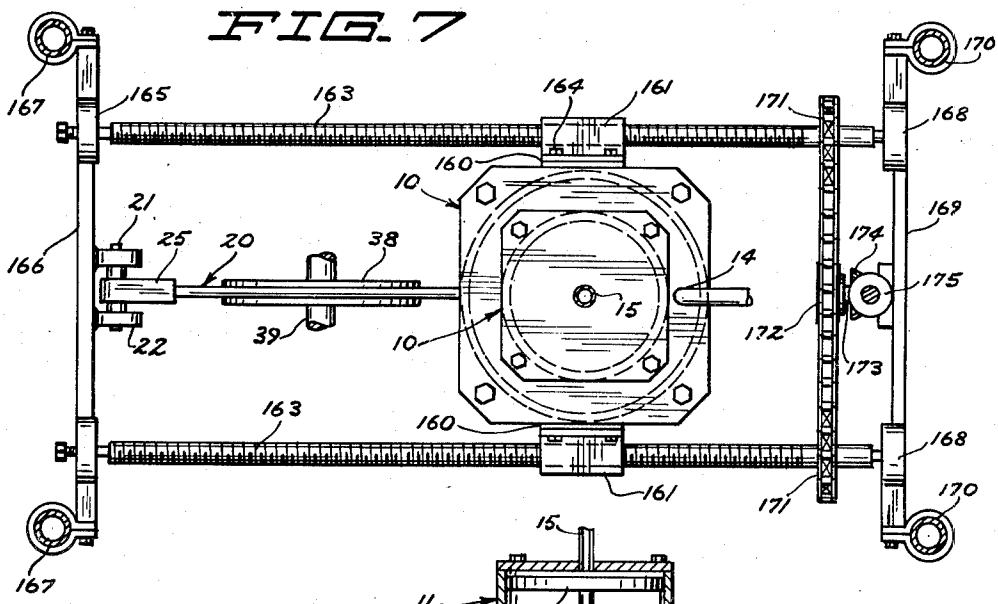
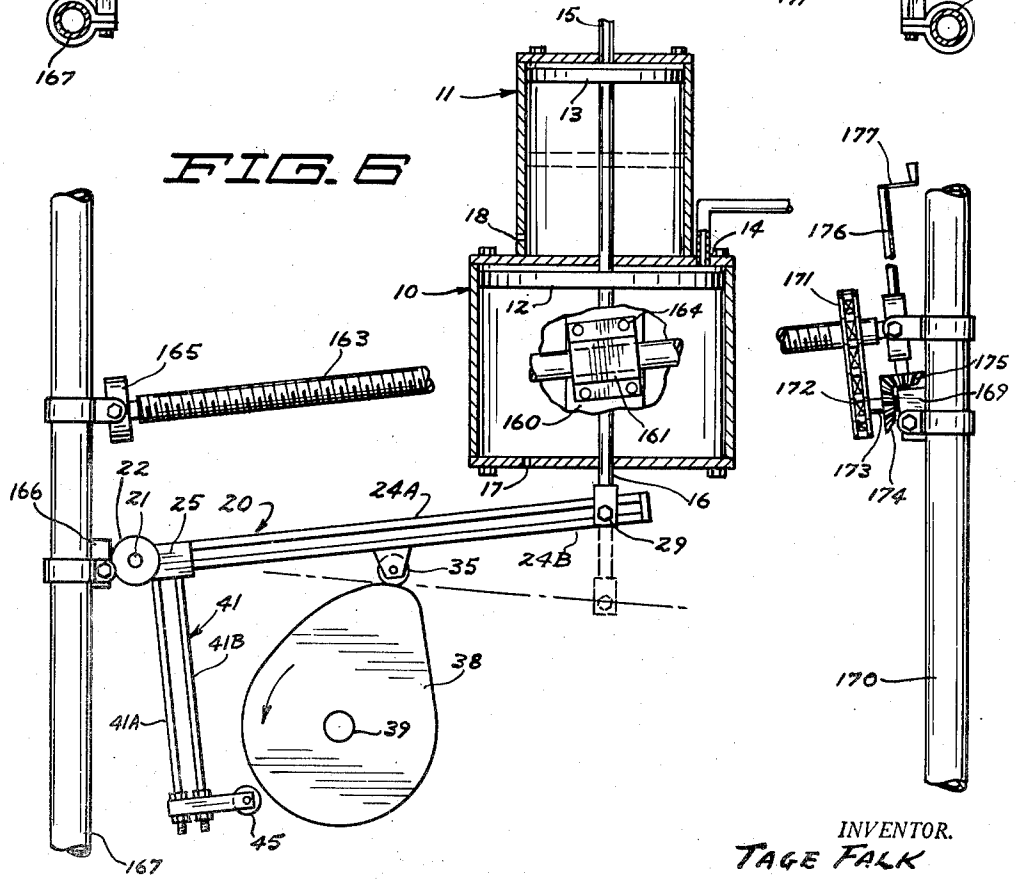


FIG. 6



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Nov. 13, 1956 T. FALK 2,770,231

RESPIRATOR SYSTEM

Filed Aug. 18, 1954 8 Sheets-Sheet 7

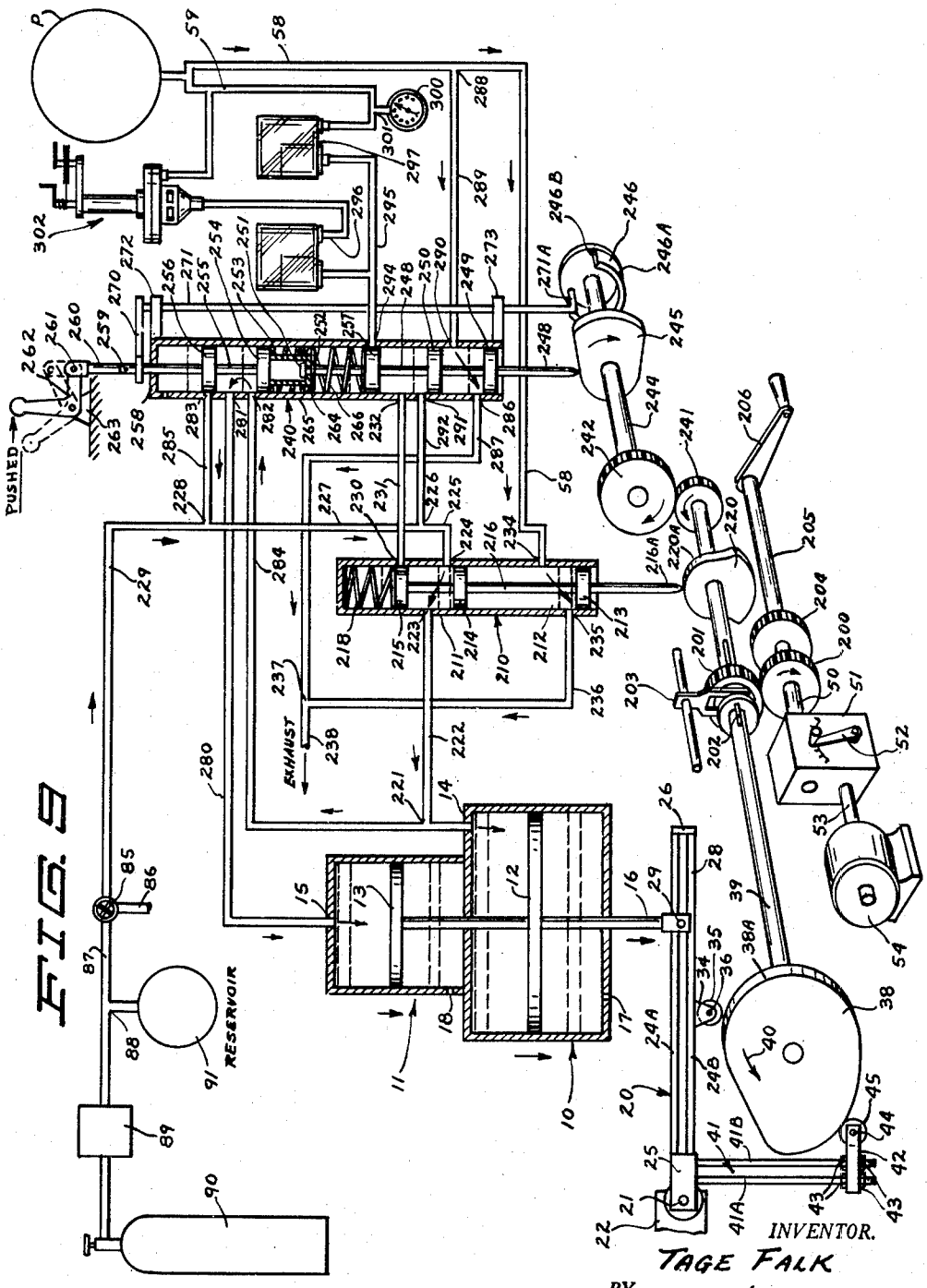


FIG. 9

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Nov. 13, 1956 T. FALK 2,770,231

RESPIRATOR SYSTEM

Filed Aug. 18, 1954 3 Sheets-Sheet 8

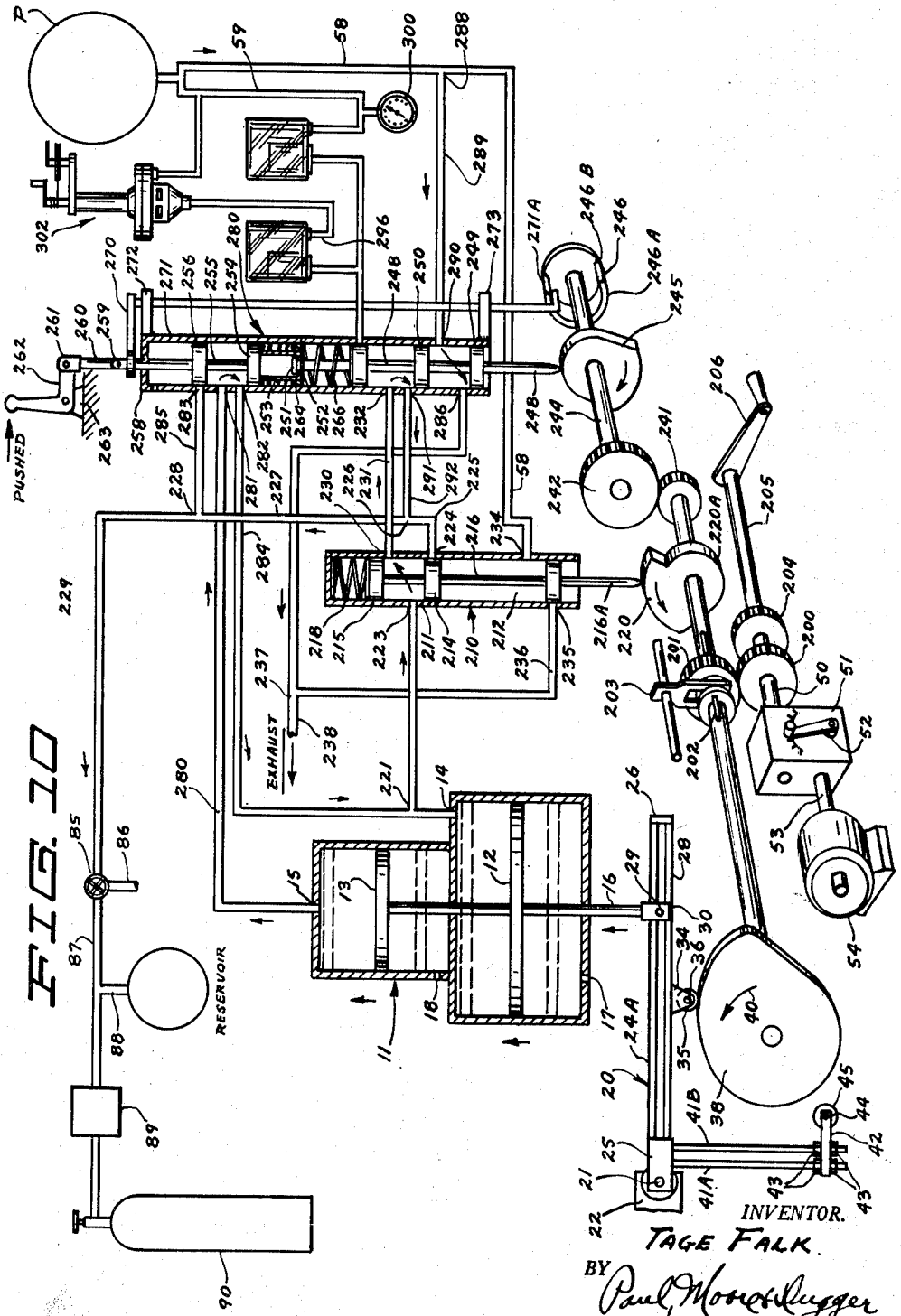


FIG. 10

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United States Patent Office 2,770,231 Patented Nov. 13, 1956

2,770,231

RESPIRATOR SYSTEM

Tage Falk, St. Paul, Minn., assignor to Smith Welding Equipment Corporation, Minneapolis, Minn., a corporation of Minnesota

Application August 18, 1954, Serial No. 450,584

12 Claims. (Cl. 128—29)

This invention relates to improvements in apparatus for control of respiration, resuscitation and anesthesia. More particularly, this invention relates to apparatus capable of automatically controlling the respiration of a patient in rhythm with, and at the same rate as the normal respiration of the patient and means for varying the volume and rate of gas introduction into the lungs of the patient and for varying, under the control of the patient or an attendant, the volumetric respiration to accommodate as may occasionally be desired, a cycle of respiration analogous to the normal sigh, and accompanying prolonged expiration thereafter to simulate the sigh and accompanying prolonged expiration occasionally occurring during normal breathing. For resuscitation and maintenance of respiration, the gas is normally simply fresh air or oxygen enriched air may be employed. For anesthesia, the anesthetic agent may be vaporized or diluted with air or other gases, such as inert gases. The selection of the particular gas or mixture being used is within the province of the physician's determination. For the purposes of this specification and in the claims, the term "gas" will therefore be understood to mean any gaseous fluid such as is prescribed by the physician.

The respirator system, which is the subject of this invention, is of the "positive-pressure" type. That is, the gas is forcibly introduced under appropriately slight but positive pressure through a face mask, tracheotomy tube or the like into the patient's respiratory system to expand the lungs in simulation of the normal inspiration (inhalation portion) of the normal respiratory cycle. For expiration of the gas, reliance is placed upon the normal elasticity of the lungs and lung cavity of the patient for expelling the gas therefrom, when permitted to do so. In this manner, the possibly dangerous effects of the imposition of an artificial breathing cycle upon the patient are avoided. It is within the province of the invention to utilize slight negative pressure during at least the last part of the expiration portion of the respiratory cycle, if such is desired.

One disadvantage of prior respirators is that they may use mechanical components which are themselves somewhat elastic and which cannot be accurately set as to pressure, volume and cycling, and furthermore, such elastic components may develop leaks, and the like. In the so-called "iron lung" type of respirator, the patient is locked in the lung chamber except for his head, which passes through an elastic wall which encircles the patient's neck. The elastic wall is essentially a gland through which the patient's neck passes and it should fit snugly, if the apparatus is to work appropriately and well, but a snug fit is uncomfortable to the patient. If this elastic wall or gland is made tight enough to be adequately leak-proof, or reasonably so, for purposes of proper operation of the "iron-lung," then the patient is made uncomfortable; if made loose enough for the patient's comfort, the elastic gland will be likely to leak. In either event, the gland encircling the patient's neck is elastic and accurate volume control in respect to the patient's lung cavity is precluded. Furthermore, since the patient is totally

encased in the remaining portions of the apparatus, the patient is deprived of easy movement, mild exercise, the advantages of an erect position, and his position cannot be easily changed nor is nursing care easy to administer.

It is a principal object of this invention to provide a respiratory system adapted to reproduce as nearly as possible the breathing cycle of the patient, and in such a manner as to allow the patient at least limited freedom of movement, an erect position if desired by the patient, with provisions being made to superpose upon the normal respiration a "sigh" cycle which may be interposed at the will of the patient or nurse, and to provide other advantages.

It is a further object of the invention to provide a complete and self-contained unit easily portable so that the patient may have a limited freedom of movement within the confines of a long electric cord leading to a power supply.

It is a further object of this invention to especially provide for variation in the volumetric quantity of air cyclically introduced into the patient's lungs and to provide for an abrupt change in the volume by which it may be increased, so as to produce a simulation of the normal sigh together with an immediately following appropriate and longer period of expiration, in simulation of the prolonged expiration period which occurs after the normal sigh during breathing.

It is a further object of the invention to provide a simple control which may be operated by the patient or inexperienced nurses' aides by which the normal and sigh portion of the breathing cycle may be utilized without danger of imposing upon the patient excessive quantities of respiratory air during any one portion of the cycle, the controls being interlocked so as to provide a desired prolonged period of expiration at the end of each sigh.

Other and further objects of the invention will become apparent as the description proceeds.

To the accomplishment of the foregoing and related ends, this invention then comprises the features hereinafter fully described and particularly pointed out in the claims, the following description setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principles of the invention may be employed.

The invention is illustrated with reference to the drawings in which:

Figure 1 is an isometric front view illustrating the exterior portions of the cabinet in which the apparatus of the invention is contained and showing those controls which are provided upon the exterior of the apparatus;

Figure 2 is a partly schematic view showing mechanical portions of the apparatus together with the connections to the patient to a source of respirator gas and the appropriate piping and valving connections of the apparatus. Figure 2 illustrates the apparatus during a normal breathing cycle and specifically during the inspiration portion of the normal cycle:

Figure 3 is a view corresponding to Figure 2 except that it shows a normal breathing cycle but during the expiration portion of the normal cycle;

Figure 4 is a view corresponding to Figures 2 and 3 except that it shows the apparatus during the sigh cycle and during the inspiration portion of such sigh cycle;

Figure 5 is an enlarged fragmentary vertical sectional view illustrating the pump portions of the apparatus together with its mounting and illustrating the mechanical drive by which the pump is oscillated. This figure also shows the manner in which the volumetric displacement of the pumping portion of the apparatus may be varied to suit the needs of the patient, and illustrates specifically an adjustment near minimum volume;

Figure 6 corresponds to Figure 5 except that it illustrates the adjustment for nearly maximum volume;

Figure 7 is a fragmentary enlarged sectional plan view of those portions of the apparatus shown in Figures 5 and 6;

Figure 8 is a graph illustrating several cycles of normal breathing and several cycles of "sigh" breathing;

Figures 9 and 10 are diagrammatic views of somewhat modified form of the invention.

Throughout the drawings, corresponding numerals refer to the same parts.

Referring to Figures 2, 3 and 4, the apparatus of the present invention includes a first cylinder generally designated **10** and a somewhat smaller capacity second cylinder generally designated **11**. Each is provided with a piston as at **12** and **13** respectively and each cylinder has a combined inlet-exhaust port as at **14** and **15** respectively. The pistons of the two cylinders are, for convenience, mounted upon a common piston rod **16** so that the pistons **12** and **13** are moved in unison. When the pistons are elevated in their cylinders, the respiratory gas above the pistons is exhausted thru the ports **14** and **15** respectively, whereas when the pistons are moved downwardly in the cylinders, respiratory gas is drawn into the space above the pistons. The lower cylinder head of cylinder **10** is provided with a port at **17** while a similar port **18** is provided in the lower portion of the cylinder **11** so that the spaces under each of the pistons is ventilated to atmosphere and the movement of the pistons therein therefore not impeded.

The mechanism for oscillating the piston rod **16** thru an adjustably, variable stroke always terminating at a given point, and of adjustably variable periodicity, may be of any of the types shown in my copending application Ser. No. 432,532, filed May 26, 1954, entitled "Respirator System." Any mechanism which is capable of moving the piston rod cyclically to and fro within the cylinders at a cyclic rate adjustable to suit the requirements of respiration of the patient, and which is capable of moving the pistons a variable stroke downward and then upward to a constant fully actuated position, may be utilized. In this instance, the aforestated requirements are met by the combination of lever arms, forming a bellcrank generally illustrated at **20** taken with the manner of mounting the cylinders and the variable speed drive for the bellcrank. The bellcrank **20** is pivoted at **21** to the machine framework support **22**. The long lever **24** of the bellcrank may for convenience be composed of two rods **24A** and **24B** which are set parallel and connected to the pivoted block **25** at one end and for good mechanical rigidity fastened together by the block **26** at the other end. Between the two rods **24A—24B**, there is a space **28** in which the pin **29** is situated and positioned at any place to thus vary the piston stroke. The pin **29** passes thru a clevis **30** on the lower end of the piston rod **16** and accordingly as the lever arm **24** oscillates arcuately up and down as shown by the double headed arrow **31**, the piston rod **16** will likewise be moved an amount depending upon the distance from the pin **21** to the pin **29**, and the throw of cam **38**. As will be described later herein, the cylinders **10—11** are mounted for translatory motion along a path as shown by the double arrow **32**, Figure 3, which therefore permits the pin **29** to be moved along in the slot **28** to a position nearer or farther away from the pivot pin **21**. Accordingly, for a given arcuate oscillation of the lever **24**, the piston rod **16** will be moved up and down a varying amount dependent upon the particular position in which the pin **29** is situated along a slot **28**. In the uppermost position of arcuate movement of the lever **24**, the pistons **22** and **23** are always raised to their uppermost positions respectively within the cylinders **10** and **11** so as always to expel from those cylinders respectively the respiratory gas contained in them. In order that this may be true regardless of the adjustment of cylinders **10** and **11**, this uppermost position of the lever **24** as determined by the left of cam **38** is made parallel to the path of translatory motion as shown by the double arrow **32**. Accordingly, regardless of the position in which cylinders **10** and **11** may be positioned, the uppermost position of the pistons **12—13** in the cylinders will always be adjacent the top of the cylinders when the piston rod **16** is moved to its raised position by cam **38**. The details of mounting of cylinders **10** and **11** are shown in Figures 5, 6 and 7 and will be described later.

To the underside of the rod **24B** there is attached a bracket **34** upon which a roller **35** is mounted at pivot pin **36**. The roller **35** is adapted to engage the peripheral edge **38A** of the cam **38** which is mounted for rotation on the shaft **39** and shaped, as described in my application aforementioned which is incorporated herein by reference. The cam is so shaped that when it is rotated in the direction of the arrow **40** the roller **35** will cause the arms **24** to be elevated (and then allowed to be lowered) rhythmically in close approximation of the normal respiration.

The downward oscillation of the arms **24** is positive and may be accomplished by any of the methods shown in my aforesaid application. One of these methods, here illustrated, includes a short bell crank arm generally designated **41**, also attached to the pivot block **25**. The arm **41** is also composed of a pair of rods **41A** and **41B** having threaded lower ends. A block **42** is held on the arms **41A** and **41B** by suitable nuts **43—43** and may therefore be adjusted with reference to pivot **21**. The arm **42** carries a pivot pin **44** on which rotates the roller **45**, so positioned that it rides upon the peripheral edge **38A** of the cam **38**. The roller **45** is positioned and adjusted so that it rides almost in contact with the cam, even when roller **34** is effective. As the cam **38** rotates in the direction of arrow **40** it will ride against the roller **45** causing it to be oscillated in the direction of the arrow **46** thereby causing the arm **24** and hence the bellcrank to be oscillated downwardly for the suction stroke of pistons **12** and **13** in cylinders **10** and **11** respectively. Note that this does not produce a suction on the patient. The upward movement of the arms **24** is accomplished as heretofore stated when the cam **38** pushes against the roller **35**. The threaded lower ends of the rods **41A** and **41B** permit the close adjustment of the roller **45** adjacent the periphery of the cam **38** so that there is little lost motion between the time that roller **35** reaches the lowermost circular portion of the cam from point **38B** to approximately the point **38C**, until the roller **45** begins to be moved by the cam.

The rotation of the cam **38** is by virtue of the shaft **39** which is driven by the gear **48** from the drive gear **49** on shaft **50** of the variable speed drive **51** which is equipped with a controller **52** for varying the speed of the output shaft **50**. The constant speed input drive shaft **53** of the variable speed drive is connected to a constant speed motor **54**. Any infinitely variable speed drive of appropriate speed range and power may be used. By varying the position of the adjustable handle **52**, the speed of rotation of the shaft **50** may likewise be varied so as to accommodate the rate of oscillation of the pistons **12—13** in their cylinders **10—11** respectively to the natural periodicity of the respiratory cycle of human or other patients.

The patient is diagrammatically illustrated by the circle designated P and it is an objective of the invention to move to the patient a given quantity of gas under slight but positive pressure. Accordingly, at the patient there is provided a face mask, tracheotomy tube, or the like, which is connected in substantially gas tight relation to the respiratory tract of the patient. At the face mask, tracheotomy tube, etc., there are made two connections, namely, a patient exhaust line **58** and a patient supply line **59**. Separate lines are used so that there is not any appreciable volume of the respiratory system in which intermingling of the enervated expiratory with the fresh incoming air from the respiratory apparatus occurs. To

this end, the connections of lines 58 and 59 are made as close as possible to the patient's tube or mask, and the latter is made of minimum volume. The patient supply line 59 connects thru junction 60 and thence thru junction 61 to the port 61 to the port 62 of a flow indicator 63, the details of which are more fully described in my application aforementioned. The flow indicator is so constructed that even the slightest flow therethru will be indicated quite apparently with minimum pressure drop. Leading to the flow indicator 63 is a line 64 which extends thru junction 65 to the port 66 of multiple valve generally designated 70.

The valve 70 has two main sections 71 and 72. The section 71 is essentially a two-way valve and provided with an antrum chamber 73 having the valve seats 74 and 75 against which the valve disk 76 is adapted alternately to seat. The valve disk is mounted on the valve stems 77 which moves in the valve body and passes thru a central web 78 which serves to separate the valve chambers 71 and 72. The valve disk 76 is normally urged downwardly by a spring 79 in the space 80 but the disk 76 may be moved upwardly with the stem 77 by the actuation of the cam mechanism.

A pipe 82 is connected at 81 to the space 80. The pipe 82 extends thru the junction 83 and line 84 to a two-way valve 85. From the valve 85 one line extends to atmosphere at 86 and when the valve 85 is in one of its two positions the line 84 is connected to atmosphere at 86. When the valve 85 is in the other of its two positions it is connected to the line 87 and thence thru junction 88 to the pressure regulator 89 and thence to the gas supply bottle 90. When atmospheric air is not used for treatment of the patient, the respiratory gas is withdrawn from the bottle 90 thru the pressure regulator 89 and thence thru junction 88 to the line 87 or to the flexible reservoir 91, which is commonly a simple small elastic balloon. Since the bottle 90 feeds gas almost constantly, the balloon 91 serves as a flexible reservoir to absorb the flow during periods when the gas is not being withdrawn for use by the patient and to yield readily the flow of respiratory gas during the suction portion of the pump's cycle. The lower section 72 of the valve is essentially an on-off (one way) valve, and it has a valve seat 92 against which the valve disc 93 is adapted to seat when the valve stem 77 is raised. Above the valve seat is an open space 95 which is connected by the pipe 96 to atmospheric air, which therefore forms an exhaust port. To the section of the valve 72 there is also connected the patient exhaust pipe 58. In the patient supply line there are several additional devices. Thus, from the junctions 65 a line extends at 98 thru the flow indicator 99 (which for convenience is made similar to the flow indicator 63), and thence thru the line 100 to an overpressure release valve generally designated 101. This overpressure release valve or "pop-off" valve 101 may be constructed as illustrated in my copending application Ser. No. 432,532 mentioned above. A pressure connection line at 102 connects from the underside of the diaphragm of the valve 101 to the junction 60 on the patient supply line 59 so as to make the overpressure release valve sensitive to the pressure delivered to the patient.

In addition to the foregoing there is provided a cam mechanism which is operated in synchronism with the oscillation of the pistons in the cylinders. Thus, the gear 48 serves to drive a gear 103 mounted upon the shaft 104. The shaft 104 is mounted for rotation and also for axial sliding movement in bearings not shown and it is constantly driven from the gear 48 regardless of the position in which it may be situated along the gear, as shown by the double arrow 105. The shaft 104 is connected through a thrust bearing 106 to the stem 107 of a two-way manually controlled valve 108. The stem 107 passes through the ends of the body of 109 of valve 108 and is provided with a collar 110 at one end. A bias spring 111 is provided between the valve body 108 and the collar 110 thereby causing the stem 107 to be normally moved in the right hand direction as shown in Figure 3. In so moving, its axial movement is communicated through the thrust bearing 106 and holds the shaft 104 in a position depending upon the valve stem 107. The shaft 104 rotates in either the Figure 3 position or the Figure 4 position, in which it is axially held by valve stem 107 of the valve 108. The valve 108 is for changing the normal respiratory cycle to the sigh respiratory cycle. Figure 3 shows the setting of valve 108 for "normal" respiratory cycle, and in this position cam 140 is effective for activating valve 70, and cam 141 is idle whereas Figure 4 shows the setting of valve 108 for the "sigh" respiratory cycle, and in this position, cam 141 is effective for activating valve 70, and cam 140 is idle. Valve 108 is essentially a two-way valve, having a valve body 109, a central antrum chamber 119, an end antrum chamber 123, and another end chamber 131. The central chamber 119 has a port 120 connected thru line 127 to the port 15 of the small cylinder 11. The antrum chamber 123 is connected thru line 124 to junction 125 on the line 126 which connects from port 14 on the large cylinder 10 to port 128 of the multiple valve 70. From antrum 131 a line 132 connects to junction 83 on the patient respiratory gas supply line 84. On the stem 107 of valve 108 there is a valve disc 122 which may be moved so as to seat against the seat 121, by the action of spring 111, or may be shifted so as to seat against the valve seat 130 when the valve 108 is manually actuated. The manual actuation of valve 108 is accomplished by a small bell crank lever 112 pivoted at 113 upon a small bracket extending from the valve body 109. A pivot pin 114 is connected to link 115 and thence thru pivot pin 116 to the valve stem 107. The spring 111 normally pushes against the collar 110 fixed to the stem 107 and normally urges the stem 107 to the right as shown in Figure 3. However, when the bell crank lever 112 is swung in the direction of the arrow shown adjacent to it in Figure 3, the stem 107 will be moved to the left, and the valve shifted to the position shown in Figure 4. Whenever this shift is made the shaft 104 is also moved.

In order to prevent shifting of the valve 107 and thus the superimposition of the sigh respiratory cycle upon the patient's respiratory system at any time except when appropriate, there is provided an interlock on the end of shaft 104. This interlock is in the form of a small disc 150 having a slot 150A of appropriate length and location in its periphery. A cooperating fixed stop 151 is mounted upon the machine frame. The shift from the normal cycle to the sigh cycle can be initiated only at the end of a normal respiratory period since it would be undesirable to pump a large quantity of air to the patient if his lungs are already filled with air from a previous cycle. Accordingly, the slot 150A has a leading edge so situated that the shift via handle 112 of valve 107 can be initiated only at the end of the normal expiration period. Likewise, the shift to return the cycle to normal breathing is, according to the invention, permitted only after the end of an expiration period. Therefore the trailing edge of the slot 150A in the disc 150 is placed appropriately so that the shift from the sigh cycle position of Figure 3 can be accomplished only when shaft 104 is rotated to the appropriate position at the end of the normal expiration. The leading edge of the slot is shaped so as to prevent jamming.

The operation of the stem 77 of the multiple valve 70 is accomplished by two cams, namely cam 140, which is effective during the normal breathing cycle, and cam 141, which is effective during the sigh breathing cycle, The cam 140 has two lobes 140A and 140B oppositely placed on the cam. The gear reduction between gear 48 and gear 103 is two-to-one and accordingly for every rotation of the pump actuating cam 38 there is one lift of the valve stem 77 of the multiple valve 70, when the shaft 104 is in a position such that the cam 140 is effective to oper-

ate against the lower end of the valve stem **77**. The sigh cycle cam **141** has only one cam lobe **141A**. The reason for this is that the sigh cycle is made twice the length of the normal cycle of breathing so as to afford a prolonged period for the expiration of the enlarged amount of respiratory gas delivered into the patient's lungs during the inspiration part of the sigh cycle. In other words, the pump apparatus during the sigh cycle pumps gas in large volume (from both of the cylinders **10** and **11**) to the patient and this is accomplished during the same length of time required for pumping the smaller volume of air to the patient during the inspiration portion of the normal respiratory cycle. However, during the sigh cycle there is provided a very prolonged expiration portion of the cycle and this is accomplished by utilizing an intervening time period (normally used for inspiration and expiration in a normal cycle) for lengthening the expiration portion of the sigh cycle. Accordingly the cam **141** has only one cam lobe **141A** and it is effective to actuate the valve stem **77** of the multiple valve **70** only for every second stroke of the pumps.

Exemplary operating conditions are illustrated by Figures 2, 3, and 4. In Figure 2, which shows the normal respiratory cycle, during the inspiration portion of that cycle, where the gas is delivered to the patient. It may be assumed that the pistons in pump cylinders **10** and **11** have been drawn down to the position shown in dotted line for the pistons in each of the cylinders so as to fill the cylinders with respirating gas. The cam **38** rotates counterclockwise as shown by the arrow **40** and in so doing is elevating the piston rod **16** in Figure 2. The motion has continued from the dotted line position of the pistons which was the lower position (as determined by the adjustment of cylinder mounting mechanism) and, as shown, the pistons are in the process of moving upwardly under the influence of the cam **38**. The multiple valve **170** has also been actuated so that its stem **77** is raised with the positioning of the valve discs **76** and **93** as shown in full lines. With the valve discs in this position, the gas within cylinder **10** is being driven out thru port **14** thence thru line **126** to antrum **73** of valve **70**. The gas flow passes thru the antrum and thence to the port **66** and via line **64** thru the flow indicator **63** to the patient supply line **59** and to the patient. At the same time, the upward movement of piston **13** within the cylinder **11** causes the fresh respiratory gas within that cylinder to be pushed out thru port **15** and thence via line **127** to the antrum **119** of valve **108** and thru the valve **108** to line **132** which connects back at junction **83** to the patient supply line. Accordingly, the only effect of cylinder **11** and piston **13** moving therein is to drive back into the respiratory gas supply line **84** the gas which was in the cylinder.

Accordingly, during the normal respiration cycle the cylinder **11** merely idles, taking in and then expelling respiratory gas from and to the line **84**. As the mechanism continues, cam **38** reaches the position at its uppermost position whence it begins to allow the roller **35** to be retracted under the influence of the operation of the cam **38** against roller **45**. At the same time, the valve stem **77** is abruptly lowered by the action of the lobes **140A** or **140B** of the cam **140**. The normal cycle during the expiration portion is shown in Figure 3. This figure illustrates that portion of the cycle and is about half complete when the pistons **12** and **13** are about midway in their stroke from the uppermost position in their path of travel to the lower dotted line position as shown in Figure 3. While this is occurring, the pistons **12** and **13** in the cylinders **10** and **11** respectively are each drawing in fresh gas from the respiratory gas supply line **84** which may be either atmospheric air or from the bottle supply **90**. The path of flow to the cylinders is from line **84** to junction **83** thence thru line **82** antrum **80** thru valve seat **75** and antrum **73** to port **128** via line **126** past junction **125** to the port **14** of the large cylinder **10**. At the same time, flow may extend from the junction **83** on line **84** via line **132** thru the antrum **131** of the valve **108** and thence thru the valve to the port **120** and via line **127** to the port **15** of the cylinder **11**. Accordingly, both cylinders suck in fresh respiratory gas. At the same time, the position of valve **70** is such as to permit a clear path of flow from the patient supply line **58** to the valve section **72** and thence thru the seat **92** to portion **95** and thence thru the exhaust line **96**. The natural elasticity of the patient's lungs and lung cavity, when distended, causes the air which has been delivered to the patient to be expired by the patient. This expiration portion of the cycle permits the stale air within the patient's lungs to be naturally expelled.

Referring to Figure 8, there is illustrated a graph showing several normal and several increased volume cycles (sigh cycles). The volumetric displacement curves are shown along a graph in which the time elements are shown in seconds. From point 0 to point 1 on the graph the operation of cylinder **10** causes respiratory gas to be pumped to the patient at a gradually increasing rate which is determined by the shape of the cam **38** which may be varied by the designer. Abruptly at position 1, the setting of the valve **70** (and accompanying operation of the piston **12** in cylinder **10**) occurs so as to permit expiration by the patient to take place from the time period 1 to time period 3. From time period 3 to period 4 there is illustrated another inspiration portion of the normal cycle and from time period 4 to time period 6 there is shown another expiration portion of a normal cycle. The remaining portions of the graph, Figure 8, will be explained with reference to the sigh cycle portion of the respiratory action.

In Figure 4 there is illustrated the setting of the valve **108** and the accompanying effects which occur during the sigh part of the inspiration cycle. Whenever the patient desires to superimpose upon his breathing a normal sigh, or whenever this is determined by the patient's nurse or physician to be desirable, it is only necessary to swing the handle **112** toward the position shown in Figure 4. The patient or attendant may apply pressure to handle **112** at any time, but the interlock cam **150** will not permit the movement of this valve stem **107** to take place until the appropriate time has been reached as previously explained. When the time occurs, the handle **112** against which manual pressure is exerted, will then be permitted to swing to the position shown in Figure 4, thus overcoming the action of the spring **11** and resetting the valve **108** to the position shown in Figure 4. This causes the cam **140** to shift to the idle position and the cam **141** to move into a position to actuate the valve **70**. In Figure 4 it will be assumed that both of the pistons in the cylinders have drawn in a fresh charge of respiratory gas according to the usual valving operation and they are now in the process of moving that air to the patient, the pistons **12** and **13** in cylinders **10** and **11** respectively being about half way from their lower position in their path of movement upward towards their fully actuated position. It will, of course, be remembered that the position of cylinders **10** and **11** may be translated with reference to the bell crank lever **20** so as to vary the volume of stroke according to the patient's needs. During the upward movement of pistons **12** and **13** the gas from each cylinder is pumped to the patient. Thus, from cylinder **10** the flow is via port **14** line **126** thru section **73** of valve **70**, as previously described, and thence thru line **64** flow indicator **63** to the patient supply line **59**. Also flow may now occur from port **15** of cylinder **11** thru line **127** to port **120** of valve **108** thence thru antrum **119** thru valve seat **121** thru antrum **117** to line **124** which connects at **125** to the line **126** thru which cylinder **10** is already delivering respiratory gas to the patient. Accordingly, the flow from cylinder **11** joins with that from cylinder **10** and the thus increased volume of flow is driven thrus the section **73** of valve **70** and via line **64** to the patient supply line **59** thereby causing the amount

of air that is moved to the patient during the sigh to be increased by the amount determined by the size of the cylinder **11**. This amount may be varied according to the design of the machine by changing the relative sizes of the two cylinders.

Usually only one sigh at a time is initiated by applying pressure to the handle **112** as previously stated. Once the sigh is started, the handle **112** may then be released but will not automatically return until the interlocking cam **150** permits this to occur. This occurrence cannot take place, however, until after a prolonged period equivalent to the time of normal expiration plus the time for one complete normal respiratory cycle. Thus referring to the shape of interlock cam **150**, the single lobe of cam **141**, and to the graph Figure 8, it will be noted that at point 6 in the time sequence, the inspiration portion of the sigh cycle is initiated and the total rate of inspired gas increased about 50 percent from 1,000 cc. per second (in this example) to about 1500 cc. per second. These rates may be varied depending upon the desires of the physician attending, by replacing cam **38** by another cam of desired shape and the volumes can be varied by adjusting the position of the cylinders. At point 6 in the time diagram, Figure 8, the inspiration portion of the sigh cycle has been completed and from point 7 to point 9, which would be the normal expiration portion of a normal cycle, the patient is expiring the gas delivered to him during the inspiration portion of the sigh cycle. This expiration continues from 9 to 10 and there is a rest period from 10 to 12. The time period from 9 to 10 would, if the cycle were normal, be that time period during which inspiration would be provided and the time period 10 to 12 would be the expiration period of the normal period. Accordingly, the time space from 9 to 12 is a second normal cycle during which the final expiration portion and pause of the sigh cycle is permitted to occur. A second full sigh cycle is shown in Figure 8 from 12 thru 18 after which there is shown a normal cycle from 18 to 21.

One apparatus by which the cylinder mechanism may be adjusted so as to achieve a variation in volume per stroke, while still achieving a complete or nearly complete expulsion of all gases in the cylinder for every stroke is illustrated in Figures 5, 6 and 7. This is one of several designs which may be utilized in accordance with the present invention. This and other designs are shown in my co-pending application aforesaid. As shown in Figures 5, 6 and 7, the cylinders **10** and **11** together with the piston rod **16**, and the pistons **12** and **13**, carried thereby, are mounted for translatory motion along a path which is parallel to the uppermost position of the bell crank arms **24**. When the bell crank arms **24** are in their raised position, as determined by the extreme position **38C** of the cam **38**, as shown in Figures 5 and 6, the arm **24**, is accordingly raised to its maximum elevated position. The term elevated is used here because in the commercial form of the apparatus illustrated the cylinders **10** and **11** are mounted above the cam **38**, but it will be understood that the cylinders **10** and **11** may be mounted horizontally with reference to the cam **38** if desired, or in any other convenient designed position. At any rate, when the lever arm **24** of the bell crank **20** is in its extreme operated position as shown in Figures 5 and 6, the piston rod **16** has been pushed as far as it will ever go due to operation of the cam **38**. At each side of the cylinder there is a mounting bracket **160** upon which there is mounted a nut **161** internally threaded to receive the screw threads **162** on the rod **163**. The nut **161** and the rod **163** have an axial arrangement which is parallel to the extreme position to which the lever arm **24** is actuated by the cam **38**. There are two such rods **163** as shown in Figure 7 and a nut **161** is provided at each side of the cylinders **10—11**. Accordingly, when the two threaded rods **163** are rotated in unison, the nuts **161** will be moved along the rods and since each of the nuts **161** are fixedly attached to its mounting plate **160** by means of the capscrews **164**, the entire arrangement of cylinders **10** and **11** are associated parts which are a unitary structure, will be moved along as by a transitory motion, that is to say it will be moved parallel to any position in which it is situated, the axis of the piston rod **16** being always parallel to its first position regardless of where it is positioned along the rods **163**. By movement of the cylinder arrangement from the position shown in Figure 5, which is a position in which the cylinders deliver a low volume of respiratory air, to the position shown in Figure 6, in which the cylinders deliver a large amount of respiratory air per stroke, it is thus possible to vary at will the amount of respiratory air per stroke delivered by each cylinder.

Each of the rods **163** is suitably journaled in a ball-bearing journal **165—165** carried by the cross frame member **166** on the main frame posts **167**. At the opposite end the rods are similarly journaled at **168—168** in the cross frame member **169** carried by the frame posts **170—170**. At the upper ends of the two rods there are provided sprockets at **171—171** which are connected together by a roller chain which is also tracked over a drive pinion **172** on the shaft **173**, the shaft **173** being supported by a suitable journal not shown and equipped with a bevel gear **174** which mates with another bevel gear **175** on the manually rotatable shaft **176** equipped with the hand crank **177**. Accordingly, by rotating the crank **177**, the shaft **176** turns the chain sprocket **172** and rotates the two rods **163** in unison so as to move the pair of cylinders **10—11** to any adjusted position, for example, as shown in Figures 5 and 6. By this way, the patient or the attendant or physician may vary the volume per stroke of respiratory gas delivered to the patient.

In Figures 9 and 10, there is illustrated a modified form of the invention by means of which the normal respiratory stroke and the optional increased volume (sigh) cycle may be provided, according to the invention. In Figures 9 and 10, the pumping apparatus is identical with that previously described. Thus the cylinders **10** and **11** having the pistons **12** and **13** respectively in them operated on the piston rod **16** is oscillated by the bell crank mechanism **20** thru the action of the cam **38** on shaft **39**. The variable speed drive of shaft **50** via motor **54**, variable speed drive **51** is likewise identical. The shaft **50** is provided with a driving gear **200** which is normally in mesh with a driven gear **201** that is on shaft **39** and keyed at **202** to slide along the shaft thru movement of the manually operated yoke **203**. When the yoke **203** is moved to the right as shown in Figure 9 the gear **201** may be moved along the shaft **39** until it slides out of engagement with gear **200** and into engagement with gear **204** which is on the shaft **205** and provided with a hand crank **206**. The two shafts **205** and **50** are axially aligned but are unconnected. In the event of power failure, it is only necessary to move the yoke **203** for shifting the gear **201** into engagement with gear **204** and then by turning the crank **206** the apparatus may be kept in motion manually until the power is again available. This same type of manual drive may be used in the principal form of the invention initially described. The intake respiratory air supply to the apparatus at **86** via valve **85**, or from the bottle supply **90** via regulator **80** junction **88** and line **87** is likewise identical with that shown in Figures 2, 3 and 4. Similarly, the patient P is supplied thru a tracheotomy tube facial mask or other positive pressure connection to the patient by the two lines **58** and **59** which are connected to the patient's mask or tube closely adjacent the mask or tube.

The balance of the apparatus is somewhat different than that shown in Figures 2 and 3. Thus, there is provided a normally operating oscillatory valve generally designated **210** having an upper section **211** which is a two-way valve section and a lower portion **212** which is an on-off valve section. The valve **201** is provided with the valve discs **213**, **214** and **215** all upon the stem

216, so as to be movable with it. A spring 218 in the upper end of the casing of valve 210 normally presses down upon the upper valve disc 215 and causes it to move downwardly, thereby holding all of the valve discs in the full line position shown in Figure 9 and also holding the lower end 216A of the valve stem in riding contact with the edge 220A of the cam 220. The cam 220 is provided with one lobe of appropriate shape as shown and as it is rotated by the shaft 39 the stem 216 is moved up and down from the full to the dotted line position as shown in Figure 9. In the full line position there is a connection from the port 14 of cylinder 12 thence via junction 221, line 222, to port 223 on valve 210. Thence the air connection is open thru the space between the valve discs 214 and 215 to the port 224 and thence thru line 225 junction 226 and line 227 junction 228 and line 229 to valve 85. It will readily be observed that when the valve disc 214 is moved upwardly to the dotted line position, it will be close off port 224 thereby preventing flow thru the line 225 and its connected lines. This movement, however, causes the valve disc 215 which has closed the port 230 to uncover that port, thereby opening line 231 which leads to port 232 of another valve which will be described. Accordingly, as the valve stem 216 of valve 210 is oscillated up and down by action of the cam 220, connection is made alternately from line 222 to one or the other of the lines 225 or 231. At the same time this up and down movement of the valve stem 216 carries the valve disc 213 from the full line position to the dotted line position. In the full line position there is an open connection from the patient exhaust line 58 to the port 234 of valve 210 and thence thru the space between the valve disc 214 and 215 and out thru port 235 and line 236 to junction 237 and thence to the exhaust at 238. Accordingly, as the valve stem 216 is moved up and down the exhaust line 58 is alternately opened and closed.

In addition to valve 210 there is provided a sigh control valve generally designated 240. It will be noted that on the end of the shaft 39 there is provided a gear 241 which meshes with a gear 242 of twice the size as 241. Accordingly the gear 242 is driven at one-half the speed of the shaft 39. Gear 242 is pinned or keyed to the shaft 244 and serves to actuate the cam 245. There is also an interlocking cam 246 keyed to the shaft 244 for preventing operation of the valve except at appropriate time periods. The cam 245 is arranged so that it operates against the lower end of the valve stem 248 of valve 240. The stem 248 carries on it three valve discs 249, 250 and 251. In addition the stem extends upwardly and at its upper end has a smaller collar 251 which is adapted to engage an aperture 252 in the lower end wall of a small tube 253 that is attached to the valve disc 254 on the upper stem 255. The upper stem 255 also carries the valve disc 256 and the stem 255 extends upwardly out of the upper end wall 258 of the casing of valve 240 and is provided at its upper end with a pin 259 connected by the link 260 to the pin 261 on a manually operable bell crank lever 262 mounted upon the machine frame 263. Within the valve chamber 240 there is a small collar 264 all around, slightly below the level of the collar 251 on the valve stem 248. This collar serves as a stop for two springs. The upper spring 265 being nested in that space within the casing of valve 240 and around the smaller tube 253. The spring 255 pushes against the underside of the valve disc 254 and is sufficient to elevate it and valve disc 256 to the full line position shown in Figure 10 when the mechanism otherwise permits this. Below the collar 264 in the valve casing 240 is another spring 266 which bears downwardly against the valve disc 251. The spring 266, however, is of lighter gauge and exerts less force than the spring 265. Accordingly, normally the spring 265 is the stronger and causes its valve discs 254 and 256 to be pushed upwardly, thereby elevating the stem 255. The small tube 253 with the inturned flange 252 is attached to the disc 254, the flange of this small tube engages the collar 251 of the lower stem 248 and also elevates the lower stem and the valve discs 249—251 thereon. Therefore, normally, the two valve stems 255 and 248 as well as all of the valve discs are in the elevated or dotted line position and the bell crank 262 is likewise in such dotted line position. When the patient wants to impose the sigh cycle on his rate of breathing, or when the attendant does this for the patient, it is only necessary to push the bell crank 262 to the right as shown by the arrow in Figures 9 and 10 and this causes the stem 255 to be lowered carrying with it its valve discs 254 and 256. The valve stem 248 is also lowered at this time but its position will be determined by contact of the valve stem with the edge of the cam 245.

The lowering action of the valve stems as just mentioned can be accomplished only at certain prescribed times in the cycle. This is brought about by an interlocking composed of a side arm 270 on the upper valve stem 255 which has a downwardly extending rod 271 attached to it. The rod extends thru holes in the bracket 272—273 on the valve casing 240 and the lower end of the rod has a hook at 271A which is adapted to extend into the path of a partial circumferential cam edge 246A on the cam 246. The cam edge 271A is of a length and is positioned so as to prevent operation of the sigh control valve except at appropriate periods. When the valve is in the normal or up position, the hook end 271 is outside of the diameter of the cam edge 246A and when that cam is in the way the hook end 271 cannot be lowered, thereby preventing the downward pushing action of the valve 240 under influence of the bell crank 262. As the mechanism is operating in its normal cycling action the cam edge 246A will be brought periodically to a position where it will prevent the hook end 271A (and rod 27 and the valve mechanism) from being operated. If during such a period the bell crank 262 is operated this will cause the hook end 271 to move down where it will engage the outer edge of cam 246A where the hook end will be held. When the trailing edge 246B of the cam 246 rides out from the position where it has been holding the hook end 271A from downward movement the continued downward pressure of the hook 271A on the rod 271, and its interlock with the upper valve stem 255 will permit that valve stem to be moved downwardly by the patient, thereby permitting the lower stem 248 also to go down when the cam 254 appropriately permits this.

The piping connections are as follows: From the port 15 of cylinder 11 a line extends at 280 to port 281 in the valve casing 240. From this port communication is established to either of the ports 282 or 283 depending upon the position of the valve discs 254 and 256. In the position shown in Figures 9 and 10 the communication is established thru port 282 to the line 284 and thence to junction 221 on line 222. When the valve discs 254—256 are in the dotted line position (which is the normal cycle position) communication is established between the port 281 on line 280 to the port 283 and port 282 is then closed. From port 283 a line 285 extends to the junction 282 on the line 229. In the lower part of the valve 240 there is provided a port 286 which is adapted to be opened and closed by the valve disc 249, it being shown open in Figures 9 and 10. From port 286 a line extends at 287 to junction 233 on the exhaust line. Communication is accordingly established from the junction 288 on the patient exhaust line 58 thru the line 289 and thence thru port 290, thence thru the space between valve discs 249 and 250 of valve 240, thence thru port 286 and line 287 to the exhaust, whenever the valve 240 is in the figure position shown in Figure 9. In the side wall of the valve casing 240 there is also

provided a port 291 which is connected thru line 292 to the junction 226 on the line 225. This port 291 is adapted to be opened and closed by movement of the valve disc 250 when the latter is in the upper position. In the dotted line position it closes the port 291 and when in the lowered position it opens that port. In the position shown in Figure 9 communication is established between the ports 232 and 291 but flow does not ensue until the valve 210 is moved to the appropriate position as shown in Figure 10. Meanwhile the disc 251 has closed the port 294 which is connected thru line 295 junction 296 thence thru the flow indicator 297 to the patient supply line 59. A pressure gauge is provided at 300 and is connected to the patient supply line at 301. To the junction 296 there is connected the overpressure relief valve 302 which is connected precisely as described with reference to Figures 2, 3 and 4.

During the normal respiratory cycle the valve 240 is in the elevated dotted line position as shown in Figures 9 and 10, due to the action of spring 256, as previously described. This serves to establish communication between the ports 281 and 283 but the valve disc 254 closes the port 282. The valve disc 251 at this time does not close the port 294 and a pathway is open for the free flow of respiratory gas from valve 210 thru line 231 thence thru port 232 in the valve 240 thence thru the space between the valve discs 250 and 251 thru port 294 and thence thru lines 295 and 301 to the patient supply line 59. Whether or not flow continues thru this line depends upon the upward and downward motion of the valve 210 which is moved up and down at the normal respiratory rate by the action of the cam 220. At the same time in this normal cycle the exhaust line of the patient is opened from 58 thru junction 289 port 234 and valve 210 thence thru the space between the discs 213 and 214 thru line 236 and junction 237 to the exhaust 238. Accordingly, the valve 240 during the normal respiratory cycle provides pathways thru which the respiratory gas is communicated to the patient during the inspiration stroke (via line 231, port 232, port 294, line 295 etc.) and whereby the exhaust gas from the patient is permitted to be bypassed to the exhaust. Therefore, during the normal cycle the valve 240 remains in an elevated position and the inspiration and expiration portions of the cycle are controlled entirely by the rhythmic operation of the valve 210 at the normal respiratory rate, as established by the operation of the cam 220. During the increased volume cycle (sigh cycle) the valve 240 comes into operation. Figure 9 shows the portion of the increased volume cycle wherein air is being drawn from the supply into both of the cylinders 10 and 11 and exhaust gas from the patient is being conducted via line 58 ports 234 and 235 of valve 210 to the exhaust. Figure 9 shows the first portion of the exhaust. Figure 10 shows how the valves operate to prolong the exhaust part of the cycle as after a large volume intake sigh has occurred.

Figure 1 illustrates in isometric view an exemplary form of cabinet in which the apparatus of the present invention may be housed for convenient use. All of the controls and accouterments, save only the hand crank and the connection nipples for the patient supply line 58 and patient exhaust line 59, are mounted on the top cover of the cabinet. Thus, across the rear portion of the top cover, there are provided the flow indicator 63 for indicating the normal flow of respirator gas to the patient, and in the opposite corner there is provided the flow indicator 99, which shows the flow thru the over pressure release valve 101. For easiest reading the indicator ball in the flow indicator 99 is usually made red while that in indicator 63 is usually made green. In normal use the green ball rises each time the patient breathes in (inspiration); the red ball rises only in the event the pop-off valve actuates. A nipple 84A is provided for connection of line 84 to the inlet supply. A pressure gauge 300 is mounted midway between the indicators. A simple on-off switch for controlling the supply to the electric motor is shown at 320. The hand crank 177, Figure 1, has geared to it a mechanical indicator 321 which therefore indicates the "volume" of stroke. Similarly, the mechanical control 52, Figuress 2 and 9, by which the rate of rotation of the variable speed drive 51 is controlled, likewise has a mechanical indicator connected to it and is exhibited at 322 on the face of the cabinet, thereby showing the operator the number of strokes per minute for which the machine is set. The crank 177, by which the position of the cylinders is adjusted for varying the volume per stroke, is placed adjacent the volume indicator 321. Similarly, the crank 52, for varying the number of strokes per minute, is placed adjacent the indicator 322. The over pressure release or (pop-off valve, however designated), 101 is likewise provided with a crank 324 connected to the indicator 325 on the face of the cabinet for adjusting and indicating the setting of that valve. For shifting from power to manual drive, as illustrated for Figure 9, there is provided a shifting lever 326 which is connected to the shifting fork 203, Figure 9. A similar arrangement may be provided for Figures 2, 3 and 4 if desired and is frequently included. The manual crank 206 is placed at the side of the cabinet and at the side of the cabinet there are also provided the nipple 58A for connection to the patient exhaust line and the nipple 59A for connection to the patient supply line. At the top of the cabinet is provided a manual lever control 112 (of Figure 3 or 252 of Figure 9) which actuates the sigh control valve. The cabinet is preferably mounted on caster wheels 330—330 so that it may be moved even by the patient, or the attendant and the machine is, of course, provided with a long electric power cord so as to facilitate its easy portability within the limits of the cord.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that I do not limit myself to the specific embodiments herein.

What I claim is:

1. A respiratory system comprising a respirator gas supply line, a first cylinder and a second cylinder each having a port and each having a piston therein, means for operating the pistons in said cylinders simultaneously for simultaneously drawing in and expelling gas thru the ports of the first and second cylinders, a patient supply line for conducting respirator gas to the patient and a patient exhaust line for exhausting gas from the patient, a multiple chamber valve and manual valve having a manual actuation for moving said manual valve to first and second positions, said multiple chamber valve and manual valve being connected to each other and to the cylinder ports and to the patient supply and exhaust lines, a mechanical drive connected to the pistons for positively actuating them in their cylinders, and first and second cam means connected to the mechanical drive so as to be actuated thereby and positioned so that the first or second cam means may actuate the multiple chamber valve, said cam means being connected to said manual actuator so as to be traversable when the actuator is moved to first and second positions such that the first cam means actuates said multiple chamber valve when the manual actuator is moved to place said manual valve in its first position and the second cam means actuates said multiple chamber valve when the actuator is moved to place said manual valve in its second position.

2. The apparatus of claim 1 further characterized in that the second cylinder has a substantially lesser volume than the first cylinder.

3. The apparatus of claim 1 further characterized in that said cam means has an even number of cam lobes such that when it is operated by the mechanical drive, the multiple chamber valve will be actuated to one position as the pistons move in their cylinders to force gas

from the cylinder ports and will actuate the multiple chamber valve to another position when the mechanical drive actuates the pistons to draw gas into the cylinder ports, and the second cam means has half as many cam lobes.

4. A respirator of the positive pressure type for normal and sigh breathing cycles comprising a gas delivery line and and exhaust line, each of said lines being adapted to be connected in substantially pressure tight relation to and at the respiratory tract of the patient, a drive, a first stroke pump, a second stroke pump, each of said pumps having a delivery port and each being connected to said drive so as to be reciprocable alternately thru simultaneous delivery and intake strokes, a multiple valve having first and second sections each movable alternately and in unison to inspiration and expiration valving positions, a two-way valve movable to normal and sigh positions, a manual control for shifting said two-way valve to either of said positions alternately, cam means for operating said multiple section valve connected to the drive so as to be operated when the pumps are operated, said cam means being shiftable and connected to said manual control so as to be moved thereby to a cam position for normal respiration and another cam position for sigh respiration, said first cylinder being connected thru the first section of said multiple section valve to the patient supply line and the patient exhaust line closed thru said second section when said multiple section valve is in its inspiration position, said patient supply line being closed and said first cylinder connected thru the first section to a source of respiration gas and the patient exhaust line opened thru said second section when said multiple section valve is in its expiration position, said second cylinder being constantly connected thru said two-way valve to a source of respirator gas when said two-way valve is in its normal position and connected to said first cylinder port so as to operate in unison therewith when said two-way valve is in its sigh position, said cam means when shifted to normal respiration position being operable to move said multiple section valve cyclically to its inspiration and expiration positions for each corresponding inspiration and expiration stroke of said pumps and operable in its sigh position to move said multiple section valve thru every second cycle of inspiration and expiration positions when and leave said multiple section valve in its expiration position during the intervening cycles.

5. The apparatus of claim 4 further characterized in that said second pump has a volumetric capacity in the range of 20% to 100% of the capacity of said first pump.

6. The apparatus of claim 4 further characterized in that each of said pumps is connected thru a manually adjustable linkage to said drive for varying the volumetric displacement of said pumps.

7. The apparatus of claim 6 further characterized in that said pumps and linkages are constructed so that each pump is moved to substantially complete volumetric delivery for each stroke.

8. The apparatus of claim 4 further characterized in that said patient supply line is provided with indicator for showing the movement of gas therethru and with an over-pressure relief valve.

9. The apparatus of claim 4 further characterized in that an interlock is provided and connected to said cam means for holding it against shifting by means of said manual control to said sigh cycle position except at the end of a normal expiration and to hold it from returning to normal cycle position except at the end of an intervening cycle.

10. The apparatus of claim 4 further characterized in that said cam means includes a first cam track having one cam lobe situated to operate said multiple valve thru one complete cycles for each complete cycle of operation of said pump in the normal respiration position and a second cam track having half as many cam lobes as said first cam track and situated to operate said multiple valve in the sigh respiration position.

11. A cyclically operable respirator comprising a plurality of cylinders each having an inlet-outlet port and pistons, means for operating the pistons in the cylinders for simultaneously drawing gas into the cylinders and simultaneously expelling gas therefrom, power means for operating the pistons cyclically, valve means for controlling inspiration and expiration during the respiration, said valve means being connected to the power means for operation cyclically thereby to a position to permit inspiration and to a position to permit expiration and at a normal respiration cyclic rate synchronized with the operation of the pistons in said cylinders or alternatively at a slower rate as during a sigh breathing position and in which during every other cycle of operation said valve means is permitted to remain in a position to allow expiration, a patient delivery line and patient exhaust line each adapted to be connected in positive relation to and at the patient, said valve means being connected to said lines and to said cylinders, a manual control having a normal respiration position and a sigh respiration position, said manual control being connected to the valve means for moving it to a normal breathing position such that only one cylinder delivers respiration gas to the patient during every cycle of operation and the patient is then permitted to expire said gas, or to a sigh breathing position in which both cylinders deliver respiration gas simultaneously to the patient during every other cycle of operation and the patient is permitted to expire said gas over a prolonged period including the intervening cycle.

12. The apparatus of claim 11 further characterized in that the valve means includes two cyclically operated valves including a normal control therefor, one valve being operated at a rate corresponding to the normal breathing cycle and the other operated at one-half of said rate.

No references cited.