Dec. 20, 1966 J. B. McDONOUGH 3,292,617

CLOSED CIRCUIT BREATHING APPARATUS

Filed Oct. 21, 1963

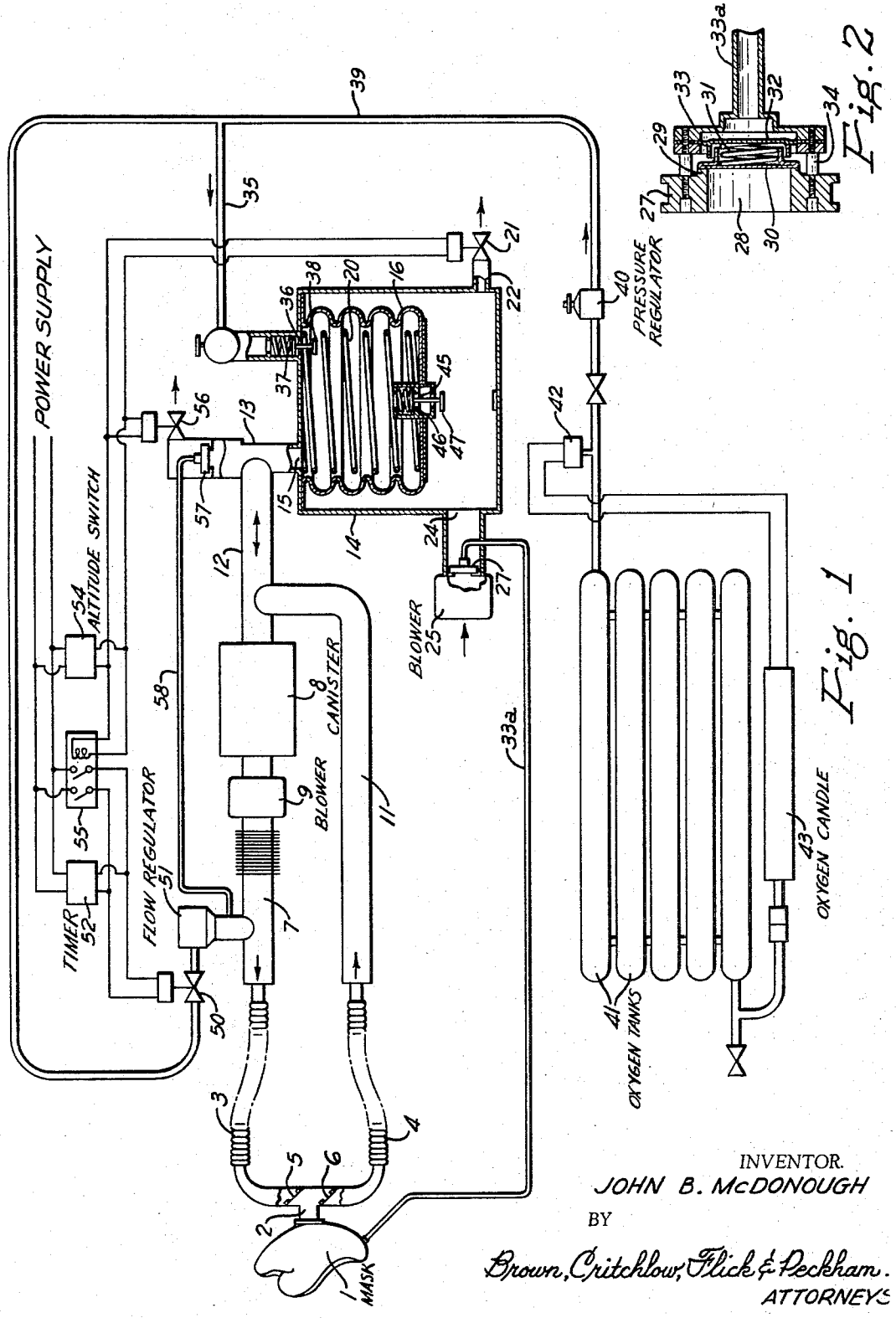


Fig. 1

Fig. 2

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United States Patent Office 3,292,617 Patented Dec. 20, 1966

3,292,617

CLOSED CIRCUIT BREATHING APPARATUS

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Filed Oct. 21, 1963, Ser. No. 317,467
5 Claims. (Cl. 128—142)

This invention relates to breathing apparatus in which the circuit normally is closed, and more particularly to the breathing bag contained in such a circuit.

In closed circuit breathing apparatus a breathing mask is connected with an air purifying canister and with a breathing bag that expands and contracts as the user breathes. One of the objections to such apparatus is that it requires considerable effort to use it because it requires work to expand and collapse the bag, and the entire system offers resistance to flow of the air stream. Over a prolonged period the increased breathing effort that is necessary can become quite fatiguing.

It is among the objects of this invention to provide breathing apparatus in which breathing is essentially resistance-free, in which the breathing bag is expanded and contracted mechanically, and in which the system is purged periodically to remove nitrogen from it. Another object is to provide such apparatus, which under certain conditions will automatically convert itself into pressure breathing apparatus.

The preferred embodiment of the invention is illustrated in the accompanying drawings, in which

FIG. 1 is a diagram of the breathing apparatus, with the breathing bag shown in section; and

FIG. 2 is an enlarged cross section of the blower-control valve.

Referring to FIG. 1 of the drawings, a breathing mask **1** of any well known construction has a combined inlet and outlet provided with a T-fitting **2**, to which flexible inhalation and exhalation tubes **3** and **4** are connected. The fitting also includes inhalation and exhalation valves **5** and **6**, so that the flow of air through the tubes is always in the same direction. The inlet end of the inhalation tube is connected to a conduit **7** that is connected to the outlet end of an air purifying canister **8** of well known construction, which may contain KO_2 for removing carbon dioxide and generating oxygen. Or, a chemical, such as LiOH, may be used that will only remove the carbon dioxide. In such a case, oxygen will be supplied in a manner that is described later. The conduit may be provided with an electric blower **9** to help reduce resistance to flow in the system, in which case valves **5** and **6** will insure proper flow if there is a power failure.

The outlet end of the exhalation tube **4** is connected to a conduit **11** that leads to the inlet end of canister **8**, where it also is connected by a conduit **12** to the side of another conduit **13** secured to a breathing bag housing **14**. Although the housing may be provided with both an inlet and an outlet, it is preferred to combine the two into one opening **15**, to which conduit **13** is connected. Disposed inside the housing and sealed to its wall around the inlet-outlet opening, is the open end of a flexible breathing bag **16**. Preferably, the bag is provided with annular pleats or corrugations to increase its flexibility as much as possible. It will be seen that when the wearer of the mask exhales, the exhaled air will be directed into the bag, which will therefore expand toward the bottom of the housing. During inhalation, air is withdrawn from the bag and passes through the canister where it is purified before it returns to the mask. During inhalation, the bag collapses upwardly in the housing.

It is a feature of this invention that means is provided for mechanically expanding and contracting the bag so

that substantially no effort will be required by the user for that purpose. Accordingly, a coil spring **20** is mounted in the bag for normally holding it expanded. At the termination of inhalation, during which the spring is compressed by the collapsing bag, the spring will expand in the bag so that no work is required on the part of the user to expand the bag. In fact, the expanding bag will tend to withdraw air from the lungs. While the bag is expanding, air escapes from the bag housing through a normally open electrically operated valve **21** connected to a second outlet **22** from the housing.

To mechanically collapse the bag during inhalation, the bag housing is provided with a second inlet **24**, through which the housing is pressurized in order to exert air pressure against the outside of the bag and thereby cause it to move upwardly in the housing and force air out of itself through opening **15** and into the lungs of the wearer of the mask. The pressurizing may be done by any type of compressor at the second inlet, but preferably by a centrifugal blower **25** that forces air into the housing faster than it can escape through valve **21**, whereby the air pressure around the bag is increased. Since the housings should be pressurized in this manner only during periods of inhalation, means are provided for periodically stopping the application of air pressure to the housing. With a continuously operating blower, this preferably is done by a valve that shuts off the flow of air from the blower to the housing. The valve is controlled by the exhalations of the wearer of the mask in such a manner that the valve will be closed at the beginning of each exhalation to permit the spring **20** to expand the bag without resistance from air pressure in the housing.

A suitable valve for this purpose is the well known Hawk valve, which has a body **27** provided with a large central passage **28** (FIG. 2) connected with the outlet of the blower. As shown in FIG. 2, the end of the passage farthest from the blower is encircled by a valve seat **29**, against which a closure member **30** is pressed by means of a coil spring **31** compressed between it and a flexible diaphragm **32**, the edge of which is clamped in a surrounding cup **33** spaced by spacers **34** from the valve body. During inhalation, air pressure from the blower forces the closure member off its seat and the air therefore flows out between the valve body and the diaphragm cup and into the bag housing to collapse the bag. However, when the user exhales, the air pressure is increased in a static tube **33***a* that connects the mask with the outer end of the diaphragm cup **33**. This pressure causes the diaphragm and spring to hold the closure on its seat and thereby shut off communication between blower **25** and the inside of the bag housing **14**.

It will therefore be seen from the description thus far that exhalation actually is aided by the expanding coil spring in the bag, and inhalation is aided by the increased air pressure in the housing around the bag, which forces the bag upwardly toward a collapsed position. As a result, this apparatus offers no resistance to breathing. It requires no effort on the part of the user to expand the collapse the bag.

In case an oxygen-generating chemical is not used in the canister, or if oxygen leaks from the system or an unusually large breath is taken during inhalation, the bag will collapse completely and open a valve in an oxygen make-up line **35**. Thus, the upper wall of the housing may be provided with an inlet port **36** that normally is closed by a spring-pressed valve **37** having a stem **38** extending down into the bag. When the bottom of the bag rises high enough to push upward on this stem, the valve is opened and oxygen will flow through the port into the bag to expand the bag until the valve closes again. The make-up line is connected to an oxygen pipe **39** extending from a pressure regulator **40**, the inlet of which is con-

nected to a suitable supply of oxygen under pressure, such as a number of oxygen tanks **41**. The pipe between the pressure regulator and the tanks may be provided with a pressure operated electric switch **42** that will close when the pressure in the pipe falls below a predetermined value. When the switch closes, it fires an oxygen candle **43** that is connected with the tanks to build up the pressure again for a short period of time.

After oxygen has been added to the system through valve **37**, the bag may be fully expanded at the next exhalation. When that occurs, the excess pressure is vented from the system by a check valve in the bag. Thus, the bottom of the bag is provided with an outlet **45** that normally is closed by a spring-pressed valve **46**. This valve has a stem **47** that projects from the outlet and which will engage the bottom of the housing just before the bag is fully expanded. This will stop the downward movement of the valve but, as the bag continues to expand, the valve will open and allow excess air to escape into the housing and out through valve **21**.

The oxygen pipe **39** also is connected through a normally closed electrically operated valve **50** to an aneroid controlled flow regulator **51**, the outlet of which is connected into the system, such as into conduit **7**. This valve is opened at predetermined intervals of time, such as about every half hour, by means of an electric timer **52**. When the valve is opened, oxygen is delivered to the system to purge it, the excess gas causing the bag to fully expand and thereby open check valve **46** so that the system will be flushed out through housing valve **21**.

Another feature of this invention is that this apparatus automatically is converted into a pressure breathing system when the ambient pressure falls below a predetermined value, such as when this apparatus is used in aircraft at high altitudes. When a predetermined altitude is reached at which the desired pressure in the system otherwise would be lost, an altitude switch **54** closes and short circuits timer **52** by closing a relay **55** connected around the timer, so that oxygen valve **50** opens and remains open. Since the increased pressure thus produced in the system closes blower valve **27** and would normally expand the bag to its full length and thereby cause the check valve in its bottom to open and allow the oxygen to escape, the altitude switch simultaneously closes the outlet valve **21** to seal the bag housing. At the same time, the altitude switch opens a normally closed electrically operated valve **56** at the outer end of conduit **13** connected with the bag housing opening **15**. As it is necessary to prevent the oxygen in the system from flowing out of the system through this vent valve as fast as it enters through the regulator, a pressure regulating valve **57** is mounted in conduit **13** in front of the vent valve for maintaining the desired pressure in the system. Only when that pressure is exceeded does oxygen escape through the vent.

Pressure regulating valve **57** may be any valve that can be adjustably loaded to prevent it from opening until a predetermined pressure in conduit **13** is reached. However, it is preferred to use a valve, the loading on which is varied automatically with the variations in opening of oxygen regulator **51** with altitude. Such a valve may be like blower valve **27**, in which case the valve **57** is connected by a static tube **58** with the outlet of regulator **51**. Therefore, as the regulator opens wider as higher altitudes are reached, the pressure in the static tube increases and consequently it requires more pressure in the system to open valve **57** before gas can escape through that valve and vent valve **56**.

I claim:

1. In closed circuit breathing apparatus, a breathing mask, a breathing bag, a housing containing the bag and having an inlet and outlet communicating with the inside of the bag, conduit means connecting the mask with said inlet and outlet to permit breathing into and out of the bag, a spring inside the bag normally maintaining it expanded, the housing having a second inlet isolated from the inside of the bag, means connected with the second inlet for periodically pressurizing the housing to collapse the bag during periods of inhalation from the bag, the housing having a second outlet for escape of air pressure therefrom between said inhalation periods to permit the spring to expand the collapsed bag, said bag having a portion provided with an opening movable toward and away from a wall of said housing, a valve normally closing said bag opening and having a member projecting therefrom engaging said housing wall when the bag approaches full expansion to open the valve, a normally open valve for said second outlet, a normally closed valve having an outlet in communication with said first-mentioned inlet, an oxygen supply line connected to the inlet of said last-mentioned valve, and means for opening the last-mentioned valve and closing said normally open valve.

2. In closed circuit breathing apparatus, a breathing mask, a breathing bag, a housing containing the bag and having an inlet and outlet communicating with the inside of the bag, conduit means connecting the mask with said inlet and outlet to permit breathing into and out of the bag, a spring inside the bag normally maintaining it expanded, the housing having a second inlet isolated from the inside of the bag, means connected with the second inlet for periodically pressurizing the housing to collapse the bag during periods of inhalation from the bag, the housing having a second outlet for escape of air therefrom between said inhalation periods to permit the spring to expand the collapsed bag, a normally closed valve having an outlet in communication with said first-mentioned inlet, an oxygen supply line connected to the inlet of said normally closed valve, said apparatus being provided with an outlet connecting the inside of the bag to atmosphere, a normally closed valve for said atmosphere outlet, means for opening said normally closed valves, and means for maintaining a predetermined oxygen pressure in the bag while said atmosphere outlet is open.

3. In closed circuit breathing apparatus, a breathing bag, a housing containing the bag and having an inlet and outlet communicating with the inside of the bag to permit breathing into and out of the bag, a spring inside the bag normally maintaining it expanded, a breathing mask, an air purifying canister, breathing conduits connecting said mask and canister with said bag inlet and outlet, the housing having a second inlet isolated from the inside of the bag, means connected with the second inlet for periodically increasing the air pressure inside the housing to collapse the bag during periods of inhalation at said mask, means controlling said first-mentioned means responsive to increase in air pressure in the mask during exhalation between said inhalation periods for rendering said first-mentioned means ineffective, the housing having a second outlet for escape of air therefrom to permit the spring to expand the collapsed bag during exhalation at the mask, a normally open valve for the second outlet, said bag having a portion movable toward and away from a wall of said housing and provided with an opening, a spring-pressed valve normally closing said opening and having a stem projecting therefrom engaging said housing wall when the bag approaches full expansion to open the valve, a normally closed valve having an outlet connected with one of said conduits, an oxygen supply line connected to the inlet of said last-mentioned valve, and means responsive to a predetermined low ambient pressure for opening the last-mentioned valve and closing said normally open valve.

4. In closed circuit breathing apparatus according to claim **3**, said apparatus being provided with an outlet connecting the inside of the bag to atmosphere, a normally closed vent valve for said atmosphere outlet, means for opening said vent valve while said normally open valve is closed, and means for maintaining a predetermined oxygen pressure in the bag while the vent valve is open.

5. In closed circuit breathing apparatus, a breathing

mask, a breathing bag, a housing containing the bag and having an inlet and outlet communicating with the inside of the bag, a conduit connecting the mask with said inlet and outlet to permit breathing into and out of the bag, a spring inside the bag normally maintaining it expanded, the housing having a second inlet and an open second outlet isolated from the inside of the bag, means connected with the second inlet for forcing air into the housing faster than it can escape through said second outlet in order to pressurize the housing to collapse the bag, and means connected with the mask and operated by air pressure therefrom during exhalation for shutting off said forcing of air into the housing, whereby said spring can expand the bag while forcing air out of the housing through said second outlet.

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