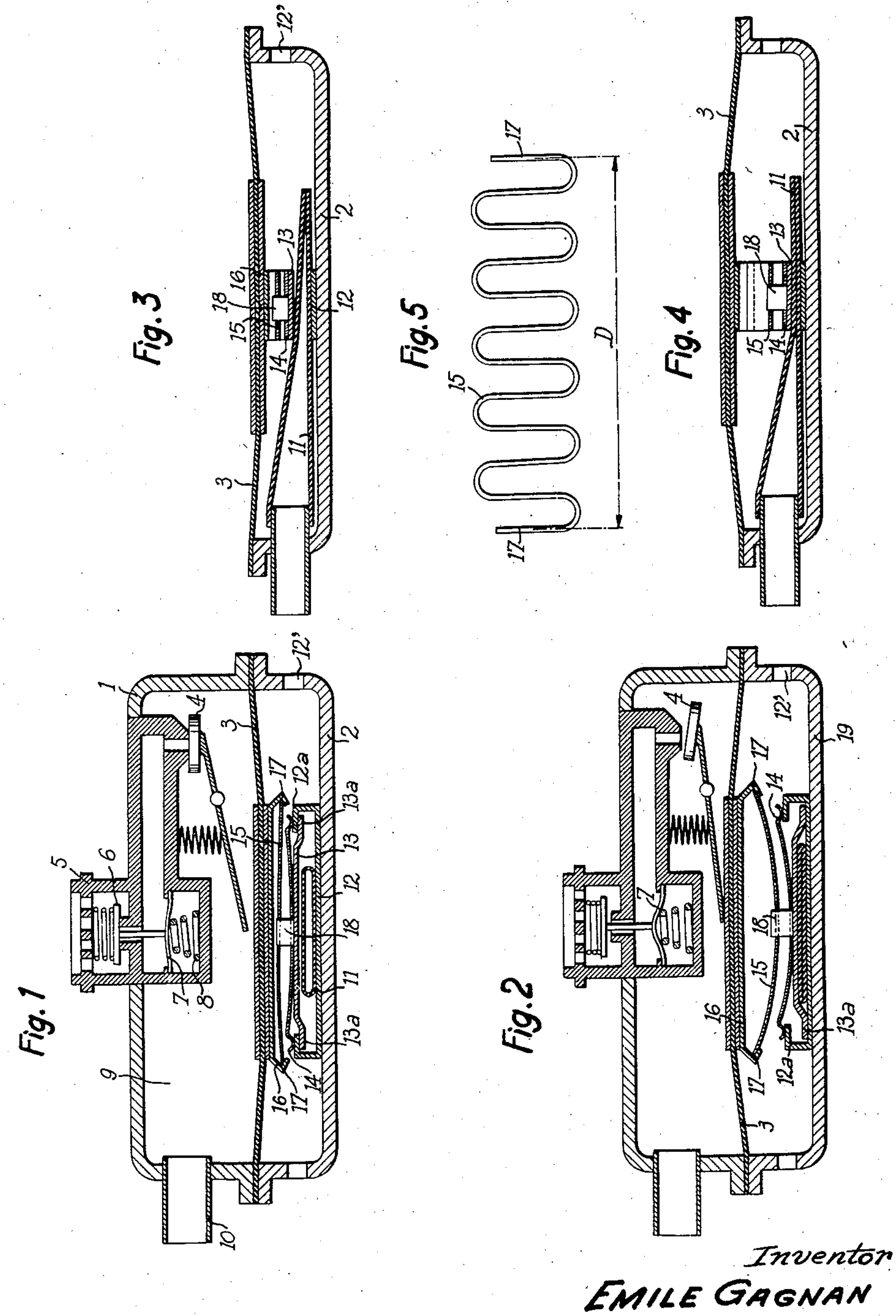
Nov. 4, 1958 E. GAGNAN 2,858,829

OPEN CIRCUIT RESPIRATORY APPARATUS

Filed March 31, 1955 2 Sheets-Sheet 1



Inventor
EMILE GAGNAN
By
Attorney

Nov. 4, 1958 E. GAGNAN 2,858,829

OPEN CIRCUIT RESPIRATORY APPARATUS

Filed March 31, 1955 2 Sheets-Sheet 2

Fig.6

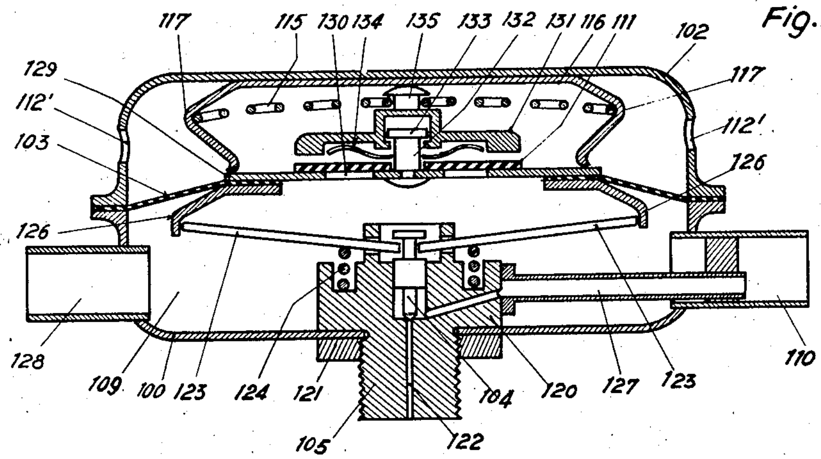


Fig.7

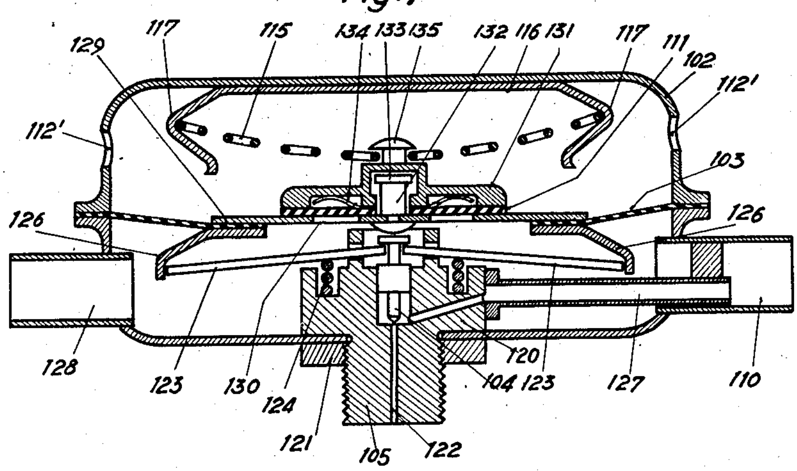
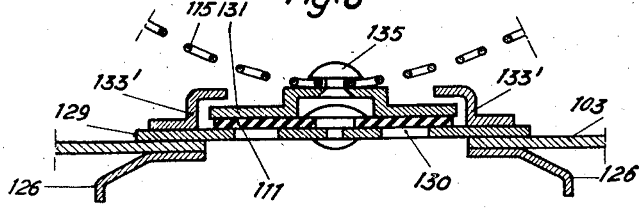


Fig.8



INVENTOR

EMILE GAGNAN

By Alan Swasey

PATENT ATTORNEY

United States Patent Office

2,858,829

Patented Nov. 4, 1958

1

2,858,829

OPEN CIRCUIT RESPIRATORY APPARATUS

Emile Gagnan, Montreal, Quebec, Canada, assignor to La Spirotechnique, Societe Anonyme, Paris, France

Application March 31, 1955, Serial No. 498,367

13 Claims. (Cl. 128—142)

The present invention is related to open circuit respiratory apparatus for use in a non-breathable atmosphere or for under water diving.

In a known type of such apparatus, the breathable gas, air, for instance, is compressed under a high pressure in a cylinder and delivered to the user by means of a pressure regulator. It is subsequently exhausted into the surrounding medium outside by the user through an exhaust valve. Usually, the regulator supplies the air in response to the inhalation of the user acting on the diaphragm of the apparatus.

The present invention aims to provide a device of this nature which allows air to be supplied to the user at a pressure higher than that supplied by a depression regulator, while allowing the expiration of this air at a pressure lower than the supply pressure. The respiratory air volumes are thus "blown in" and expiration takes place without the least sensation of effort, the result being a great ease of breathing, particularly appreciated by divers.

In order to obtain this result, the apparatus according to the invention utilizes a stored volume of compressed gas which is fed into a regulator similar to those of usual apparatus, but in which the diaphragm is subjected to the action of a variable action device the thrust of which upon said diaphragm decreases when the latter moves away from its operative position for driving the delivery valve of the regulator, means being provided for controlling the expiration flap of the respiratory circuit so as to close it while the regulator is delivering fresh air.

Other features and advantages of the invention will appear from the following description of three embodiments of a respiratory apparatus represented, by way of example only, in the appended drawings, in which:

Figure 1 is an axial section of a regulator with its diaphragm in the position of release of the exhaust valve flap or expiration position.

Figure 2 is a view, similar to Figure 1, but with the diaphragm in the air intake or inhalation position, the exhaust valve flap being locked.

Figure 3 is a partial axial section of the expander through a plane perpendicular to the section plane of Figure 1.

Figure 4 is a view similar to Figure 3, but corresponding in location to Figure 2.

Figure 5 is a plan view of one preferred embodiment of the spring used in the apparatus of Figures 1 to 4.

Figure 6 is an axial section of an alternative construction of the regulator assembly of a respiratory apparatus, the exhaust valve flap of which is located on the diaphragm, the elements of this regulator being represented in the relative positions which correspond to an expiration.

Figure 7 is a similar view, but for an air intake or inhalation phase.

Figure 8 shows, in axial section, a further simplified modification of the exhaust valve flap and its locking device during an air intake or inhalation phase.

2

The regulator used in the open circuit respiratory apparatus of the general type considered and represented in Figures 1 to 4 comprises, as some devices of this type, a casing formed of two portions **1** and **2**, between which there is tightly clamped a flexible diaphragm or deformable membrane **3**, the motions of which control an air intake flap valve **4** in the channel supplying air to the user.

In the construction shown, the valve flap **4** is disposed at the outlet end of a first stage regulator which is adapted to supply air under pressure from a high pressure cylinder (suitably connected to the intake end **5** of the regulator) at a pressure between the pressure of air in the cylinder and the inhalation pressure of the user. The valve flap **4** is mounted on the end of a lever arm **4*a*** pivotally mounted as indicated at **4*b*** and is normally resiliently biased into closing position by a spring **4*c***.

The other end of the lever arm **4*a*** is in the path of the centre of the regulator diaphragm **3** so that flexure of the diaphragm by inhalation of the user acts to open the valve flap **4**.

The first stage regulator shown is mounted in the upper portion **1** of the casing and consists of a valve **6** which is controlled by a diaphragm **7**. The valve **6** includes a stem **6*a*** which contacts the diaphragm **7** and the diaphragm **7** is subjected on the outer face to the thrust of a spring **8** and to the pressure of the air in the inhalation chamber **9**.

A suitable connection, not illustrated, is provided to the chamber **9**, through the pipe **10**, from the usual air delivery conduit extending to the diver's mask or mouthpiece. An air exhaust conduit (not illustrated) leads from the mouthpiece or mask to the lower portion of the casing and is connected to the exhaust flap valve **11**.

As shown, the diaphragm **3** seals off the inhalation chamber **9** from the lower casing portion **2** and the lower casing portion **2** is provided with a plurality of openings **12′** so that the pressure of the surrounding water, when the apparatus is in use, acts on the lower surface of the diaphragm.

In accordance with the present invention, the diaphragm **3** is subjected, on its outer face, not only to the pressure of the surrounding water but also to an additional variable thrust caused by a spring, for instance, and adjusted so as to deliver the air to the respiratory tracts of the diver at a pressure higher than that of the surrounding water at the average level of the lungs, for transforming the inhalation into a forced in-blowing. During this in-blowing of air at these higher pressures, means are provided to retain the exhaust flap valve **11** in closed condition to avoid air loss to the outside.

In a preferred construction, the lips of the exhaust flap **11**, which are of the "duck bill" type, are engaged between the bottom cross-member of the yoke **12**, suitably secured on the bottom of the lower casing portion **2**, and a plate **13** supported by a flexible blade **14** abutting at its two ends against the flanged ends **12*a*** of the arms or sides of the yoke **12**. The flexible blade **14** acts as a spring for moving the plate **13** away from the cross-member of the yoke **12**, the motion being limited by the abutting of the ends **13*a*** of the plate against the flanges **12*a*** of the arms of the yoke **12**. Downward pressure of the plate **13** squeezes the lips of the flap **11** against the lower member of the yoke **12** and so maintains the exhaust flap **11** in closed condition.

The plate **13** and the flexible blade **14** which carries it are coupled with an elastic blade **15**, the two ends of which are connected with the ends of a stirrup **16** suitably secured to the outer face of the diaphragm **3**. The overall length of the blade **15** is greater than the distance between its connection points 17 to the stirrup 16 and, therefore, it is flexed or bent into an arcuate shape.

The coupling between the blade 15 and the plate 13, in the construction shown, is ensured simply by a clip 18 which connects the mid point of the blade 15 with the mid point of the blade 14. Both these blades 14 and 15, are of resilient material; for example, they may conveniently consist of resilient metal wire such as a piano wire, shaped, as shown in Figure 5, into loops lying in one plane when free, the distance D being greater than the distance between the attachment points 17 on the corresponding stirrup 16.

The operation of this arrangement is as follows:

Figure 1 corresponds to the case when the diver has just breathed out into the water and the pressure in chamber 9 has become substantially equal to the pressure of the surrounding water at the centre of thrust of the outer face of the diaphragm 3. The diaphragm 3 is shown in a position wherein the intake flap valve 4 is closed, and the blades or springs 14 and 15 occupy positions in which no appreciable resilient action is exerted on the diaphragm 3. The tension of the blade 14 overcomes that of the blade 15 (which is low, due to its flattening) and the flap 11 is released by the raising of the plate 13. The result is that expiration is effected normally through the flap 11, no overpressure being caused by the diaphragm 3.

When the user starts to breathe in, see Figure 2, the depression created in the chamber 9 depresses the diaphragm 6 inwards, the points 17 being carried along in this motion, and the clip 18 held by the plate 13 remaining fixed. As a result, the blade 15 initiates a curvature reversal and begins to push against the clip 18 with an increasing force. When this force is sufficient, the plate 13 is suddenly depressed and the blade 15, having suddenly accentuated its camber pushes back the diaphragm 3 in the direction opposite to the plate 13 with an increasing force, which has the result of causing the regulator to deliver air under an overpressure corresponding to this value increased by the reaction from the blade 15, the exhaust flap 11 being locked. This is overpressured in-breathing phase corresponding to Figure 2.

At the end of this phase, the user, by slightly forcing his expiration instigates the return motion of the diaphragm 3 towards the plate 13. As soon as this motion has been started, the effective thrust of the blade 15 on the diaphragm decreases with the attenuation of its curvature. This causes an accentuation of the initiated motion which is accelerated by the instability of the equilibrium obtained. The diaphragm 3 is suddenly pushed back and the plate 13 is again applied onto the flap 11 as soon as the thrust of the blade 15 overcomes the tension of the blade 14. The position is restored to that of Figure 1 and the expiration goes on with the complete drop of any overpressure in the respiratory circuit. The cycle of operations is then repeated at every stroke of in-breathing and expiration of the user.

In the alternative construction shown in Figures 6 and 7, the regulator is of the type having a single expansion stage. The source of air at high pressure is connected to the threaded end piece 105 of a block 120 secured by a nut 121 to the bottom of the portion 100 of the casing. The air arrives through the duct 122 and its flow is controlled by a needle valve 104 suitably guided in the block 120. This valve 104 is controlled by levers 123 which are subjected directly to the thrust of the diaphragm 103 of the regulator and which have their fulcrums on their block 120. These levers, for instance, and as shown, are subjected to the thrust of a spring 124 which keeps their inner ends in contact with parts 126 secured to the inner face of the diaphragm 103. This spring biases the needle valve 104 in its closing direction. The air delivered when the needle valve 104 is open is led through a tube 127 to the pipe 110 connected with the flexible hose leading to the mask or to the user's mouthpiece. The pipe 110 is not in direct communication with the chamber 109 of the regulator adjacent the inner face of the diaphragm 103 and the air exhausted is brought back to this chamber 109 through a tube 128 in such a way that the air delivered into the pipe 110 does not mix with the expired gases and the user only breathes pure air.

The top portion 102 or cover of the casing is secured on the portion 100 by any suitable means and tightly retains the periphery of the diaphragm 103 the central portion of which is reinforced by a rigid disc 129, provided with holes 130 and which constitutes the seat for the expiration flap 111. This flap may be formed of a flexible rubber disc for instance, and it may be locked on its seat for closing the holes 130, by a plate 131, the hub of which is guided axially by a pin 132 attached to the centre of the disc 129. The maximum spacing between the plate 131 and the flap 111 is adjusted by a stop and, for instance, by a flange 133 formed at the end of the pin 132. The plate 131 is biased in the direction away from the disc 129 by a spring 134. It is coupled, on the other hand, with the mid point of a spring 115 consisting of a blade or preferably an elastic metal wire such as shown in Figure 5 and described above. This spring is mounted between two fixed points constituted, in the construction shown, by the grooves 117 provided by folding the arms of a stirrup 116 secured on the bottom of the portion 102 of the casing of the regulator, the distance between the grooves 117 being less than the length D of the spring 115 when free. The coupling of the spring 115 and plate 131 for locking the flap 111 is effected, for instance, by forcing the branches of its central loop inside a groove of a knob 135 provided on the hub of the plate 131.

The ends of the arms of the stirrup 116 constitute stops for limiting the displacements of the diaphragm 103 towards the bottom of the casing portion 102, or upwards, in the construction shown in the drawings.

The operation is as follows:

The relative positions of the elements represented in Figure 6 correspond to the expiration phase. The diaphragm 103, subjected on its outer face to the pressure of the surrounding medium which acts through the holes 112' of the casing portion 102 has been pushed back by the expiration thrust and the spring 115 has been pushed back towards the bottom of the casing portion 102; the plate 131 is moved away by the spring 134 of the exhaust flap 111 which is released and the user breathes out normally through the pipe 128 and orifices 130 and 112'. At the end of the expiration, the user starts a depression which closes the flap 111 and causes a displacement of the diaphragm 103 in the opening direction of the needle valve 104. This displacement of the diaphragm 103 is transmitted to the mid point of the spring 115 by the pin 132 and knob 135 and when the spring 115 is sufficiently bent it applies to the plate 131 a thrust which is sufficient for applying it in the flap 111 by overcoming the reaction of the spring 134. The exhaust flap 111 is locked and, through the levers 123, the needle valve 104 is opened and delivers air at a pressure which is determined by the valve of the thrust caused by the spring 115. The components of the apparatus are then in the positions represented in Figure 7.

At the end of the inhalation phase, the user stops inhaling and begins a new expiration phase by initially accentuating the forcing back effect of the gases which he exhausts into the regulator. The diaphragm 103 is displaced in the direction for shutting the needle valve 104 and when the thrust of the spring 134 exceeds that of the spring 115 the plate 131 moves suddenly away from the flap 111 and all the elements resume the positions they occupied in Figure 6 and which correspond to an expiration phase. The operating cycle described above is repeated.

In the further modified embodiment represented in Figure 8, the spring 134 has been omitted, which, in the case of the constructions shown in Figures 6 and 7, tends to move the plate 131 away from the disc 129. In the construction shown in Figure 8, the stop which limits the relative spacing of these two elements is constituted by lugs 133' suitably secured on the disc 129. In this modified embodiment, use is made of the point of the stroke of the centre of the spring 115 where the reversal of the direction of thrust of this spring takes place. When the user holds back his inhalation for starting the expiration phase, the diaphragm 103 is pushed upwards and the camber of the spring 115 is reversed as well as the force it applies to the plate 131; the latter is moved away from the disc 129 thereby releasing the exhaust flap 11 which opens for the expiration phase.

At the end of the expiration, the suction exerted by the inhalation of the user causes a downward displacement of the diaphragm 103 and the reversal of the camber of the spring 115 and of the direction of the force it exerts on the plate 131; the latter is applied on the disc 129 and locks the exhaust flap 111, the diaphragm 103 regulating the air delivery according to the pressure required.

What I claim is:

1. In an open circuit breathing apparatus of the type having a presure regulator including an inner chamber, an inlet valve in said chamber for a breathable gas fed from a pressure source, valve controlling means mounted in said regulator including a flexible diaphragm having an outer face subjected to the pressure of the medium surrounding the regulator, an exhaust valve mounted in said regulator adjacent the exterior surface of said diaphragm, an air intake connection extending from said regulator chamber to a mouthpiece and an exhaust connection extending from said mouthpiece to said exhaust valve, a resilient variable action means mounted in said regulator adjacent to and in operative connection with said diaphragm and exhaust valve adapted to apply a supplemental force to said diaphragm and a closing force to said exhaust valve during movement of said diaphragm in the direction opening said air valve and a quick reverse force to said diaphragm and release of said exhaust valve during movement of said diaphragm in the opposite direction, whereby air is caused to be delivered to the user at a pressure higher than the pressure of the medium acting on said diaphragm and is exhausted through said exhaust valve by the user at a pressure lower than said air delivery pressure.

2. In a breathing apparatus as claimed in claim 1 wherein said exhaust valve is disposed in spaced apart relationship from said diaphragm and said variable action means comprises a cambered resilient spring disposed between said diaphragm and exhaust valve, said spring being connected to said diaphragm and also to valve closing means disposed in operative engagement with said exhaust valve.

3. In a breathing apparatus as claimed in claim 1 wherein said exhaust valve is mounted on said diaphragm and said variable action means comprises a cambered resilient spring connected to said exhaust valve.

4. In a breathing apparatus as claimed in claim 2 wherein said cambered resilient spring consists of a flat blade of resilient metal mounted adjacent to and centrally of said diaphragm between two spaced apart retaining members in a normally arcuate shape with the connection to said valve closing means located centrally of said blade.

5. In a breathing apparatus as claimed in claim 2 wherein said cambered resilient spring consists of an elongated length of resilient metal wire shaped into parallel loops forming a flat resilient band, said band being mounted adjacent to and centrally of said diaphragm between two spaced apart retaining members in a normally arcuate shape with the connection to said valve closing means located centrally of said formed resilient band.

6. In a breathing apparatus as claimed in claim 3 wherein said cambered resilient spring consists of an elongated length of resilient metal wire shaped into parallel loops forming a flat resilient band, said band being mounted adjacent to and centrally of said diaphragm between two spaced apart retaining members in a normally arcuate shape with the connection to said exhaust valve located centrally of said band.

7. In an open circuit breathing apparatus of the type having a pressure regulator including a casing having an inner chamber, air inlet valve in said chamber for a breathable gas fed from a pressure source, valve controlling means mounted in said regulator including a flexible diaphragm having an inner face forming one wall of said inner chamber and an outer face subjected to the pressure of the medium surrounding the regulator, a flapper type exhaust valve mounted on said regulator casing adjacent the outer surface of and in substantial alignment with said diaphragm, air intake and exhaust connections from a mouthpiece to said regulator inner chamber and exhaust valve respectively, a supporting stirrup having spaced apart terminal arms mounted on said diaphragm outer face, an elongated resilient member mounted between the arms of said stirrup whereby it is retained in a tensioned arcuate form, a flanged yoke mounted in said casing with the flanges disposed each side of said exhaust valve and a pressure plate mounted for sliding movement between said yoke flanges and extending over said exhaust valve, a resilient flat spring connected centrally to said pressure plate with the terminal ends bearing on said yoke flanges, and a connecting member between said flat spring and the centre of said bowed elongated resilient member supported by said diaphragm, whereby deflection of said diaphragm in one direction by inhalation of the user and the pressure of the surrounding medium is augmented by the resilient tensioned action of said elongated member to apply an increased deflecting force to the diaphragm and the further bowing of said elongated member forces said flat spring in a reverse arc against said pressure plate closing said exhaust valve, and during expiration the pressure within the inner chamber against the diaphragm deflects the diaphragm in the opposite direction and augmented through the reflex of said flat spring, the arc of said elongated member is reversed releasing said exhaust valve allowing expiration of air at a pressure lower than the pressure at which it was delivered to said inner chamber.

8. In an open circuit breathing apparatus as claimed in claim 7 wherein said elongated resilient member comprises a flat spring.

9. In an open circuit breathing apparatus as claimed in claim 7 wherein said elongated resilient member comprises a length of resilient metal wire formed in parallel undulating loops forming a substantially flat resilient band.

10. In an open circuit breathing apparatus of the type having a pressure regulator including a casing having an inner chamber, an inlet valve in said chamber for a breathable gas fed from a pressure source, valve controlling means mounted in said regulator including a flexible diaphragm having an inner face forming one wall of said inner chamber and an outer face subjected to the pressure of the medium surrounding said regulator, said diaphragm including at least one opening constituting an exhaust gas passage from said inner chamber, an exhaust flap valve mounted on said diaphragm and controlling the passage of exhaust gas through said diaphragm, flap controlling means mounted on said diaphragm over said exhaust flap, a supporting yoke having spaced apart arms mounted in said casing above and in alignment with said exhaust flap controlling means, an elongated resilient

variable action member mounted between said yoke arms in a tensioned arcuate formation and being connected centrally of its length to said flap controlling means, and air intake and exhaust connections from a mouthpiece to said air inlet valve and inner chamber respectively, whereby inhalation of the user acts to flex the diaphragm in one valve opening direction and the valve opening action of the diaphragm under the pressure of the surrounding medium is resiliently increased by said resilient member while the resilient member is bowed so as to depress the said flap controlling means to retain said flap in closed condition, and upon expiration, the diaphragm is flexed in the opposite direction so as to reduce and suddenly reverse the curvature of said resilient member raising said exhaust flap control means allowing expiration of air at a pressure lower than the pressure at which it was delivered from said air inlet valve.

11. In an open circuit breathing apparatus as claimed in claim 10 wherein said exhaust flap controlling member is resiliently biased away from said flap by a cambered spring disposed between said exhaust flap and flap controlling member.

12. In an open circuit breathing apparatus as claimed in claim 10 wherein said elongated resilient member comprises a length of resilient metal wire formed in parallel undulating loops forming a substantially flat resilient band.

13. In an open circuit breathing apparatus of the type having a pressure regulator including an inner chamber, an inlet valve in said chamber for a breathable gas fed from a pressure source, valve controlling means mount-

ed in said regulator including a flexible diaphragm having an outer face subjected to the pressure of the medium surrounding the regulator, an exhaust valve mounted in said regulator adjacent the exterior surface of said diaphragm, an air intake connection extending from said regulator chamber to a mouthpiece and an exhaust connection extending from said mouthpiece to said exhaust valve, a first resilient variable action member mounted in said regulator adjacent to and in operative connection with said diaphragm and a second resilient variable member in operative connection with said exhaust valve, said first and second resilient variable action members being flexed in one direction by the movement of said diaphragm in the inhalation phase to add a supplemental force to the inlet valve opening action of said diaphragm, and by its connection said first resilient member flexes said second resilient member in an exhaust valve closing direction, and in the initial reverse movement of said diaphragm in the exhaust phase said flexed second resilient member overcomes the resilient action of said first member and quickly reverses its flexure to augment the exhaust valve opening movement of said diaphragm, whereby air is caused to be delivered to the user at a pressure higher than the medium acting on said diaphragm and is exhausted through said exhaust valve by the user at a pressure lower than said air delivery pressure.

References Cited in the file of this patent

UNITED STATES PATENTS

2,453,475 Tobias ---------------- Nov. 9, 1948