June 27, 1961 P. F. EARLY 2,989,970

DEMAND INHALATOR

Filed Sept. 5, 1956

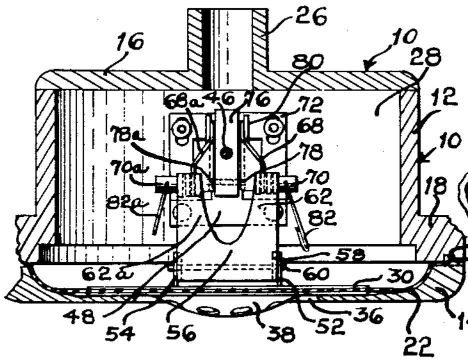

FIG. 4

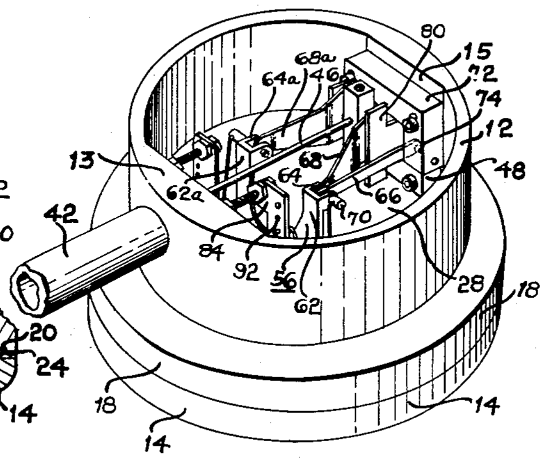

FIG. 1

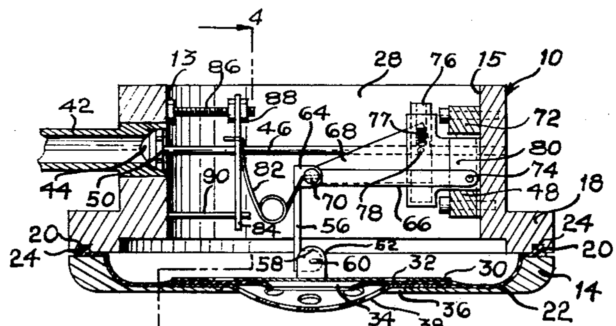

FIG. 3

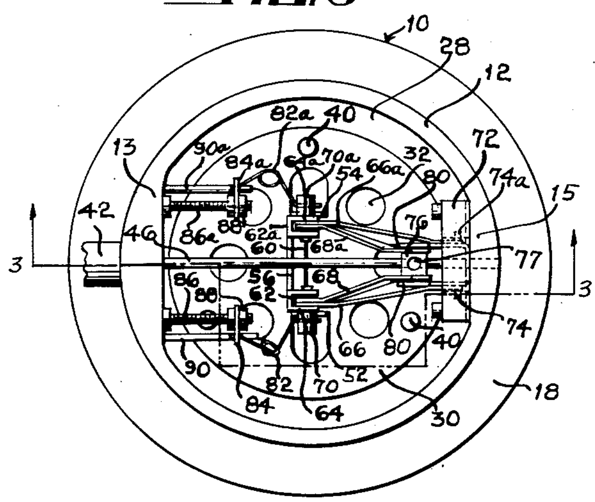

FIG. 2

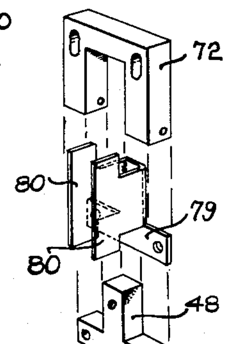

FIG. 5

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DEMAND INHALATOR

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12 Claims. (Cl. 137—63)

This invention relates to inhalators for supplying special gases and medicaments to a patient and more particularly to an inhalator responsive to the demands of the patient.

The demand inhalator of this invention is the type wherein a patient wearing a face mask attached to the inhalator inhales and exhales through the inhalator. As the patient inhales, a gas is introduced into the inhalator for inhalation by the patient. The amount of gas introduced is in proportion to the demand of the patient. When the patient exhales, the flow of gas into the inhalator is interrupted and the exhaled gases are vented to the ambient atmosphere.

One object of the present invention is to provide an inhalator fully responsive to the demands of the user. To achieve this characteristic, the flow of gas into the inhalator is regulated by a pressure sensitive diaphragm biased with a substantially constant force such that the force required to actuate the inhalator is independent of the gas volume delivered by the inhalator.

Another object of this invention is to provide in an inhalator a novel lever arrangement for actuating a stop valve in response to movement of a pressure sensitive diaphragm. The lever arrangement has the characteristic of providing high mechanical advantage in a limited space.

A further object of this invention is to provide in an inhalator a pressure sensitive diaphragm functioning as a flapper valve providing for exhalation by the patient.

Other objects and advantages reside in the construction of parts, the combination thereof and the mode of operation, as will become more apparent from the following description.

In the drawings, FIGURE 1 is a perspective view of the inhalator with an end portion removed to expose the inner mechanism.

FIGURE 2 is a top plan view of the inhalator of FIGURE 1.

FIGURE 3 is a sectional view taken substantially along the line 3—3 of FIGURE 2.

FIGURE 4 is a sectional view taken substantially along the line 4—4 of FIGURE 3, the view showing in section the end portion removed in FIGURES 1, 2, and 3.

FIGURE 5 is an exploded detail perspective view of support members employed in the inhalator.

Referring to the drawings in detail, the inhalator is housed in a substantially cylindrical housing **10** including a tubular member **12** and end plates **14** and **16**. The inner wall of the tubular member **12** is provided with diametrically opposite facets **13** and **15** for purposes to be described in detail in the following. At one end of the tubular member **12** is an annular outwardly extending flange **18** having an annular recess **20** therein. A flexible membrane or diaphragm **22** having an annular rib **24** at the margin thereof seated in the annular recess **20** extends radially across the tubular member **12**.

The end plate **14** closes the end of the tubular member **12** adjacent the diaphragm **22** and is secured to the annular flange **18** by any suitable means. The margin of the diaphragm **22** provides a gasket for sealing the gap between the end plate **14** and the flange **18**.

The end plate **16** shown in FIGURE 4, is secured to the opposite end of the housing **10** by any suitable means. A conduit **26** integral with the end plate **16** is

adapted for attachment to a face mask or breathing tube or the like. The end plate **16**, the tubular member **12**, and the diaphragm **22** thus define a chamber **28** within the housing **10** which communicates through the conduit **26** to a face mask or the like and ultimately with the lungs of a person using the inhalator.

To provide for exhalation through the inhalator housing, the central portion of the diaphragm **22** is utilized as a flapper valve. A rigid disc or plate **30**, seen best in FIGURE 2, is secured to the inner surface of the diaphragm **22**, the disc being provided with an annular ring of apertures or perforations **32** adjacent the perimeter thereof. Opposite the unperforated central portion of the disc **30**, the diaphragm **22** is provided with an aperture **34**, the aperture being smaller than the unperforated portion of the disc. An aperture **36** is also located centrally in the end plate **14**. Clearly, if the pressure within the chamber **28** rises above atmospheric pressure, air or gas will move through the perforations **32** in the disc **30**, forcing the apertured central portion of the diaphragm outwardly, the gas escaping to the ambient atmosphere. When the pressure in the chamber **28** falls below that of the ambient atmosphere, the diaphragm **22** will be drawn tightly against the disc **30**, closing the perforations therein and prohibiting the passage of air from the ambient atmosphere into the chamber **28**.

The diaphragm is protected by a perforated shield **38**, the shield **38** and disc **30** being secured together by rivets **40** passing through the diaphragm **22**. The shield **38** is arched outwardly from the diaphragm **22** to allow the central portion thereof to perform as a flapper valve.

A gas for inhalation by the person using the inhalator is supplied to the chamber **28** through a conduit **42** in the wall of the tubular member **12**. The gas may be supplied under pressure from any suitable reservoir. The flow of gas into the chamber **28** is regulated by a stop valve **44**, preferably constructed from a resilient material, adapted to seat in the conduit **42**. The stop valve **44** is mounted upon one end of a shaft **46** traversing the chamber **28**. The other end of the shaft **46** is journalled for sliding motion into a T-shaped support block **48** mounted upon the facet **15** on the opposite side of the tubular member **12**. A spider member **50**, secured to the shaft **46** adjacent the stop valve **44** and engaging the wall of the conduit **42**, centers the valve with respect to the conduit **42**, without restricting the passage of gas through the conduit **42** and around the stop valve **44**.

The flow of gas through the conduit **42** into the chamber **28** is regulated in accordance with the pressure in the chamber **28** by a lever arrangement which will now be described.

Struck out from the disc **30** are two opposing lugs **52** and **54** each provided with an aperture therein. A bracket member **56** provided with apertured lugs **58** at one end thereof is pivotally secured to the lugs **52** by a suitable pin **60** passing through the apertures in the lugs **52** and **54**. A U-shaped cut out portion in the opposite end of the bracket member **56** defines two legs **62** and **62*a*** in the bracket member, each leg being provided with a pair of parallel apertured lugs **64** and **64*a***. The legs of the bracket member **56** extend substantially perpendicular to the plane of diaphragm **22** into the chamber **28**.

Two levers, **66** and **68**, are pivotally secured to the leg **62** by a pin **70** passing through the apertures in the lugs **64**. Similarly, two levers, **66*a*** and **68*a***, are pivotally secured to the leg **62*a*** by a pin **70*a*** passing through the apertures in the lugs **64*a***. The levers **66** and **66*a***, which are longer than the levers **68** and **68*a***, are pivotally secured at their opposite ends to the legs of a U-shaped block **72** mounted adjacent the T-shaped block **48** on the facet **15** of the tubular member **12**. Pins **74** and **74*a***, there being one journalled in each leg of the U-shaped block **72**, provide the pivotal axes for the levers **66** and **66*a***, respectively.

The levers **68** and **68*a*** are pivotally secured at their opposite ends to a block **76** mounted upon the shaft **46** which supports the stop valve **44**. Pins **78** and **78*a***, journalled in the block **76** in substantial radial alignment with the shaft **46**, provide the pivotal axis for the levers **68** and **68*a***, respectively. The block **76** is fixedly secured to the shaft **46** by a set screw **77**, as shown in FIGURES 2 and 3.

To prevent rotation of the shaft **46** and the block **76** secured thereto, the levers **68** and **68*a*** secured to opposite sides of the block **76** are made substantially triangular in shape, as shown in FIGURES 1 and 3, thereby creating a large bearing surface for the block **76**. A bracket member, **79**, sandwiched between the T-shape block **48** and the facet **15** of the tubular member **12**, is provided with parallel projecting flanges **80** extending on either side of the levers **68** and **68*a***, which flanges function to fix the angular orientation of the block **76** and therefore the shaft **46**. The arrangement of the bracket member **79**, T-shaped block **48**, and U-shaped block **72** is shown in exploded detail in FIGURE 5.

As best seen in FIGURE 3, the levers **66** and **66*a*** extend substantially normal to the bracket member **56** and parallel to the plane of the diaphragm **22**. The levers **68** and **68*a***, which can be represented by imaginary lines extending from the pivot pins **70** and **70*a*** to the pivot pins **78** and **78*a***, extend at an obtuse angle relative to the bracket member **56**. It is apparent that as the pressure in the chamber **28** falls below atmospheric pressure, the diaphragm **22** will move axially into the chamber **28** forcing the bracket member **56** to move axially upwards, as viewed in FIGURE 3. The maximum upward movement of the bracket member **56** is determined by the U-shaped cut out portion therein which provides clearance for the shaft **46**. As the bracket member **56** moves axially upwards, the effective angle between the lever pairs **66** and **68**, and **66*a*** and **68*a***, will decrease approaching zero angle. The block **76** is thereby constrained to move axially, carrying with it the shaft **46** and displacing the stop valve **44**, so as to open the conduit **42**. Due to a mechanical advantage in the lever arrangement, the force moving the stop valve **44** is many times greater than the force exerted by the diaphragm **22**.

The lever structure just described is referred to hereinafter as substantially constituting a double slider-crank mechanism: one slider-crank mechanism consisting of levers **66, 68** and the slider block **76**; and the other slider-crank mechanism consisting of lever **66**, lever **56** and the slider block or lug **52**.

It can be shown mathematically that, to a first approximation, the mechanical advantage of the lever arrangement is proportional to the cotangent of the angle between the levers **66** and **68**. Thus, as this angle approaches zero, the mechanical advantage becomes infinite. By adjusting the size and proportion of parts, the angle between the levers **66** and **68** can be adjusted over a wide range, thus varying the mechanical advantage as desired. It is, of course, apparent that as the mechanical advantage increases, the displacement of the stop valve **44** decreases, placing a practical limitation upon the mechanical advantage.

Due to the pressure of the gas in the conduit **42**, as well as gravitational effects, it is not only desirable, but necessary, to bias or load the diaphragm **22** to its extreme position in the housing **10**. This is accomplished by providing a pair of hairpin springs **82** and **82*a*** attached to fixed supports **84** and **84*a***. The supports **84** and **84*a*** are mounted in fixed spaced relation to the facet **13** by threaded shafts **86** and **86*a***, respectively, the supports **84** and **84*a*** being secured to the threaded shafts **86** and **86*a*** by suitable nuts **88**. Rods **90** and **90*a*** projecting normally from the facet **13** through suitable apertures in the supports **84** and **84*a***, respectively, orient the supports axially in the chamber **28**.

In each support **84** and **84*a***, a plurality of axially aligned apertures **92** are provided. One arm of the hairpin spring **82** is projected into a suitable aperture in the pin **70** in the bracket member **56**, and the other arm of the hairpin spring **82** is projected into one of the apertures **92** of the support **84**, to thereby secure the spring **82** to the support. Similarly, the arms of the spring **82*a*** are secured respectively to the pin **70*a*** in the bracket member **56** and the support member **84*a***.

It is to be noted that the full spring tension of each spring is directed upon the pins **70** and **70*a*** and only the axial component of this tension is transmitted to the diaphragm **22**. As viewed in FIGURE 3, an imaginary line passing through the ends of the spring **82** will make an acute angle with the lever **66**. The axial component of the spring tension delivered by the spring **82** will be determined approximately by the product of the spring tension times the sine of this acute angle for relatively small displacements of the diaphragm **22**.

Clearly, as this angle approaches zero, the axial component of the spring tension approaches zero. By varying the axial position of the arm of the spring **82*a*** secured to the support **84*a***, the axial component of the spring tension can be varied over a wide range, to thereby adjust the loading of the diaphragm **22**. The same reasoning applies to the spring **82*a***.

As the bracket member **56** moves axially in the chamber **28**, being driven by the diaphragm **22** in response to pressure reduction in the chamber **28**, the axial component of the spring tension decreases. Simultaneously, the springs **82** and **82*a*** must be compressed slightly as the bracket member **56** moves axially, thereby increasing the total tension delivered by each spring. By proper arrangement of parts, the variation in spring tension opposing the axial movement of the diaphragm **22** is adjusted to just compensate the increasing restoring force of the diaphragm itself so as to produce a substantially constant force biasing the diaphragm into the home position, the net restoring force on the diaphragm being thereby independent of the displacement of the diaphragm.

It is important to note that the springs **82** and **82*a*** must be so positioned that the ends thereof must never become aligned with the lever **66**. Otherwise, it would be possible to obtain a finite diaphragm displacement which is stable, or biased oppositely, so that the diaphragm **22** would not return to its home position when the pressure in the chamber **28** is equal to that of the atmosphere. In the operation of the inhalator, a face mask is attached to the conduit **26** and a source of gas under pressure is connected to the conduit **42**. As the patient inhales through the conduit **26**, the pressure in the chamber **28** lowers below that of the ambient atmosphere. As soon as the pressure differential across the diaphragm **22** is sufficient to overcome the loading of the diaphragm **22**, the diaphragm moves axially, opening the stop valve **44**.

As the stop valve **44** opens, gas passes through the conduit **42** into the inhalator chamber **28** and eventually to the patient. The diaphragm will quickly move to a position such that the amount of gas flowing into the chamber **28** equals the amount demanded by the patient, the patient maintaining a negative lung pressure just sufficient to overcome the opposing force of the diaphragm **22** and springs **82** and **82*a***. Since this force is substantially constant and independent of the diaphragm displacement, the negative pressure the patient must maintain is independent of the volume of gas demanded by the patient. The patient thus obtains a proper amount of gas without experiencing a resistance or drag in the inhalator as he attempts to increase or decrease his breathing volume.

As the patient ceases to inhale, the pressure in the chamber 28 approaches atmospheric pressure and the diaphragm 22 actuates the stop valve 44 to close the gas inlet. The force with which the gas inlet is closed is determined by the loading of the diaphragm 22, amplified by the mechanical advantage of the lever mechanism.

When the patient exhales, the diaphragm 22 cooperating with the disc 30 operates as a flapper valve to release the exhaled gas to the ambient atmosphere.

In the event of failure of the inhalator mechanism, as, for example, the stop valve 44 becoming jammed in the open position, the flapper valve operation of the diaphragm 22 provides a safety feature for the patient. The instant the pressure in the chamber 28 rises above atmospheric pressure, gas is vented through the aperture 34 in the diaphragm 22 out of the chamber 28. Thus, it is impossible to create a pressure in the chamber 28 substantially greater than atmospheric pressure.

Although the preferred embodiment of the device has been described, it will be understood that within the purview of this invention various changes may be made in the form, details, proportion and arrangement of parts, the combination thereof and mode of operation, which generally stated consist in a device capable of carrying out the objects set forth, as disclosed and defined in the appended claims.

Having thus described my invention, I claim:

1. In a demand inhalator for attachment to a face mask or the like of the type including: a housing defining a gas receiving chamber; means providing a gas inlet to said chamber; valve means for regulating the flow of a gas through the gas inlet; and an inherently resilient pressure sensitive means responsive to the gas pressure within said chamber, wherein the said pressure sensitive means undergoes a displacement in response to pressure changes within said chamber; the combination therewith of a valve operating linkage means responsive to displacement of said pressure sensitive means and mechanically interconnecting the latter to said valve means for actuating said valve means in proportion to the displacement of said pressure sensitive means; and yielding means interposed in said linkage means with one end of said yielding means being affixed to a movable pin connection of said linkage means for pivotal and translational movement with said pin, whereby said yielding means may be made to supplement the inherent resiliency of said pressure sensitive means so as to bias pressure sensitive means with a substantially constant force independent of the displacement thereof.

2. A demand inhalator according to claim 1 wherein the other end of said yielding means is affixed to an adjustable fixed pivot whereby the magnitude and the direction of the biasing force exerted upon said diaphragm may be selected as desired.

3. In a demand inhalator for attachment to a face mask or the like of the type including: a housing defining a gas receiving chamber; means providing a gas inlet to said chamber; resilient pressure sensitive means responsive to a gas pressure differential between said chamber pressure and atmospheric pressure, said pressure sensitive means undergoing a displacement when the gas pressure within said chamber is below that of the ambient atmosphere; and valve means associated with said gas inlet; the combination therewith of a valve operating linkage means comprising a pair of slider crank mechanisms, the turning pair of one of said mechanisms being pinned to the turning pair of the other of said mechanisms, biasing means interconnected at said common pinned interconnection between the turning pairs of said mechanisms, said linkage means being responsive to displacement of said pressure sensitive means and mechanically interconnecting the latter to said valve means for displacing said valve in proportion to the displacement of said pressure sensitive means with varying mechanical advantage as said linkage means travels.

4. The demand inhalator according to claim 3, wherein one link of the turning pair of one of said mechanisms is common to a link of the turning pair of the other of said mechanisms.

5. A demand inhalator according to claim 3 wherein said valve means constitutes the slider of one of said mechanisms and the displacement of said pressure sensitive means approximates rectilinear motion.

6. In an assembly including a housing providing a gas receiving chamber, pressure sensitive means responsive to pressure variations in said chamber, means providing a gas inlet to said chamber, means providing a gas outlet from said chamber, valve means disposed in said gas inlet, said valve means having an open position and a closed position: valve operating means responsive to said pressure sensitive means for positioning said valve means, and yielding means biasing said pressure sensitive means, said valve operating means including a shaft engaging said valve means and so mounted as to be constrained to translational motion, a first lever, means pivotally securing one end of said first lever to said shaft, a second lever, means pivotally securing one end of said second lever to the other end of said first lever, said yielding means being connected to the pivotal connection between the first and second levers, means pivotally securing the other end of said second lever to said housing, said first and second levers being disposed at an acute angle with respect to one another, and further linkage means pinned to and operated by said pressure sensitive means pivotally engaging at least one of said levers.

7. A demand inhalator for attachment to a face mask or the like including, in combination: a housing defining a gas receiving chamber; means providing a gas inlet to said chamber; valve means for regulating the flow of a gas through the gas inlet; an inherently resilient pressure sensitive means responsive to the gas pressure within said chamber, said pressure sensitive means undergoing a displacement in response to pressure changes within said chamber; valve operating linkage means approximating a double slider-crank mechanism responsive to displacement of said pressure sensitive means and mechanically interconnecting the latter to said valve means for displacing said valve in proportion to the displacement of said pressure sensitive means with varying mechanical advantage as said linkage means travels, and yielding means interposed in said linkage means with one end of said yielding means being affixed to a movable pin connection of said linkage means and the other end of said yielding means being affixed to an adjustable fixed pivot so arranged that the magnitude and the direction of the biasing force exerted upon said diaphragm may be selected as desired, and the yielding means supplements the inherent resiliency of said pressure sensitive means so as to bias said pressure sensitive means with a substantially contant force independent of the displacement thereof.

8. The demand inhalator according to claim 7, wherein said linkage means comprises a pair of slider crank mechanisms, the turning pair of one of said mechanisms being pinned to the turning pair of the other of said mechanisms.

9. The demand inhalator according to claim 8, wherein one link of the turning pair of one of said mechanisms is common to a link of the turning pair of the other of said mechanisms.

10. A demand inhalator according to claim 7 wherein said valve means constitutes the slider of one of said mechanisms and the displacement of said pressure sensitive means approximates rectilinear motion.

11. The demand inhalator of claim 7 wherein said valve operating means includes a shaft engaging said valve means and so mounted as to be constrained to translational motion, a first lever, means pivotally securing one end of said first lever to said shaft, a second lever, means pivotally securing one end of said second lever to the other end of said first lever, means pivotally securing the other end of said second lever to said housing, said first and second levers being disposed at an acute angle with respect to one another, and a third lever, means piv-

otally securing one end of said third lever to the pivotal connection between said first and second levers, and means pivotally securing the other end of said third lever to said pressure sensitive means.

12. In a demand inhalator for attachment to a face mask or the like of the type including a housing defining a gas receiving chamber; means providing a gas inlet to said chamber; valve means for regulating the flow of a gas through the gas inlet; and an inherently resilient pressure sensitive means responsive to the gas pressure within said chamber to move alternately to two opposed extreme positions from a neutral unactivated position, wherein the said pressure sensitive means undergoes a displacement in response to pressure changes within said chamber; the combination therewith of a valve operating linkage means responsive to displacement of said pressure sensitive means and mechanically interconnecting the latter to said valve means for actuating said valve means in proportion to the displacement of said pressure sensitive means; said valve operating linkage means including a bracket member pivotally secured at its one end to said pressure sensitive means, said bracket member at its end furthest from said pressure sensitive means being formed in a bifurcated portion, there being a pair of valve operating linkage means pivotally attached, separately, at one end, one to each of the furcations of said bracket, and pivotally attached at their

other ends to a portion of said valve means, yielding means for loading said pressure sensitive means comprising two springs attached, separately, at one end, one to each of the furcations of said bracket, and attached separately, at their other ends, one to each of a pair of adjustable standards adapted to be locked in fixed position relative to said housing after adjustment whereby said springs may be differentially prestressed in any desired manner to provide any desired degree of biasing force on said linkage means.

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