

Dec. 7, 1965

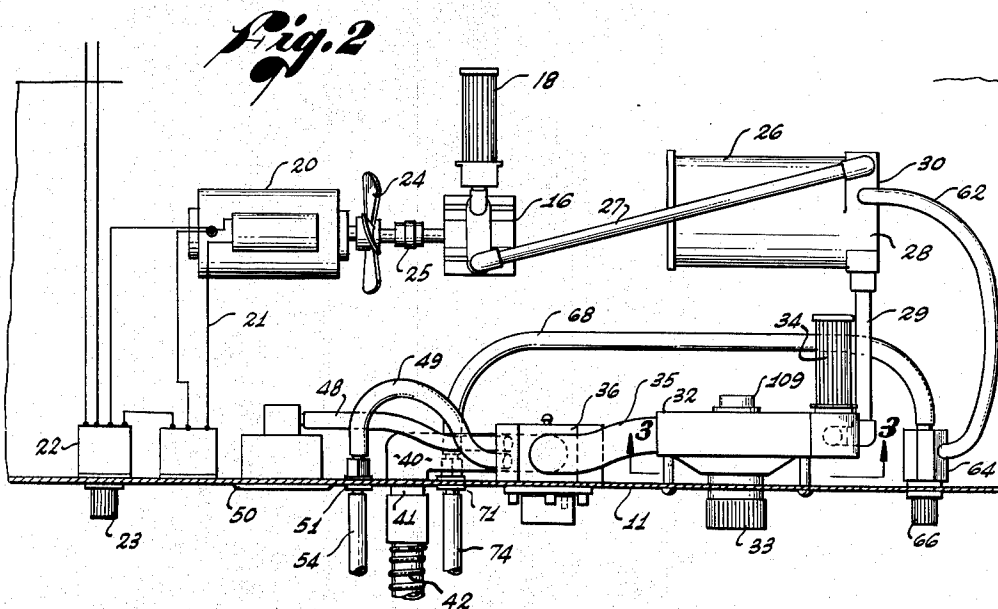
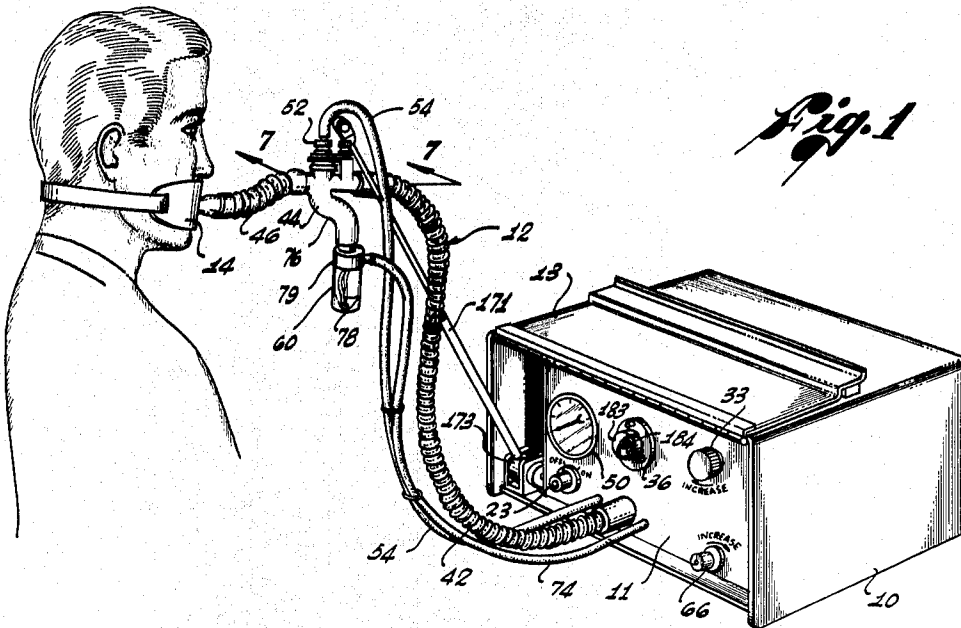
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3,221,733

PRESSURE BREATHING THERAPY UNIT

Filed Oct. 2, 1961

2 Sheets-Sheet 1



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PRESSURE BREATHING THERAPY UNIT

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2 Sheets-Sheet 2

Fig. 3

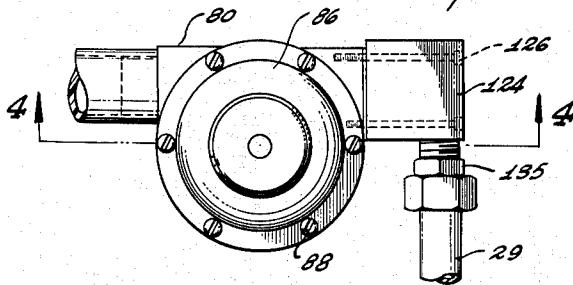


Fig. 4

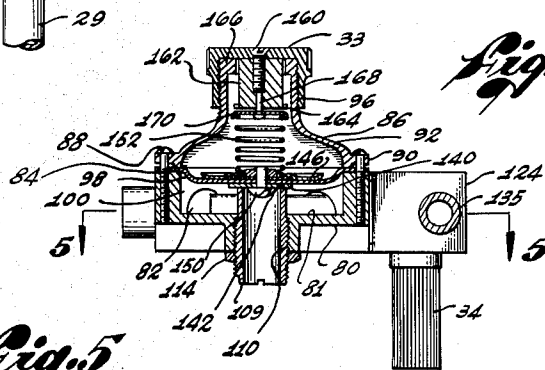


Fig. 5

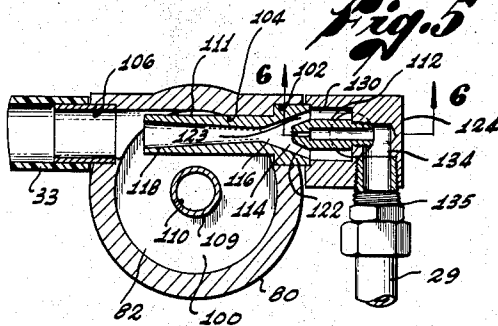


Fig. 6

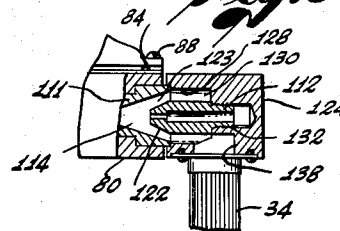
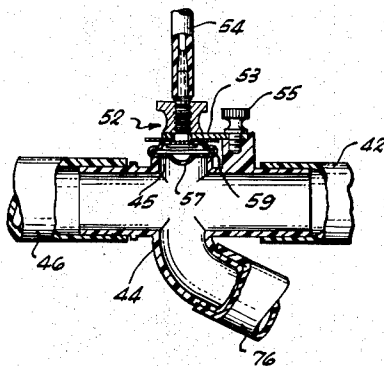


Fig. 7



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3,221,733

PRESSURE BREATHING THERAPY UNIT

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13 Claims. (Cl. 128-29)

This invention relates to respiration apparatus, and more particularly to a portable intermittent positive pressure breathing unit.

Intermittent positive pressure breathing, commonly known as IPPB, denotes a type of induced respiration or assisted breathing. IPPB is widely used as an effective means of relieving and treating various respiratory disorders, having proven to be a valuable method of therapy in cases where dyspnea, inadequate ventilation, or chronic loss of pulmonary function are present. Ideally, IPPB involves inflation of the lungs during inspiration under a mild pressure of 10 to 30 cm. of water (gauge pressure). This followed by a passive phase in which the pressure is rapidly released, preferably to ambient pressure. By virtue of the elasticity of the lung-thorax system, the lungs automatically contract to achieve expiration when the pressure is released. Optionally, vaporized or nebulized medication or water are added to the delivered gas which, depending upon the condition being treated, is usually room air or room air enriched with oxygen.

IPPB therapy of the type of present concern is that which is prescribed for patients who control the rate and rhythm of their own breathing, but require treatment at periodic intervals. Presently used units for administering this therapeutic treatment are of two basic types. One type uses pressurized gas, such as oxygen, stored in a tank or bottle as the power source, whereas the other type unit uses compressed room air. By compressed room air, it is meant ambient air compressed by the unit itself, rather than that stored in a bottle or tank under pressure.

There are certain operational volumetric flow and pressure requirements of units of both basic types. One such requirement is that gas under a pressure in excess of 400 cm. of water be furnished to operate the nebulizer. On the other hand, as suggested above, the maximum pressure requirement of a patient is approximately 30 cm. of water. This maximum pressure occurs when the lungs are filled at the end of inspiration. Relative to volumetric flow requirements, an average patient has a peak flow requirement of approximately 80 liters per minute. The peak flow occurs at the beginning of inspiration with the patient's flow requirement dropping off rapidly toward the end of inspiration and, of course, being zero during expiration. As contrasted to this relatively large peak flow requirement of the patient, approximately 5 liters per minute of gas under relatively high pressure (in excess of 400 cm. of water) is required to effectively operate the nebulizer.

Meeting these flow and pressure requirements presents no serious problem in the case of oxygen powered units. The oxygen is stored within its bottle under ample pressure to effectively operate the nebulizer. Moreover, the pressure of the delivered mixture may be reduced and the volume correspondingly increased by known regulation equipment to meet the patient's demands.

A somewhat more difficult problem is posed in the case of units powered by compressed room air. The required volumetric flows and pressures have heretofore been developed in the latter type of unit by various means. One means is to provide a relatively low-volume and high-pressure air pump for operating the nebulizer and

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a separate blower for supplying the patient with the main volume of relatively low-pressure air. Another means is to provide a relatively large capacity air pump adapted to meet both the peak flow requirement (80 liters per minute) of the patient and also to develop the high pressure (400 cm. of water) to operate the nebulizer. This last mentioned means is undesirable from the patient's standpoint unless further equipment is incorporated in the system. As is well known, compressing a gas, such as air, increase its temperature. Breathing this heated air is uncomfortable to the patient, as well as medically undesirable. Moreover, compression causes condensation of moisture in the air into water droplets, resulting in drying of the air and in the droplets collecting in the apparatus. Breathing dry air is also uncomfortable from the patient's standpoint and medically very undesirable. Thus, the delivered air is unsuitable for the patient, unless equipment is provided to both cool the air and to add moisture. In addition, the water droplets must be collected and removed in order to prevent damage to the apparatus.

It will be appreciated that both units powered by bottled oxygen and those powered by compressed room air are inherently large and bulky. As a consequence, neither type is adapted to be transported from place to place. The oxygen powered units are cumbersome by reason of a large oxygen bottle necessarily accompanying the regulation equipment, if the unit is to be used for more than a very short period of time. Furthermore, oxygen bottles should not be moved without proper handling equipment for safety reasons. Similarly, units powered by compressed room air are relatively immovable, since they embody either a pump and blower, or a relatively large pump, as well as other necessary control and filtering equipment. Accordingly, patients who must frequently use IPPB units are not able to travel unless great effort is expended in moving the cumbersome, presently available equipment.

In view of the foregoing, it is an object of this invention to provide an improved IPPB unit which obviates the above discussed problems of the prior art.

A further object is to provide an improved IPPB unit which is highly portable.

It is another object of this invention to provide an improved IPPB unit of the type powered by compressed room air, the air for powering the unit being furnished by the relatively small, high-pressure and low-volume air pump.

Still another object is to provide an IPPB unit embodying selectively operable means for adding nebulize medication or water to the delivered gas.

It is a still further object to provide an improved IPPB unit which is highly effective in accomplishing its intended purpose, yet which is easily operable, compact in size, and light in weight.

Another object of this invention is to provide a portable IPPB unit adapted to be readily assembled for use and to be disassembled for convenient transportation.

It is a still further object of this invention to provide a unit of the type described embodying optional means for enriching the delivered air with oxygen.

A further object is to provide a flow and pressure regulator for use in an IPPB system of the type described for aspirating ambient air with the system, and for adjustably establishing the maximum inspiration pressure, and for maintaining a constant load on the pump.

It is still another object to provide an IPPB unit of the type powered by compressed room air in which the temperature and moisture content of the delivered air is essentially the same as the room air.

A final object of this invention is to provide an im-

proved IPPB unit of the type described, adapted to be used as a manually or automatically operated resuscitator.

These and other objects and advantages of the invention will be better understood by referring to the following detailed description, reference being made to the accompanying drawings in which:

FIGURE 1 is a perspective view of the unit of the invention with a patient being shown receiving treatment;

FIGURE 2 is a semi-schematic plan view of a portion of the unit housed within the case shown in FIGURE 1, certain parts being partially or completely removed or rearranged to show underlying parts more clearly;

FIGURE 3 is a front elevational view on an enlarged scale of the regulator and portions of the connecting conduits of the unit, taken in the direction of the arrows 3—3 in FIGURE 2;

FIGURE 4 is a sectional view of the regulator taken on the line 4—4 of FIGURE 3 with the connecting conduit portions shown in the latter figure removed;

FIGURE 5 is a sectional view taken on the line 5—5 of FIGURE 4 with the connecting conduit portions illustrated in the positions occupied, as in FIGURE 3;

FIGURE 6 is a partial section taken on the line 6—6 of FIGURE 5; and

FIGURE 7 is a sectional view of the manifold assembly and the exhalation valve of the unit, taken on the line 7—7 of FIGURE 1.

Referring to the drawings, and in particular to FIGURE 1, the respiration unit of the invention may be seen to comprise generally a case 10 with a front control panel 11 housing regulation and control equipment, and delivery means 12 including a suitable face mask 14 for supplying the compressed air and, optionally, nebulized medication or water to the patient.

As suggested above in the discussion of the objects, the present invention resides in certain specific elements of the overall system and in the combination of those specific elements with a limited number of others. In order to facilitate understanding the invention, a brief description is first given of the entire system and its mode of operation.

Mounted within the case 10 is a pump 16 for drawing or aspirating room air into the system through a filter 18 and compressing it. The pump is powered by the motor 20 which, in turn, is energized by an electric circuit 21 including a switch 22. Preferably, the motor 20 and pump 16 are cooled by means of a fan 24. The motor 20 and pump 16 are operatively connected by a flexible coupling 25 adapted to accommodate a moderate degree of relative angular rotation.

From the pump 16, the compressed air flows to a filter 26 through a conduit 27, circulates through the filter, and passes out through a flow divider 28. The filter inlet and outlet and the flow divider 28 are all incorporated in a manifold assembly 30 mounted on the end of the filter 26.

The greater portion of the compressed and filtered air passes from the flow divider 28 through a conduit 29 to a flow and pressure regulator 32. Briefly, the purpose of the regulator 32 is threefold. It is to aspirate ambient air into the system so as to meet the patient's flow requirement; to adjustably establish the maximum inspiration pressure applied to the patient; and to maintain a constant load on the pump 16. Adjustment of the regulator to vary the maximum inspiration pressure is achieved by rotating the knob or cap 33 on the control panel 11. To insure that the air supply to the patient is free of dust and the like, a filter 34 is provided on the regulator 32 to filter the air there being aspirated into the system.

In series with the regulator 32 downstream of the latter is a control valve 36, the two members being connected by conduit 35. Preferably, the valve 36 is of the type disclosed in Patent No. 2,483,722 to Vivian

Ray Bennett. In general, the valve 36 functions to control flow to the patient in accordance with his requirements. At the start of inspiration, the valve is actuated to deliver compressed air to the patient. When the predetermined maximum inspiration pressure is reached, the valve closes and permits the patient to expire. The operating characteristics of the valve 36 are such that, within the normal range of operating pressures (10 to 30 cm. of water), the valve 36 has a peak flow capacity of approximately 90 liters per minute. The minimum flow is approximately 4 liters per minute.

Flow from the control valve 36 (during inspiration) is to the patient. Such flow takes place through an L-shaped conduit 40 having a coupling portion 41 projecting exteriorly of the front panel 11 of the case and then through a main hose 42 detachably connected to the coupling portion of the conduit 40. Continuing, primary flow is from the hose 42 through a manifold assembly 44 and a flexible hose 46 to the face mask 14.

Another outlet conduit 48 from the valve 36 is coupled to a pressure gauge 50 mounted on the front panel 11 of the case 10 with its indicating face visible from the exterior, as illustrated in FIGURE 1. The gauge 50 is arranged to register mask pressure or the inspiration pressure applied to the patient's lungs. By viewing the gauge 50 and manipulating the regulator knob 33, it is possible to adjust the maximum inspiration pressure to any desired level within the range of 10 to 30 cm. of water.

A third outlet of the valve 36 is connected to an exhalation valve 52 mounted on the manifold assembly 44. Connection is by a conduit 49 that joins a coupling 51 in the front panel 11 and thence by a flexible tube 54 to the valve 52. Referring to FIGURE 7, the exhalation valve is carried by a bracket assembly 53 which, in turn, is removably secured to the manifold assembly by a thumb screw 55. The valve 52 embodies a diaphragm 57 that functions, during inspiration of the patient and under the influence of pressure supplied by the control valve 36 through tube 54, to close a relief passage 45 in the manifold assembly 44. The diaphragm is forced downwardly by compressed air onto a seat 59 on the manifold assembly 44 to close the passage 45. During expiration, the pressure in the tube 54 is released and the diaphragm is moved off its seat 59 to permit the patient to expire to the atmosphere through the passage 45.

Going back in the system to the flow divider 28, the remainder of flow from the pump 16 is directed by the divider to a nebulizer 60 mounted on the manifold assembly 44. Flow takes place from the flow divider 28 through a conduit 62 to a valve 64 which may conveniently comprise a needle valve. The valve 64 is adjusted by rotating its knob 66 on the panel 11 to control the operation of the nebulizer 60, flow being variable between a predetermined maximum and minimum. Some flow through valve 64 in the nebulizer circuit is always desired in order that surges of back pressure are not applied to the pump 16, as valve 64 is adjusted.

Proceeding from the valve 64, a conduit 68 extends from valve 64 to a coupling 71 mounted in the front wall of the case 10. When the system is assembled for use, a flexible tube 74 has one of its ends connected to the coupling 71 and the other to the nebulizer inlet. As shown in FIGURE 1, the nebulizer outlet is connected to the manifold assembly 44 and maintained in assembly therewith by means of a short length of tubing 76.

The relatively high pressure air from the pump 16 delivered to the nebulizer 60 through the above described path, operates the nebulizer in a manner well known in the art. In such operation, the liquid medication or water stored in the container or vial 78 of the nebulizer is vaporized or nebulized and added to the main volume of air flowing (during inspiration) from the valve 36 to the face mask 14. Addition of the nebulized medication or

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water to the main stream of compressed air takes place in the manifold assembly 44.

With the construction and arrangement and the general operative relation of the various elements of the overall system in mind, attention is now directed to certain specific elements of the combination and, in particular, to the pump 16 and regulator 32.

The pump 16 is of the oil-free type for health reasons. Preferably, it has a flow capacity of approximately 20 liters per minute at an output pressure of approximately 450 cm. of water. Compression of the air to a pressure just slightly greater than the minimum required to operate the nebulizer is desirable, so as to minimize the resulting heating and drying of the air and the formation of water droplets in the apparatus.

A pump having the specified rating may be readily purchased on the market, which pump is both extremely small in size and light in weight. It will be appreciated that such a small and light-weight pump is highly desirable in the present application where portability is a major factor.

It will be recalled that the peak flow requirement of a patient is approximately 80 liters per minute occurring near the beginning of inspiration and the maximum pressure requirement is in the range of 10 to 30 cm. of water occurring at the termination of inspiration. It will also be recalled that a volumetric flow of approximately 5 liters per minute at a pressure in excess of 400 cm. of water is required to effectively operate a nebulizer. Comparing the patient and nebulizer, flow and pressure requirements with the rating of the pump, the following conclusions may be reached. First, the flow and pressure output of the pump 16 are ample to operate the nebulizer 60. In contrast, the volumetric flow of the pump 16 is insufficient to meet the peak flow requirement of the patient, whereas the pressure output of the pump is well above even the maximum inspiration pressure requirement of the patient.

Since the pressure output of the pump 16 is ample to effectively operate the nebulizer 60, the flow divider 28 and needle valve 64 are arranged to direct between 2 and 5 liters per minute of the relatively high pressure air (450 cm. of water) directly to the nebulizer. The exact flow rate depends, of course, upon the adjustment of the valve 64, accomplished by means of the knob 66.

The main portion of flow from the pump 16, i.e. between 15 and 18 liters per minute, is routed by the flow divider 28 to the regulator 32. As briefly described above, one function of the regulator 32 is to aspirate ambient air into the system to furnish the balance required to meet the patient's demands. Since the peak flow requirement of the patient is approximately 80 liters per minute, while approximately 15 to 18 liters per minute flows to the regulator, room air must be, at least momentarily, aspirated into the system in the ratio of approximately 4 to 1.

Another function of the regulator 32 is to adjustably establish the maximum inspiration pressure applied to the patient. At peak flow, when room air is being aspirated into the system at a ratio of approximately 4 to 1, sufficient reduction is taking place coincidentally with the increase in flow. However, as flow drops off toward the end of inspiration and little or no ambient room air is being aspirated into the system, a reduction in pressure from the pump output pressure of approximately 450 cm. of water to the maximum inspiration pressure of 10 to 30 cm. of water is necessary.

A third and final function of the regulator 32, which function is related to that discussed immediately above, is to maintain a substantially constant load on the pump 16. Considerable regulation is required to achieve this end as the flow in the system varies from a maximum of 80 liters per minute during inspiration to a minimum of between 2 to 5 liters per minute during expiration.

The regulator 32 comprises a body 80 shaped to pro-

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vide a cylindrical groove 82 centrally thereof, the groove 82 having a diameter which is large with respect to its length. The annular end face of the body 80 adjacent the mouth of the groove 82 affords a seating shoulder 84.

Attached to the body 80 directly opposite the groove 82 is a hollow cover or bonnet 86, attachment being accomplished by means of a series of angularly spaced screws 88. As shown in FIGURE 4, the bonnet has an annular mounting flange 90 at one end positioned adjacent the seating shoulder 84 of the body 80 which is bored to receive the mounting screws 88. Extending from the mounting flange away from the body 80 is an inwardly tapering central section 92 which, in turn, merges with a necked down opposite end portion 96.

Interposed between the seating shoulder 84 and the mounting flange 90 is a flexible diaphragm 98. Referring to FIGURE 4, the diaphragm 98 cooperates with the walls of that groove 82 to provide a cylindrical pressure chamber 100. The diaphragm 98 is mounted so as to be capable of limited movement with respect to the body 80 toward and away from the opposite end wall 81 thereof.

Inlet passage to the pressure chamber 100 is through an outer bore 102 and a coaxial inner bore 104 of reduced diameter, as illustrated in FIGURE 5. Similarly, outlet passage from the chamber 100 is provided by a bore 106 in the body which, in the illustrative embodiment is coaxial with the inlet bores 102 and 104. A bleed or pressure-relief passage from the chamber 100 is afforded by means of a sleeve 109 having one end positioned within the chamber adjacent the diaphragm 98 and the opposite end exteriorly of the body. The sleeve 109 is externally threaded and received within a correspondingly threaded bore 110 that extends through a mounting flange 114 and the end wall 81.

The means for aspirating room air in the system includes a venturi tube 111 and a corresponding nozzle 112. The venturi tube 111 is externally shaped so as to be received snugly within the bore 102 in the body. As illustrated in FIGURE 5, the venturi includes an inwardly flared inlet portion 114, a throat portion 116, and an outwardly flared outlet portion 118. The venturi is positioned so that it discharges in the chamber 100 adjacent the outlet bore 106.

Compressed air from the pump 16 is jetted into the venturi tube 111 through the nozzle 112, this relatively high pressure air being supplied by the conduit 29. As shown, the nozzle 112 is positioned with its tapered nose portion 122 within the inlet portion 114 of the venturi and spaced radially inwardly of the wall thereof, thereby providing an annular passage 123. The nozzle 112 is mounted in this position by means of a head 124 which, in turn, is secured to the body 80 by screws 126. The head 124 has a forward bore 128 for receiving the nozzle 112 with the periphery of the latter annularly spaced radially inwardly of the wall of the bore to provide an annular passage 130 communicating with the passage 123. Joining the bore 128 and extending rearwardly in the head 124 is a coaxial bore 132 having an internally threaded portion for the reception of a correspondingly threaded portion of the nozzle 112. Communicating with the bore 132 and extending radially outwardly therefrom is a bore 134 (FIGURE 5), which serves to complete the air passage from the conduit 29 to the nozzle 112. As shown, connection of the conduit 29 to the head 124 is by a threaded coupling 135.

Flow of the ambient or aspirated air to the venturi tube 111 is through the filter 34 (FIGURE 6) and thence through a bore 138 which communicates with the annular passage 130. As illustrated in FIGURES 5 and 6 and as described above, a flow path is provided through the bore 138 and the communicating annular passages 123 and 130 to the inlet portion 114 of the venturi tube 111.

In operation of the regulator 32, relatively high pressure (450 cm. of water) air from the pump 16 is jetted by the nozzle 112 into the venturi tube 111. The result

is that a suction is created in the inlet portion 114 and ambient air is aspirated or drawn into the pressure chamber 100 of the system through the above described path. The nozzle 112 and venturi tube 111 operate so that when pressure in the chamber 100 is a minimum, the ratio of ambient air aspirated into the system to compressed air jetted by the nozzle is approximately 4 to 1. As the pressure within the chamber 100 increases toward the end of inspiration, the resistance to flow through the venturi tube 111 correspondingly increases and the ratio of aspirated air to jetted air decreases.

By virtue of the venturi tube 111 having its outlet portion 118 positioned within the chamber 100, discharge from the venturi takes place into a comparatively large space. The effect of this is that the chamber 100 functions to stabilize the pressure within the system and thereby insure an optimum flow pattern to the patient.

Regulation of the pressure within the chamber 100 to insure that it does not exceed a predetermined maximum is achieved by yieldably closing the bleed passage through the sleeve 109. Closing is by spring biasing a sealing disk 140 carried by the diaphragm 98 against the end face 142 of the sleeve 109. As illustrated in FIGURE 4, the sealing disk 140 is secured on one side of the diaphragm 98 and a spring retainer 146 is secured on the opposite side by a bolt 148 extending through diaphragm and a nut 150. Since the diaphragm 98 is relatively flexible and movable with respect to the body 80, the diaphragm carried sealing disk 140 is movable toward and away from the engaging surface 142 of the sleeve 109.

A compression spring 152 is mounted within the bonnet 86 and arranged with one end abutting the retainer 146 of the diaphragm. The compression of the spring 152 is varied by means of an assembly carried by the cap 33 threadedly engaged on the necked down portion 96 of the bonnet. As shown, the assembly includes a cylindrically shaped insert 162 secured to the cap 33 by a screw 160. The insert has a radially projecting top flange 164 at its inner end adapted to abut an inwardly projecting annular flange 166 on the bonnet to limit the outward movement of the cap 33 relative to the bonnet. Rotatably mounted on the insert 162 by means of a pin 168 is a retainer 170 for engaging the outer end of the compression spring 152.

From the foregoing description, it will be appreciated that the maximum pressure occurring within the chamber 100 may be adjustably established within limits by rotating the cap 33 relative to the bonnet 86 to vary the compression of the spring 152. The pressure within the chamber 100 is released through the bleed passage of the sleeve 109 when the chamber pressure just exceeds the biasing force applied by the spring 152. When this occurs, the sealing disk 146 is forced off the seat to establish communication to the atmosphere.

As mentioned above, the pressure-relief means is constructed so that maximum pressure which can occur within the chamber 100 is approximately 32 cm. of water. It will be appreciated that such a maximum will occur when the cap 33 is screwed fully down on the bonnet 96, as in FIGURE 4. Conversely, the pressure relief means has a lower limit of adjustment of approximately 7 cm. of water. Relief occurs at this lower limit when the cap 33 is backed off as far as possible. Since the relief of pressure in the system occurs downstream of the nozzle 112 and since the pressure at the nozzle is always substantially greater than the chamber pressure, essentially a constant load is maintained on the pump 16. This feature of the respirator of the invention is extremely important, as pump wear is greatly accelerated by variation in load.

To use the respiration unit, assuming it to be in a disassembled condition, the delivery means 12 are connected to the case 10. Connection is accomplished by first attaching the various delivery hoses 42, 54 and 74 to their corresponding couplings 41, 51, and 71, respec-

tively, projecting from the front panel 11 of the case. The manifold assembly 44 is disposed at a convenient height by securing it to a telescoping shaft or support arm 171 detachably and pivotally connected, as at 173, to the case 10. The hoses 42 and 54 are then connected at their ends to the respective inlet couplings on the manifold assembly 44, and the hose 74 is connected at its opposite end to the nebulizer 60. Flow passage from the manifold assembly 44 to the face mask 14 is established by connecting the opposite ends of the flexible hose 46 to the two members.

If use of the nebulizer is prescribed, liquid medication or distilled water is put in the nebulizer container 78, as directed. The container 78 is screw-threaded on the cap portion 79 of the nebulizer to facilitate this operation.

Power is next applied to the motor 20 to commence operation of the system by actuating the main switch 22 with the knob 23 on the front panel 11. As noted, the motor 20 drives the pump 16 which, in turn, supplies pressurized air to the regulator 32 and to the nebulizer 60. Since there is no flow demand by the patient at this stage, the mask 14 not yet being in place, the control valve 36 is in a closed position. Accordingly, as during expiration of the patient, the regulator 32 operates in the manner described above to relieve pressure in the chamber 100 and, hence, in the system when it reaches a level sufficient to overpower the spring 152. On the other hand, pressurized air is being continuously supplied to the nebulizer 60, the exact flow rate being established within the limits of 2 to 5 liters per minute by the position of the valve 64. With this flow taking place, nebulizer adjustment is accomplished by rotating the knob 66, as necessary, until a fine mist or fog of the medication or water is produced by the nebulizer 60.

After nebulizer adjustment, the next step is to reduce the maximum inspiration pressure setting to a low level by backing off the cap 33 of the regulator 32 to reduce the spring compression. This is desirable to insure that no more than the desired pressure is applied to the patient's lungs when the mask 14 is first fitted in place. As a safety factor, should the disk 140 stick in its closed position, pressure relief takes place through the passageway provided for air aspirated into the chamber 100. That is, pressure is relieved in the chamber to the atmosphere through a path back through the venturi tube 111 and the communicating passages 123 and 130 and out through the filter 34. The various parts are designed and arranged so that the maximum pressure which can occur in the chamber 100, even if the primary means of pressure relief fails, is approximately 32 cm. of water.

It will be understood that prior to opening of the valve 36, responsive to inspiration by the patient, the pressure gauge 50 continuously reads zero. This is true for the reason that the gauge 50 is coupled to the valve 36 and is adapted to read mask pressure. In order to test the system prior to use on the patient, if such testing is desired, a conventional rubberized test lung (not shown) may be used.

Following adjustment of the maximum inspiration pressure to a low level, the mask 14 is fitted on the patient and secured in position, as by a strap 15. In the event a mouth piece type mask is used, as in the illustrative case, a conventional nose clip may be used as the patient must breathe entirely through the mouth to use the unit effectively.

To commence IPPB therapy, the patient merely breathes at his normal rate and rhythm. Upon a slight inspiratory effort by the patient, the diaphragm 57 of the exhalation valve 52 is drawn down on its seat 59 on the manifold assembly 44, as illustrated in FIGURE 7. This serves to close the relief passage 45 in the manifold assembly. Coincidentally with the closing of the exhalation valve 52, a slight negative pressure is drawn in the

main hose 42 leading to the valve 36. This causes the valve 36 to open and supply compressed air from the flow and pressure regulator 32 to the patient in accordance with his demands. As flow from the regulator 32 takes place, pressure in the chamber 100 drops rapidly. When the biasing force of the spring 152 exceeds the chamber pressure, the disk 140 seats on the shoulder 142 and blocks the pressure relief passage through the sleeve 109.

Near the termination of inspiration, i.e., as the maximum pressure is being reached, flow through the valve 36 rapidly decreases. Moreover, when the pressure in the chamber 100 of the regulator 32 exceeds the spring pressure, air is dumped or exhausted through the passage provided by the sleeve 109.

As explained above, the patient's lungs are sufficiently elastic to achieve expiration on their own accord. As the valve 36 closes, pressure in the hose 54 supplying the exhalation valve is released permitting the diaphragm 57 to be lifted off its seat 59. This, in turn, opens the relief passage 45 in the manifold assembly and permits the patient to expire to the atmosphere.

Continuously, during both inspiration and expiration, nebulized medication or water are supplied by the nebulizer 60 to the manifold assembly 44. During inspiration, when flow is taking place through the manifold assembly 44 to the patient, this nebulized liquid is added to the compressed air being supplied. During expiration, the nebulized liquid charges manifold assembly 44 for the next period of inspiration, the excess being vented to the atmosphere.

The regulator is adjusted to establish a maximum inspiration pressure as prescribed. Adjustment is accomplished by rotating the knob 33 and observing the gauge 50 to set the pressure at the termination of inspiration at the desired level. Normally, a few complete cycles of breathing are required to obtain the desired adjustment.

The unit of the invention is effective to administer ideal IPPB therapy. The patient controls the rate and rhythm of breathing, yet little muscular effort is required to actuate it. The lungs are inflated during inspiration to the pressure which is readily adjustable by the patient to any desired maximum within a safe range. Expiration takes place directly to the atmosphere and not against a positive pressure in the system. Moreover, because of the regulator aspirating ambient air and mixing it with the compressed air from the pump in a ratio of approximately 4 to 1, the temperature of the air supplied to the patient is approximately equal to room temperature. For this same reason, the moisture removal problem of certain prior units using compressed air as the power source is obviated.

The unit is adapted to be assembled and adjusted for use by the patient himself with a minimum of effort. Only two adjustments are necessary, one being for the nebulizer 60 and the other being for the regulator 32. Moreover, these adjustments are independently made by simply rotating the knob 66 and the cap 33, respectively, on the panel 11. The only gauge to observe in making the adjustments is the gauge 50 which indicates mask pressure and is observed in conjunction with adjusting maximum inspiration pressure.

In preparing the unit for convenient transporting, the delivery means 12 are removed from the case 10. To this end, the various hoses, the mask 14, and the nebulizer 60 are all disconnected from the manifold assembly 44. In similar fashion, the manifold assembly is detached from the support arm 171 and the latter is, in turn, removed from its pivotal mounting 173 on the case 10. Preferably, these last mentioned parts are then stored in a compartment (not shown) in the rear of the case 10. In the preferred embodiments, covers, such as the front cover 13 shown in FIGURE 1, are provided on the case to conceal both the front panel 11 and the rear storage compartment. With the various parts stored in

the case 10 and the front panel 11 concealed and, hence, protected, the case may be gripped with a handle 180 and conveniently carried from place to place. The case 10 is preferably constructed of a metal, such as steel or aluminum, for reasons of strength and rigidity. With the parts so protected by the case, the unit is adapted to withstand shock as, for instance, during shipment without any resulting damage.

A complete unit having the operating characteristics described, as well as the storage compartment for the various parts of the delivery means 12, may be constructed of a size of approximately 14" long, 10" deep, and 8" high and of a weight less than 25 pounds. This small size and light weight are important features of the present unit, as it is intended to be hand carried. Such a highly portable unit is made possible by virtue of the particular construction and arrangement of certain specific elements and their operative relations. More specifically, the novel flow and pressure regulator 32 makes it possible to use a small size pump having an output flow considerably less than the patient's peak flow requirement. Air is aspirated into the system so as to furnish the balance of flow necessary to meet the peak requirement of the patient. Besides serving this important function, the regulator also provides means for adjustably establishing the maximum inspiration pressure applied to the patient and, simultaneously, for maintaining a constant load on the pump.

In treating certain ailments, it is desired to enrich the delivered room air with oxygen. To accomplish this, the nebulizer input hose 74 is removed from its coupling 71 on the case and connected to an oxygen source. The extent of enrichment of the air depends, of course, on the flow rate of the oxygen through the nebulizer. As an example, normal room air contains approximately 21% oxygen. With an oxygen flow rate of 5 liters per minute through the nebulizer 60, the air delivered to the working surfaces of the lungs will have an oxygen concentration of approximately 30%.

Still another use of the unit of the invention is as a resuscitator or for administering artificial respiration. To accomplish this function, the valve 36 must be cycled manually or automatically with a separate attachment. A dust cover 183 on the exposed end of the valve 36 is removed and manual cycling is by moving the projecting drum pin 184 up and down to open and close the valve. The rhythm of breathing in this case is determined by the person cycling the valve. An attachment for automatically accomplishing cycling of the valve may be purchased on the market as, for example, the Bennett model CA-170 automatic cycling attachment.

Although one embodiment of the invention has been illustrated and described in detail, it will be understood that this was by way of example and that numerous changes in the design and construction and arrangement of the various elements of the combination may be made without departing from the spirit and scope of the invention.

I claim:

1. In a respiration unit having an air pump and valve means connected to said pump for controlling air flow to a patient, a flow and pressure regulator in series with and between said pump and valve means, said regulator comprising: a body; a movable diaphragm secured to said body and cooperating therewith to define a pressure chamber; means in said body forming an inlet passage; aspirator means mounted on said body and arranged for receiving compressed air from said pump and discharging into said chamber through said inlet passage, said aspirator means being powered by compressed air from said pump to aspirate ambient air into said chamber at a rate dependent upon the pressure in said chamber; means in said body forming an outlet passage from said chamber for delivering air to said valve means; means in said body forming a relief passage from said chamber

to the atmosphere; seal means carried by said diaphragm and movable into and out of passage-closing relation wherein it blocks flow through said relief passage; and means on said body biasing said seal means into said relation, said biasing means being movable responsive to pressure in said chamber above a predetermined maximum to permit said seal means to move out of said relation, thereby permitting flow through said relief passage.

2. In a respiration unit having a source of compressed gas and valve means connected to said source for controlling gas flow to a patient, a regulator in series with and between said source and said valve means, said regulator comprising: a body; means on said body cooperating therewith to define a pressure chamber; a venturi tube having an inlet portion, a throat portion and an outlet portion, said venturi tube being mounted on said body with its inlet portion communicating with the atmosphere and its outlet portion discharging into said chamber; a nozzle mounted on said body adjacent the inlet portion of said venturi tube, said nozzle being adapted to jet compressed gas from said source into the throat portion of said venturi tube and thereby aspirate ambient air into said chamber; means on said body forming an outlet passage from said chamber for delivering the mixture of compressed gas from said source and aspirated air to said valve means; and pressure-relief means mounted on said body and communicating with said chamber and with the atmosphere, said last mentioned means being adapted to relieve pressures in said chamber above a predetermined maximum.

3. In a respiration unit having an air pump and valve means connected to said pump for controlling air flow to a patient, a flow and pressure regulator in series with said pump and valve means, said regulator comprising: a body; a movable diaphragm secured to said body and cooperating therewith to define a pressure chamber; a venturi tube having an inlet portion, a throat portion and an outlet portion, said venturi tube being mounted on said body with its inlet portion communicating with the atmosphere and its outlet portion discharging into said chamber; a nozzle mounted on said body adjacent the inlet portion of said venturi tube, said nozzle being adapted to jet compressed gas from said pump into the throat portion of said venturi tube and thereby aspirate ambient air into said chamber at a rate dependent upon the pressure therein; means on said body forming an outlet passage from said chamber for delivering air from said chamber to said valve means; means on said body providing a pressure-relief passage from said chamber to the atmosphere and a seating shoulder adjacent the mouth of said passage; seal means carried by said diaphragm and movable therewith into and out of sealing engagement with said seating shoulder, said seal means blocking flow through said relief passage when in said engagement and permitting such flow when out of said engagement; and a spring mounted on said body biasing said seal means into said sealing engagement, said spring yielding to pressures in said chamber above a predetermined maximum acting on said diaphragm to cause said seal means to move out of said engagement.

4. The subject matter of claim 3 including means on said body and accessible from the exterior thereof for adjusting the biasing force of said spring.

5. A respiration unit comprising: an air pump having an inlet and an outlet and a predetermined volumetric flow capacity below the peak flow requirement of the patient and output pressure greater than the maximum inspiration pressure to be applied to the patient; a motor for driving said pump; a flow and pressure regulator connected to the outlet of said pump, said regulator including a central chamber, aspirator means for aspirating ambient air into said chamber to increase flow therethrough above the predetermined volumetric flow capacity of the pump while simultaneously reducing the pressure proportionately below said predetermined output pressure, and pres-

sure-relief means affording communication between said chamber and the atmosphere for relieving pressures in said chamber above a predetermined maximum; valve means having an inlet connected to the outlet of said regulator and an outlet, said valve means being operable to control flow from said regulator; and a face mask having an inlet connected to the outlet of said valve means.

6. A respiration unit, as in claim 5, wherein the ratio of aspirated air to air supplied by the said pump is intermittently approximately 4 to 1.

7. A respiration unit comprising: an air pump with an inlet and an outlet, said pump having a volumetric flow capacity of approximately 20 liters per minute and an output pressure of approximately 450 cm. of water; power means for driving said pump; a regulator having an inlet connected to the outlet of said pump, said regulator including aspirator means for aspirating ambient air to increase the flow through said regulator to approximately 80 liters per minute when the pressure adjacent the outlet of said regulator approaches ambient pressure and pressure-relief means adjustable to establish a maximum outlet pressure in said regulator within the range of 10 to 30 cm. of water; valve means having an inlet connected to the outlet of said regulator and an outlet; and a face mask having an inlet connected to the outlet of said valve means.

8. A respiration unit for administering intermittent positive pressure breathing therapy to a patient, comprising: an air pump having an inlet and an outlet, said pump having a volumetric flow capacity below the peak flow requirement of the patient and an output pressure greater than the maximum inspiration pressure requirement of the patient and sufficient to nebulize a liquid; power means for driving said pump; a flow divider having an inlet connected to the outlet of said pump and first and second outlets; a flow and pressure regulator having a chamber and an inlet coupled to the first outlet of said flow divider and an outlet, said regulator including aspirator means for intermittently aspirating ambient air into said chamber and thereby simultaneously increasing the volumetric flow through the outlet of said regulator to at least equal to the patient's peak flow requirement, and pressure-relief means for adjustably limiting the pressure in said chamber to no more than the maximum inspiration pressure requirement of the patient; a face mask having an inlet connected to the regulator outlet; valve means in series with said regulator and said face mask, said valve means being responsive to respiration of the patient for controlling the flow of compressed air from said regulator to said mask; and a nebulizer having an inlet connected to the second outlet of said flow divider and an outlet communicating with said face mask, said nebulizer being adapted to nebulize a liquid and add the nebulized liquid to the compressed air flowing from said valve means to said mask.

9. A respiration unit comprising: an air pump with an inlet and an outlet, said pump having a volumetric flow capacity of approximately 20 liters per minute and an output pressure of approximately 450 centimeters of water; power means for driving said pump; a flow divider having an inlet connected to the outlet of said pump and first and second outlets; a flow and pressure regulator having a chamber and an inlet connected to the first outlet of said flow divider and an outlet, said regulator including aspirator means for aspirating ambient air into said chamber to intermittently increase flow through the outlet of said regulator to approximately 80 liters per minute, and pressure-relief means adjustable within predetermined limits to establish a maximum outlet pressure; a main valve having an inlet connected to the outlet of said regulator and an outlet, said valve being operable to control flow from said regulator; a control valve having an inlet connected to the second outlet of said flow divider and an outlet, said control valve being adjustable to vary the flow therethrough; a nebulizer having an inlet connected to the outlet of said control valve,

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and an outlet; and delivery means including a face mask and hoses for providing communication from the outlets of said main valve and said nebulizer to said mask.

10. A respiration unit as in claim 9 wherein said control valve is adjustable to vary its outlet flow within the range of 2 to 5 liters per minute.

11. A respiration unit comprising: a case having a control panel; an air pump mounted in said case and having an inlet and an outlet; motor means mounted in said case for driving said pump; a flow divider mounted in said case and having an inlet connected to the outlet of said pump and first and second outlets; a regulator mounted in said case and having a chamber with a compressed air inlet connected to the first outlet of said flow divider and an outlet, said regulator including aspirator means for aspirating ambient air into said chamber and pressure-relief means for relieving pressures in said chamber above a predetermined maximum, said pressure-relief means having a control knob mounted on said front panel for adjustably establishing said predetermined maximum pressure within upper and lower limits; a main valve mounted in said case and having an inlet connected to the outlet of said regulator and an outlet; a control valve mounted in said case and having an inlet connected to the second outlet of said flow divider and an outlet, said control valve having a knob mounted on said panel for adjustably establishing the flow therethrough; a nebulizer having an inlet connected to the outlet of said control valve and an outlet; and delivery means including a face mask and hoses providing communication from the outlets of said main valve and said nebulizer to said face mask.

12. In a respiration unit having a source of compressed gas and valve means connected to said source for controlling gas flow to a patient, a regulator in series with and between said source and said valve means, said regulator comprising:

a body;

means on said body cooperating therewith to define a pressure chamber;

means in said body forming an inlet passage to said chamber;

means in said body forming an outlet passage from said chamber for connection to said valve means;

aspirator means connected to said source and arranged for discharge through said inlet passage into said chamber, said aspirator means being powered by compressed gas from said source to aspirate ambient air into said chamber;

pressure-relief means on said body including a valved passage between said chamber and the atmosphere, said pressure-relief means being operable to relieve

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pressures in said chamber above a predetermined maximum;

and means on said body and operatively associated with said pressure-relief means for adjustably establishing said predetermined maximum pressure.

13. A respiration unit for administering intermittent positive pressure breathing therapy to a patient, comprising:

an air pump having an inlet and an outlet and a predetermined volumetric flow capacity below the peak flow requirement of the patient and output pressure greater than the maximum inspiration pressure to be applied to the patient;

power means for driving said pump;

a regulator including a body, means on said body cooperating therewith to define a pressure chamber, means on said body forming inlet passage to said chamber, means on said body forming an outlet passage from said chamber, aspirator means connected to the outlet of said pump and arranged to discharge compressed air through said inlet passage into said chamber, said aspirator means being powered by compressed air from said pump to aspirate ambient air into said chamber to increase flow therethrough to meet the patient's peak flow requirement, pressure-relief means on said body including a valved passage between said chamber and the atmosphere, said pressure-relief means being operable to relieve pressures in said chamber above a predetermined maximum, and means on said body and operatively associated with said pressure-relief means for adjustably establishing said predetermined maximum pressure; valve means having an inlet connected to the outlet passage of said regulator, and an outlet, said valve means being operable to control flow from said regulator;

and a face mask having an inlet connected to the outlet of said valve means.

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