Jan. 19, 1960 A. M. MAYO 2,921,594

BREATHING APPARATUS

Filed April 1, 1955 2 Sheets-Sheet 1

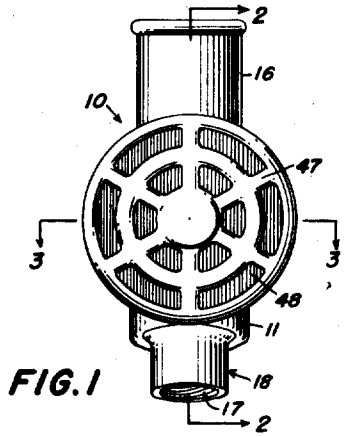


FIG. 1

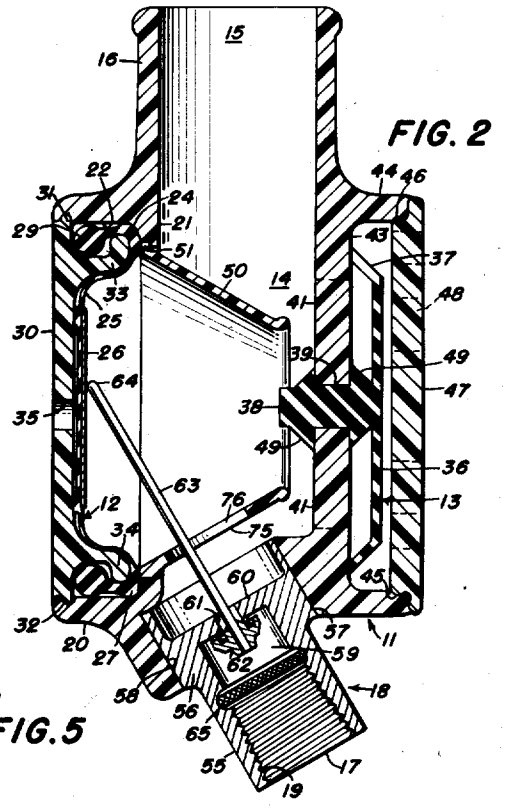


FIG. 2

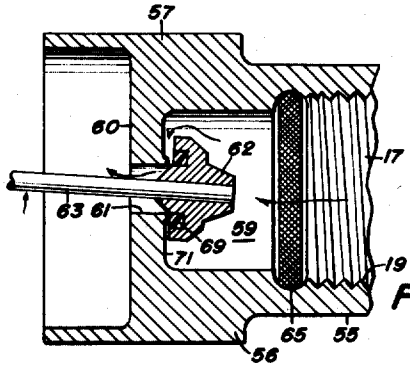


FIG. 5

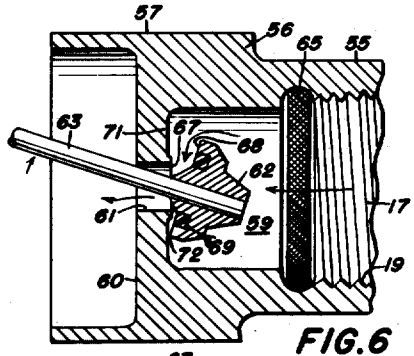


FIG. 6

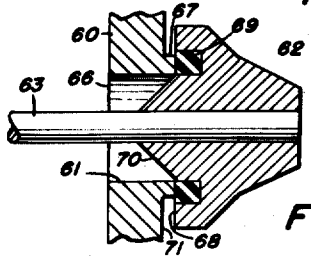


FIG. 4

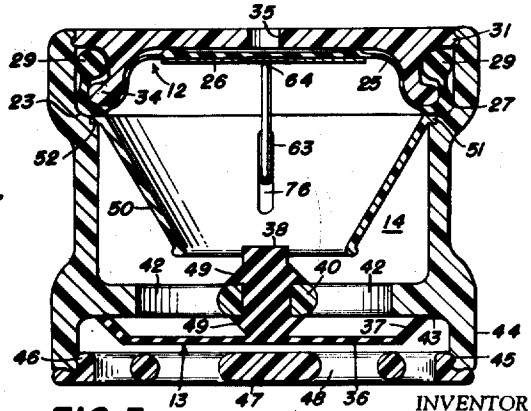


FIG. 3

INVENTOR
ALFRED M. MAYO

BY

ATTORNEY

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BREATHING APPARATUS

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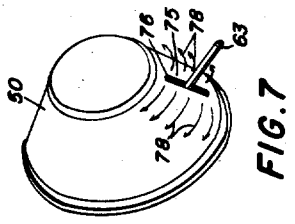
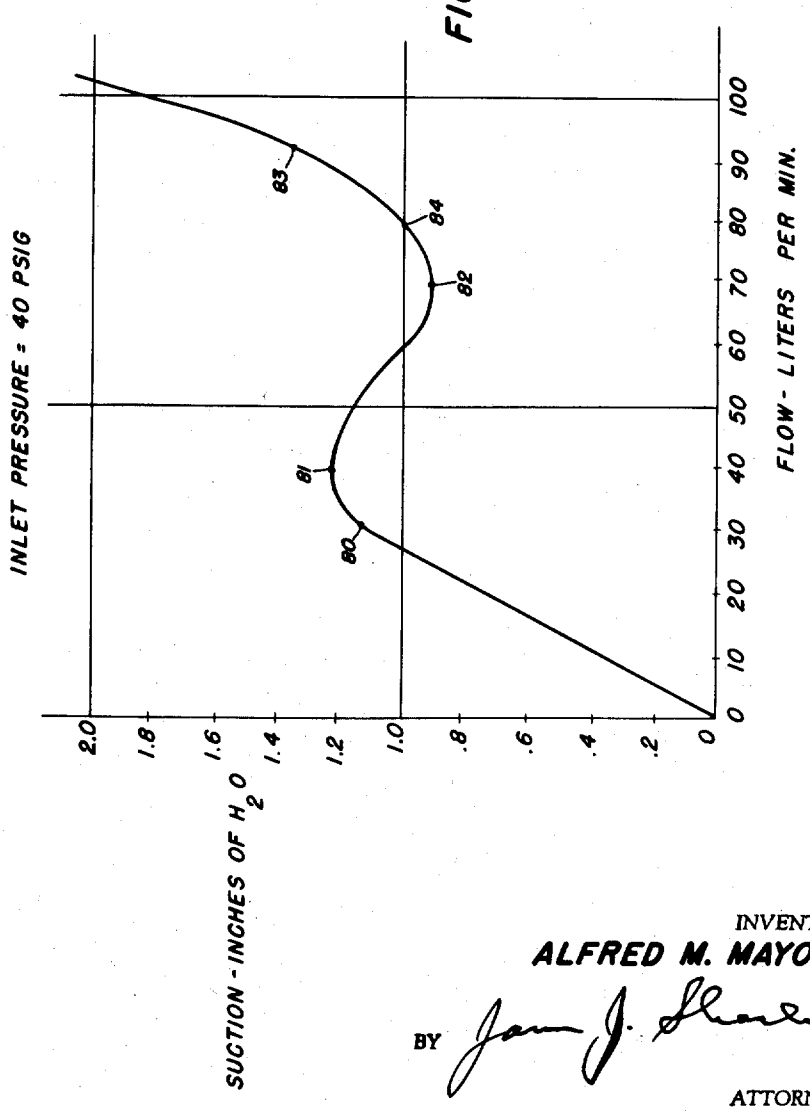


FIG. 7

FIG. 8



INVENTOR
ALFRED M. MAYO
BY
ATTORNEY

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BREATHING APPARATUS

Alfred M. Mayo, Palos Verdes Estates, Calif.

Application April 1, 1955, Serial No. 498,593

6 Claims. (Cl. 137—64)

This invention relates to improvements in breathing apparatus of the demand type.

Breathing apparatus of the demand type operate on the principle of supplying breathing fluid, such as air or oxygen or a mixture of air and oxygen, during the inhalation phase in the cycle of breathing and exhausting used or foul fluid during the exhalation phase. This is usually accomplished by apparatus including inhalation and exhalation diaphragms subject to pressure differentials between the respiration pressure and the ambient pressure. The exhalation diaphragm operates responsively to relatively high respiration pressure created during the exhalation phase of the breathing cycle for exhausting foul breathing fluid expired from the lungs. Generally, the inhalation diaphragm forms a wall of a pressure or respiration chamber communicating with the tracheal passage of the person being served and is constructed to move in accordance with suction created during the inhalation phase for operating a valve device which controls the flow of breathing fluid from a relatively high pressure source into the chamber and hence to the lungs. Due to the short period of the breathing cycle and the short interval of the inhalation phase of each cycle, it is necessary to provide an apparatus capable of responding quickly to extremely small pressure differentials, such as a pressure less than one inch of water, and supplying a volume of breathing fluid during the inhalation phase, in accordance with the demand of the person being served, in order to permit natural breathing under pressure without requiring expenditures of more than normal breathing efforts. Breathing apparatus provided by prior art, although capable of responding fairly quickly to small pressure differentials, require the development of a measurable force for operating the valve device which controls the flow of breathing fluid into the pressure chamber. Since the operating force for the valve device is derived from the suction developed during the inhalation phase, it presents resistance to breathing.

Generally the valve device comprises an orifice connecting the respiration chamber and the source of relatively high pressure breathing fluid, and a valve member positioned for cooperation with the orifice to control the flow of fluid therethrough. The valve member is located on the high pressure side of the orifice to utilize the relatively high pressure of the source of breathing fluid for holding the valve member in closed position. In order that the valve member may open responsively to slight pressure differentials on the inhalation diaphragm, the diaphragm and the valve member are operatively connected through a force multiplying arrangement as provided by a tilt valve assembly, for example. In such an assembly the valve member is in the form of a disc joined to one end of a valve stem of small cross-sectional area as compared to the diameter of the orifice. The valve stem passes through the orifice and into the respiration chamber with its other end in operative relation with the inhalation diaphragm. The valve stem is disposed at an

oblique angle with respect to the plane of the inhalation diaphragm so that the valve member tilts about one side of the orifice and moves away from a diametrically opposite side upon movement of the diaphragm responsively to suction developed during the inhalation phase. For uniform dependable operation of this type of valve device it is necessary to provide means for concentrically positioning the valve stem and the valve member with respect to the orifice when the valve member is in closed position. The prior arrangements employ spring means for accomplishing this centering function which inherently increases the force required for moving the valve member from the closed position. Since there exists a limit to the degree of force amplification obtainable, due to the practical size of the breathing apparatus and the required flow characteristics of the orifice, for example, the force required to overcome the action of the centering spring means before the valve member moves from the closed position, increases the breathing effort.

Conventional breathing apparatus of the above type do not provide a volume of breathing fluid during the inhalation phase of the breathing cycle in accordance with the actual demand of the individual being served, and are not capable of providing natural breathing without the expenditure of an abnormal breathing effort or without employing an extremely large diaphragm which results in an unwieldy regulator. This is so even if the degree of opening of the valve device controlling the flow of breathing fluid to the respiration chamber is substantially proportional to the force applied to the diaphragm by the suction developed during the inhalation phase of the breathing cycle. The force required to initially move the valve device from its closed position, including the force required to overcome the resistance offered by the valve member centering means, prevents establishment of a true proportional relationship between the suction and the degree of valve opening. Also, the volume of breathing fluid introduced into the respiration chamber during the inhalation phase is adversely disproportional to the degree of suction developed. This results from certain inherent characteristics of the demand type of breathing apparatus in addition to the resistance that must be overcome to initially move the valve apparatus from its closed position. The pressure drop due to friction in the passageway between the valve apparatus and tracheal passage of the person being served, and the effect upon the suction acting on the inhalation diaphragm by the stream of breathing fluid introduced into the respiration chamber, are probably predominant factors effecting this result.

In the case of artificial breathing under water in which a pressurized diving suit is not employed, commonly known as "skin diving" further problems are presented. In addition to the requirement of a breathing apparatus of light weight, compact and sturdy construction designed for relatively easy manufacture at low cost, the high density of water presents problems not present when breathing in fluids of relatively lighter density, such as atmospheric or subatmospheric air. As mentioned above, breathing apparatus of the demand type generally include inhalation and exhalation diaphragms operative responsively to slight pressure differentials for controlling the flow of breathing fluid to the tracheal passage during the inhalation phase, and exhausting foul or used breathing fluid during the exhalation phase, respectively. Due to the relatively great density of water, in order to prevent a material increase in the breathing effort, the inhalation and exhalation diaphragms must operate at substantially the same pressure differential. If a pressure differential exists between the operating pressures of the

diaphragms, a proportionally greater breathing effort will be required to permit natural breathing.

It is therefore an object of the present invention to provide a breathing apparatus capable of permitting natural breathing under pressure without the need of expending more than normal breathing efforts.

Another object is to provide a novel breathing apparatus in which the volume of breathing fluid supplied to the tracheal passage of the person being served during the inhalation phase of the breathing cycle is in accordance with the person's actual demand.

Another object is to provide a novel breathing apparatus in which the volume of breathing fluid introduced into the respiration chamber during the inhalation phase of a breathing cycle is not directly proportional to the degree of suction acting on the inhalation diaphragm.

Another object is to provide a novel breathing apparatus of the demand type in which a volume of breathing fluid is introduced into the respiration chamber during the exhalation phase of a breathing cycle in excess of a volume of breathing fluid proportional to the degree of suction acting on the inhalation diaphragm, to supply a volume of breathing fluid to the tracheal passage in accordance with the actual demand of the person being served.

Another object is to provide a breathing apparatus including a novel valve assembly for controlling the flow of breathing fluid into the respiration chamber which is self-centering and does not require an additional breathing effort to effect the centering operation.

Other objects and features of the present invention will appear more fully from the following detailed description considered in connection with the accompanying drawings which disclose one embodiment of the invention. It is to be expressly understood that the drawings are designed for purposes of illustration only and not as a definition of the limits of the invention, reference for the latter purpose being had to the appended claims.

In the drawings, in which similar reference characters denote similar elements throughout the several views:

Fig. 1 is an elevational view of a breathing apparatus constructed in accordance with the principles of the present invention;

Fig. 2 is a view in section taken along the line 2—2 of Fig. 1;

Fig. 3 is a view in section taken along the line 3—3 of Fig. 1;

Fig. 4 is an enlarged fragmentary view in section of a valve device shown in Fig. 2, the valve device being illustrated in closed position;

Fig. 5 is an enlarged fragmentary view in section of the valve device shown in Fig. 2, the valve device being illustrated in one phase of its open position;

Fig. 6 is an enlarged fragmentary view in section of the valve device shown in Fig. 2, the valve device being illustrated in another phase of its open position;

Fig. 7 is an isometric view of a portion of the breathing apparatus shown in Figs. 2 and 3 illustrating a principle of operation employed by the present invention, and

Fig. 8 is a diagram illustrating the suction-flow characteristic of a breathing apparatus constructed in accordance with principles of the present invention.

In general the present invention provides a breathing apparatus of the demand type including a respiration chamber having an outlet adapted for communication with a person to be served and an inlet communicating with the respiration chamber through an orifice controlled by a valve device and adapted to be connected to a source of breathing fluid under relatively high pressure. An inhalation diaphragm and an exhalation diaphragm are provided forming opposed walls of the respiration chamber and are adapted to move responsively to differential variations in pressure within and without the chamber. The inhalation diaphragm operates a tilt valve device of a two-stage type which controls the flow of fluid from the inlet through the orifice, while the inhalation diaphragm controls valve means for exhausting used or foul gas from the respiration chamber to without the breathing apparatus. An arrangement is also provided for reducing the pressure within the respiration chamber responsively to the flow of a stream of breathing fluid thereto. The latter arrangement and the two-stage tilt valve device, while functioning independently to effect a supply of breathing fluid in accordance with the actual demand of the individual being served, combine to produce a performance which enables the person being served to experience natural breathing cycles under pressure without the need for the expenditure of more than normal breathing efforts.

As shown in Figs. 1, 2 and 3 of the drawings a breathing apparatus **10** constructed in accordance with the principles of the present invention comprises a main hollow casing **11** of substantially cylindrical form adapted to support an inhalation diaphragm **12** forming one of its walls and an exhalation diaphragm **13** forming another wall in diametric relation with the inhalation diaphragm. The casing **11** and the diaphragms **12** and **13** define a respiration chamber **14** having a fluid outlet **15** formed by a cylindrical extension **16** from one side of the casing **11**, and a fluid inlet **17** of a valve assembly **18** positioned in an opposite side of the casing. The fluid outlet **15** is adapted to be connected to the tracheal passage of the person being served, by means of a flexible conduit and a breathing mask, for example, and functions as a passageway for breathing fluid on its way to the tracheal passage as well as for conducting to the respiration chamber used or foul fluid expelled from the lungs during the exhalation phase of the breathing cycle. The inlet **17** includes a threaded bore **19** adapted for forming a connection with a source of breathing fluid under relatively high pressure. The breathing fluid may comprise atmospheric air, oxygen, or atmospheric air enriched with oxygen stored under relatively high superatmospheric pressure in a portable container designed for such purposes.

The inhalation diaphragm **12** is supported within a circular flange **20** extending outwardly from the casing **11**. An annular flange **21** projects inwardly from the internal cylindrical surface **22** of the cylindrical flange **20** and presents an outwardly facing cylindrical shoulder **23** spaced inwardly with respect to the outer edge of the cylindrical flange and joined to the inner surface **20** by a fillet portion **24**. The inhalation diaphragm **12** may be constructed of any suitable flexible material, such as rubber, and includes a main circular body portion **25** provided with a centrally located bearing plate **26**. At its periphery the portion **25** merges into an enlarged annular portion **27** supported by the annular shoulder **23**. The enlarged portion may be formed to fit snugly against the fillet portion **25** and the adjacent portion of the inner surface **20**. The enlarged annular portion **27** extends rearwardly a short distance away from the annular shoulder **23** and terminates in an enlarged annular bead **29** of circular cross section. The inhalation diaphragm is maintained in the position shown in the drawings by means of circular cover member **30** joined to the cylindrical flange **20** by a circumferential bead **31** projecting from the edge of the cover member and adapted to enter a complementary circumferential groove **32** provided in the cylindrical flange adjacent its outer edge. The circular cover plate includes an inwardly projecting annular flange portion **33** which merges into an outwardly extending annular flange portion **34** spaced from the cover plate a distance corresponding to the cross-sectional diameter of the annular bead **29**. The external surfaces of the annular flange portion **34** which are parallel to the annular shoulder **23** and the inner surface **22** are proportioned to snugly contact corresponding inside surfaces of the enlarged portion **27**. The cover plate **30** is also provided with plurality of openings **35**, only one of which is shown in the drawings,

so that external pressure may be applied to the outside surface of the diaphragm 12.

The exhalation diaphragm 13 is also constructed of flexible material, such as rubber, and includes a main body member 36 of circular configuration merging into an angularly disposed inwardly projecting peripheral valve member 37. The exhalation diaphragm is supported on the casing by a centrally disposed member 38 extending from the main body member and tightly mounted in an opening 39 provided in a central hub 40 joined to the casing 11 by a plurality of coplanar radial members 41 spaced from each other to provide openings 42. The outer periphery of the openings 42 lie on a circle within a circle defined by the peripheral edge of the valve member 37, while the plane of the outer surface of the radial supporting members 41 extends radially outwardly beyond the circle defined by the peripheral edge of the valve member 37 to present a cylindrical valve seat 43 adapted for cooperation with the valve member. The casing 11 includes a cylindrical flange portion 44 extending outwardly from the cylindrical valve surface 43 and provided with an internal circumferential groove 45 adapted to receive a complementary circumferential bead 46 formed on the edge of a cover plate 47 which overlies the outer edge of the cylindrical flange 44. The cover plate 47 is provided with a plurality of openings 48 so that the exhalation diaphragm is subject to the pressure surrounding the breathing apparatus and to allow substantially unimpeded exhaust of used breathing gas during the exhalation phase of the breathing cycle. The exhalation diaphragm is constructed and so positioned in the casing so that the valve member 37 is in gas-tight contact with the valve seat 43 to block fluid flow through the openings 42 whenever the external pressure exceeds the pressure within the chamber 14. However, the presence of a relatively high pressure in the respiration chamber causes the periphery of the valve member to flex upwardly for exhausting the chamber. The diaphragm may be positively mounted on the casing by means of annular fillets 49 extending outwardly from the circular supporting portion 48 to contact either or both side surfaces of the hub portion 40.

A hollow member 50 of frusto-conical shape is positioned in the respiration chamber 14 in concentric relation with the inhalation diaphragm 12. The large diameter end of the conical member is supported on the casing adjacent the enlarged annular portion 27 of the diaphragm by means of an outwardly extending flange 51 adapted to lie in an annular recess 52 formed in the annular flange 21. The conical member 50 functions as a support for the inhalation diaphragm to limit inward movement of the diaphragm and thus prevent injury to the diaphragm in the event an abnormally relatively high pressure exists externally of the breathing apparatus. As described more fully below, the conical member also functions as means for reducing the pressure of the fluid acting against the inhalation diaphragm during the inhalation phase of the breathing cycle. For this reason the conical member extends a greater distance away from the periphery of the inhalation diaphragm than would be necessary to merely support the inhalation diaphragm, and terminates adjacent the chamber side of the radial supporting members 41.

The valve assembly 18 includes a cylindrical housing 55 having an enlarged end portion 56 presenting an external surface 57 adapted to snugly fit into a suitable opening 58 provided in the casing 11. If desired the surface 57 may be knurled. The inlet passageway 17 extends inwardly beyond the threaded bore 19 to form a high pressure chamber 59 defined by a transverse partition wall 60. An orifice 61 is centrally formed in the partition wall 60 to provide a fluid communication between the inlet 17 and the chamber 14. Fluid flow through the orifice 61 is controlled by a disc valve 62 located in the high pressure chamber 59. The disc valve 62 is of the tilt type and is connected to one end of a valve stem 63 which passes through the orifice 61 into the chamber 14 with its other end 64 extending into abutting relation with the bearing plate 26 of the inhalation diaphragm 12. A suitable filter member 65 may be provided in the inlet passageway 17.

The valve stem 63 is mounted at an oblique angle with respect to the plane of the inhalation diaphragm 12 and the valve assembly is constructed so that inward and outward movements of the diaphragm are converted into tilting movements of the valve member 62. Since the valve stem 63 is in concentric relation with the orifice 61 when the valve member 62 is in closed position as described below, the valve assembly 18 is mounted in the casing 11 at an oblique angle with respect to the diaphragm 12.

Details of the construction of the valve assembly 18 and the manner in which the valve 62 controls the flow of fluid from the inlet 17 to the chamber 14 are more fully understood with reference to Figs. 4, 5 and 6 of the drawings. As shown, the orifice 61 includes a discharge opening 66 on the chamber side of the partition wall 60 and is provided with a raised circumferential valve seat 67 on the inlet side. The disc valve 62 includes a valve face 68 lying in a plane perpendicular to the longitudinal axis of the valve stem 63, and the valve face is recessed to carry an annular ring 69 of resilient material, such as rubber, adapted to contact the valve seat throughout its periphery upon the disc valve being urged into contact with the valve seat and concentrically positioned with respect to the orifice 61, as shown in Fig. 4. The disc valve 62 is urged into this position responsively to the high pressure fluid in the chamber 59 acting on the surface of the disc valve opposite the valve face 68. In order to position the disc valve in concentric relation with the orifice 61, the disc valve is provided with a concentric conical portion 70 extending outwardly from the valve face 68 in a direction toward the chamber 14. The diameter of the conical portion 70 at its base adjacent the valve face is such as to snugly fit within the valve seat 67. With this arrangement, the disc valve is automatically centered with respect to the orifice upon its movement in a direction toward the chamber 14.

The valve face 68 of the disc valve 62 is of a diameter substantially greater than the diameter of the valve seat 67 and when the disc valve 62 is in closed position as shown in Fig. 4, the periphery of the valve face 68 extends radially outwardly from the valve seat in spaced relation with surface 71 on the inlet side of the partition wall 60. When the end 64 of the valve stem 63 moves to the right, as viewed in Fig. 2 of the drawings, upon inward movement of the inhalation diaphragm 12, the disc valve 62 tilts away from one side of the valve seat about a diametrically opposite point of the valve seat. This action is shown in Fig. 5. Upon further movement of the valve stem 63, the disc valve continues to tilt about a point of the valve seat until a peripheral point 72 of the valve face 68 contacts the surface 71 of the partition wall 60, and thereafter upon continued movement of the valve stem the disc valve tilts with respect to the valve seat about the peripheral point 72 as a fulcrum. This phase of the valve operation is shown in Fig. 6. Inasmuch as the periphery of the valve face 68 is displaced a greater radial distance than the valve seat from the longitudinal axis of the valve stem, it is apparent the disc valve will move a greater degree away from the valve seat for a given increment of movement of the valve stem when its fulcrum point comprises a peripheral point of the valve face 68.

As mentioned above, one of the objects of the present invention is to provide a novel breathing apparatus operable to provide a source of breathing fluid in accordance with the actual demand of a person being served

in such a manner as to permit natural breathing under pressure without necessitating the expenditure of more than normal breathing efforts. In accordance with the principles of the present invention the foregoing is accomplished by the provision of a novel arrangement for controlling the pressure in the respiration chamber **14** responsively to the flow of a stream of breathing fluid thereto, and by the use of a two-stage valve operable responsively to a predetermined degree of movement of the inhalation diaphragm to increase the rate of flow of breathing fluid fed to the respiration chamber upon a given increment of movement of the inhalation diaphragm. While these features combine to provide a breathing apparatus which permits natural breathing under pressure without expending abnormal breathing efforts, they are also individually effective in supplying breathing fluid in accordance with the actual demand of the person being served throughout a wide range of breathing cycles.

The arrangement provided by the present invention for controlling the pressure in the respiration chamber responsively to the flow of a stream of breathing fluid into the chamber comprises the provision of a fluid stream diffusion member or plate **75** positioned in the respiration chamber **14** in spaced relation with the discharge opening **66** of the orifice **61** and in the path of the stream of fluid introduced into the chamber. The diffusion member **75** is stationary relative to the discharge opening **66** and lies in a plane substantially perpendicular to the longitudinal axis of the orifice **61** for effecting maximum diffusion of the stream of fluid with a concomitant pressure drop in the respiration chamber in accordance with the rate of flow and velocity of the fluid stream. Inasmuch as the diffusion member **75** is positioned in the respiration chamber in front of the discharge opening **66**, the diffusion member is provided with an elongated slot **76** for the passage of the valve stem **63** therethrough. The slot **76** preferably has a width dimension no greater than necessary for allowing unrestricted tilting movement of the valve stem.

In accordance with another feature of the present invention, the portion of the conical member **50** in the region of the orifice **61** is employed as the diffusion member **75**. As shown in the drawings, the conical member **50** extends substantially completely transversely of the respiration chamber and terminates in close proximity with the inside surface of the radial members **41**. Although the conical member is shown constructed of fluid impervious material, it is to be expressly understood other structures may be employed. For example, the inhalation diaphragm may be supported by an open framework extending outwardly into the respiration chamber a sufficient distance to support the diaphragm and including a portion of fluid impervious material in the region of the discharge opening of the orifice presenting a sufficient area to provide the required diffusion. Also, the provision of a baffle member extending around at least the inlet side of the inhalation diaphragm and in spaced relation with the walls of the respiration chamber, as provided by the conical member **50**, presents an arrangement which prevents fluttering of the inhalation diaphragm due to turbulence in the respiration chamber upon the introduction of a high velocity stream of breathing fluid thereto.

The passageways formed between the adjacent spaced surfaces of the conical member and the internal walls of the housing **11** are substantially isolated from the fluid within the respiration chamber affecting movement of the inhalation diaphragm and function to maintain a quiescent volume of fluid to affect the diaphragm while conducting the breathing fluid through the respiration chamber from its inlet to its outlet. Thus the use of a conical member **50**, as shown in the drawing not only functions to support the inhalation diaphragm when subject to abnormal pressure differentials, but also diffuses the incoming stream of breathing fluid in such a manner as to reduce the pressure within the respiration chamber, and comprises a baffle which prevents the incoming stream of breathing fluid from impinging upon the inhalation diaphragm and provides a substantially isolated passageway through the respiration chamber to maintain the fluid affecting inhalation diaphragm movements in a quiescent state unaffected by turbulence due to the incoming stream. In addition, the use of the conical member **50** offers advantages in simplicity of construction and lends to the use of a control valve of the tilt type.

The manner in which the portion **75** of the conical member **50** diffuses the stream of breathing fluid entering the respiration chamber **14** is illustrated in Fig. 7 of the drawings. The stream of fluid entering the respiration chamber impinges on the diffusion member **75** with the result that the fluid stream is diffused into a plurality of thin streams **78**, or a thin sheet of fluid, moving along the external surface of the member **75**. The bending of the fluid stream during the process of its diffusion produces a pressure reduction which effects movement of fluid from within the conical member by aspiration and increases the suction acting on the inhalation diaphragm.

The curve shown in Fig. 8 illustrates the suction-flow characteristic of a breathing apparatus constructed in accordance with the principles of the present invention. This curve was obtained by connecting a source of fluid at 40 pounds per square inch pressure to the inlet **17** and a vacuum pump to the outlet passageway **15**, and by operating the vacuum pump to subject the breathing apparatus to predetermined rates of flow measured in liters per minute. The suction values were obtained by measuring the pressure in the outlet passageway **15** for the different rates of flow. According to this curve the rate of flow and the suction follow a substantially linear relationship from zero flow and suction to a point **80** corresponding to a suction value of approximately 1.1 inches of water and a rate of flow of approximately 30 liters per minute. At point **80** the linear relationship ceases and thereafter the flow increases at a greater rate than the suction until point **81** is reached where the suction is approximately 1.2 inches of water and the flow approximately 40 liters per minute. From point **81** to point **82** the rate of flow increases, although the suction falls off to approximately 0.9 inch of water, and in the remaining portion **83** of the curve from a point **84** the suction and flow follow a substantially linear relationship.

The portion of the curve between points **80** and **84** which displaces the linear portion from the portion **83**, is produced due to the combined effect of diffusion of the incoming fluid stream and of the two-stage tilt valve. The feature of displacing the curve by the intermediate portion **80—84** provides a breathing apparatus capable of providing natural breathing under pressure without expenditure of abnormal breathing effort. A breathing apparatus not including these features of the present invention would possess a suction-flow characteristic approximating a curve formed by joining the portion **83** to the linear portion at the point **80** of first deviation. A breathing apparatus having such a characteristic would require a suction in excess of two inches of water to provide a flow of 60 liters per minute and the flow would drop off at high rates due to choking of the input orifice. The latter disadvantage is not present in a breathing apparatus provided by the present invention due to the action of the two-stage tilt valve in automatically increasing the size of the orifice for a given increment of inward movement of the inhalation diaphragm during the range of high rates of flow. Thus the orifice does not choke at high rates of flow and the apparatus is capable of supplying a volume of breathing gas to meet the actual demand of the person being served even in the case of abnormal or "gasping" breathing cycles requiring the supply of a large volume of breathing fluid within a relatively short period.

The principles of the present invention described above will be more fully understood by considering the operation of a breathing apparatus during a breathing cycle. For convenience, the breathing cycle will be considered as initiating with the beginning of the exhalation phase. Upon exhalation of a person being served, the foul or used breathing fluid expelled from the lungs is conducted through the mask and flexible conduit, discussed above, and enters the passageway **15** increasing the pressure in the respiration chamber **14** and hence the pressure acting on the inside surface of the valve portion **37** of the exhalation diaphragm **13**. When the pressure in the chamber **14** builds up to a value in excess of the external pressure, the valve portion **37** flexes outwardly from the valve surface **43** exhausting foul breathing fluid from the breathing apparatus. At the end of the exhalation phase the chamber **14** contains foul breathing fluid at a pressure slightly below the external pressure as determined by the force required to open the exhalation valve. Expansion of the lungs of the person being served at the beginning of the inhalation phase produces a source of suction which is transmitted through the passageway **15** to the respiration chamber **14**. This action results in the person receiving the foul breathing fluid remaining in the respiration chamber at the end of the inhalation phase; however, this is not disadvantageous since breathing regulators embodying the principle of the present invention may include respiration chambers of relatively small volume and the small quantity of carbon dioxide present has a stimulating effect. When the pressure in the resipration chamber is reduced to a value below the external pressure, the inhalation diaphragm **12** moves inwardly and tilts the valve **62** away from the valve seat **67** allowing the flow of high pressure breathing fluid into the chamber. It is preferable to design the inhalation diaphragm **12** to possess a normal tendency to move inwardly of the chamber and exert a pressure through the tilt valve arrangement, of a sufficient magnitude to balance the force exerted on the open face of the valve member **62** by the high pressure fluid in the chamber **59**. With this arrangement high sensitivity may be obtained so that breathing fluid is introduced into the respiration chamber whenever the pressure in the chamber drops slightly below the external pressure. Upon an increase in suction in the chamber **14** as the inhalation phase proceeds, the inhalation diaphragm **12** moves further inwardly of the chamber increasing the size of the opening to the orifice **61**. Initially, the rate of flow into the respiration chamber is directly proportional to the suction moving the inhalation diaphragm, however as the rate of flow increases the pressure in the chamber is reduced due to the aspiration effect resulting from diffusion of the stream when it impinges on the plate **75**. This results in an increase in the rate of flow without a proportional increase in suction. As the suction further increases the valve member **62** moves to its second stage of opening in which a greater rate of flow results upon a given increment of inward movement of the diaphragm.

The provision of means for producing an aspiration effect responsively to diffusion of the incoming stream and of a two stage valve for increasing the rate of flow for a given increment of inward movement of the inhalation diaphragm during high rates of flow, allows the construction of a compact breathing apparatus including a respiration chamber of relatively small volume and an inhalation diaphragm of relatively small area which is operable to supply the proper volume of breathing fluid during the inhalation phase of the breathing cycle as determined by the demand of the person being served without requiring abnormal breathing effort. The diffusion feature for increasing the rate of flow of the breathing fluid into the respiration chamber without a proportional increase in suction not only tends to negative a reduction in suction due to the discharge of the breathing fluid into the respiration chamber and to compensate for the suction required to initially rock the tilt valve from its closed position, but, together with the two-stage valve feature, insures the supply of the proper volume of breathing fluid during the inhalation phase of a natural breathing cycle. Also, the provision of the diffusion member **75** in the path of the fluid stream entering the respiration chamber not only effects a reduction of pressure in the chamber by producing an aspiration effect but also prevents the incoming stream from adversely affecting normal operation of the inhalation diaphragm. This action is particularly manifest in the use of the conical member **50**, constructed of fluid impervious material, as a support for the diaphragm as well as a diffusion means. In this case the inhalation diaphragm is surrounded by a continuous shield which prevents the incoming fluid from impinging upon the inhalation diaphragm and restricts the inhalation diaphragm to influence by a quiescent volume of fluid free from turbulence occasioned by the breathing fluid stream.

The conical member **70**, which centers the valve **62** when moved to closed position, does not increase the force required for opening the valve. Thus a breathing apparatus including valve centering means of this character will respond more rapidly to lower pressure differentials and aid in obtaining natural breathing cycles.

As mentioned above, the present invention also provides a breathing apparatus particularly adapted for serving a person who may be surrounded by a fluid of a relatively great density, as in the case of "skin diving"; the breathing apparatus being characterized in that little, if any, pressure differential exists between the operating pressures of the inhalation and exhalation diaphragms. As shown in Fig. 2, the inhalation and exhalation diaphragms **12** and **13** form opposite walls of the respiration chamber **14** and are subject to the same external pressure. This arrangement establishes a condition in which there exists substantially no differential between the pressure at which the exhalation diaphragm closes and the pressure at which the inhalation diaphragm opens. The importance of this feature will be more fully understood by considering a condition in which the exhalation diaphragm is mounted on the body of the person being served at a point above the inhalation diaphragm. With these relative locations, the exhalation diaphragm would close at a pressure below the pressure at which the inhalation diaphragm opens as determined by the difference in fluid head between the diaphragms. In the case of "skin diving," due to the high density of water, only a slight difference in elevation of the inhalation and exhalation diaphragms will result in a substantial pressure differential between their operating pressures adversely affecting the breathing effort required. Should the exhalation diaphragm close at a relatively low pressure, the inhalation diaphragm would necessarily possess low sensitivity to prevent premature opening of the inlet valve. Thus a higher degree of suction, equivalent to the pressure differential, would be required to open the inhalation diaphragm. According to the present invention these difficulties are eliminated by forming the inhalation and exhalation diaphragms as diametrically opposed walls of the respiration chamber. This arrangement prevents the development of a material pressure differential between the operating pressures of the diaphragms irrespective of the location of the breathing apparatus with respect to the body of the person being served.

While the various components of the breathing apparatus described above may be constructed of any suitable material in order to provide a compact apparatus capable of long life that may be manufactured at a relatively low cost, it is preferable to form the casing **11** and the cover plates **30** and **47** of plastic material, such as molded nylon. Such material possesses excellent anti-corrosion characteristics, especially in salt water, and may be easily fabricated into the necessary form to provide a compact

breathing apparatus of light weight. Also, with molded nylon the casing **11** may be made to possess sufficient resilient characteristics so that the cover members may be supported and sealed in the casing **11** by normal inward deflection of the cooperating walls of the casing. The other components of the breathing apparatus may be constructed of molded plastic material, while it is preferable to machine the valve assembly **18** from metallic stock to obtain the required accuracy of the orifice **61**, the valve seat **67** and the means for automatically centering the disc valve **62**.

There is thus provided by the present invention a novel breathing apparatus of light-weight, compact construction capable of long dependable operation and which may be manufactured at relatively low cost. The breathing apparatus includes novel features which act alone and in combination to supply a volume of breathing fluid during the inhalation phase in accordance with the actual demand of the person being served to enable the person to breathe naturally without exerting more than normal breathing efforts even though the breathing apparatus is of compact construction including an inhalation diaphragm of small area and a respiration chamber of small volume as compared to conventional designs. The breathing apparatus described above also includes a novel arrangement for reducing to a minimum the force required to initially open the valve device which controls the flow of breathing fluid. Moreover, the present invention provides a breathing apparatus particularly adapted for "skin diving" in which the inhalation and exhalation diaphragms operate at substantially the same pressure to provide high sensitivity.

Although only one embodiment of the present invention has been disclosed and described above, it is to be expressly understood that various changes and substitutions may be made without departing from the spirit of the invention as well understood by those skilled in the art. Reference therefore will be had to the appended claims for a definition of the limits of the invention.

What is claimed is:

1. A breathing apparatus comprising a hollow casing including a curved inner wall defining an opening, a flexible diaphragm positioned in the opening and secured to the casing so that the casing and the diaphragm form a chamber, the casing having a fluid inlet adapted to be connected to a source of fluid under pressure and a fluid outlet in communication with the chamber, a longitudinally curved diffusion plate located in the chamber with a curved edge thereof in contiguous relation with the curved inner wall of the casing adjacent the opening, the curved diffusion plate extending in a direction away from the opening in spaced overlying relation with a portion of the inner wall of the casing, means forming an orifice between the fluid inlet and the chamber, the orifice being located in said portion of the inner wall of the casing in substantial symmetrical relation with the longitudinal dimension of the curved diffusion plate and the orifice having a discharge opening on its chamber side for discharging a stream of fluid into the chamber and onto the diffusion plate, valve means operatively associated with the orifice for controlling the flow of fluid through the discharge opening into the chamber, the flexible diaphragm being movable responsively to differential variations in pressure within and without the chamber, and means responsive to movement of the diaphragm for controlling the valve means.

2. A breathing apparatus comprising a hollow casing including a curved inner wall defining a circular opening, a flexible diaphragm positioned in the opening and secured to the casing so that the casing and the diaphragm form a chamber, the casing having a fluid inlet adapted to be connected to a source of fluid under pressure and a fluid outlet in communication with the chamber, the flexible diaphragm being movable to within the chamber responsively to differential variations in pressure within and without the chamber, a hollow conical member supported in the chamber in symmetrical relation with respect to the diaphragm and in spaced overlying relation with respect to the inner wall of the casing with its large diameter end in contiguous relation with the curved inner wall adjacent the opening to form a support for the diaphragm upon movement of the diaphragm into the chamber, means forming an orifice between the fluid inlet and the chamber, the orifice having a discharge opening on its chamber side for discharging a stream of fluid into the chamber, valve means operatively associated with the orifice for controlling the flow of fluid through the discharge opening into the chamber, and means responsive to movement of the diaphragm for controlling the valve means, the hollow conical member including a portion formed of fluid impervious material overlying in spaced relation the orifice and a portion of the inner wall surrounding the orifice and being substantially symmetrically positioned with respect to the path of the stream of fluid discharged from the orifice.

3. A breathing apparatus comprising a hollow casing including a curved inner wall defining a circular opening, a flexible diaphragm positioned in the opening and secured to the casing so that the casing and the diaphragm form a chamber, the casing having a fluid inlet adapted to be connected to a source of fluid under pressure and a fluid outlet in communication with the chamber, the flexible diaphragm being movable to within the chamber responsively to differential variations in pressure within and without the chamber, a hollow conical member formed of fluid impervious material supported in the chamber in symmetrical relation with the diaphragm and with the large diameter end of the hollow conical member in contiguous relation with the curved inner wall of the casing adjacent the opening to form a support for the diaphragm upon movement of the diaphragm into the chamber, a portion of the hollow conical member being in spaced overlying relation with a portion of the inner wall of the casing, means forming an orifice between the fluid inlet and the chamber, the orifice having a discharge opening on its chamber side for discharging a stream of fluid to the chamber, valve means operatively associated with the orifice for controlling the flow of fluid through the discharge opening into the chamber, and means responsive to movement of the diaphragm for controlling the valve means, the orifice being located in said portion of the inner wall of the casing in substantial symmetrical relation with the longitudinal dimension of said portion of the hollow conical member so that the stream of fluid discharged from the orifice into the chamber impinges upon said portion of the hollow conical member.

4. A breathing apparatus comprising a hollow casing including a curved inner wall defining an opening, a flexible diaphragm positioned in the opening and secured to the casing so that the casing and the diaphragm form a chamber, the casing having a fluid inlet adapted to be connected to a source of fluid under pressure and a fluid outlet in communication with the chamber, a longitudinally curved diffusion plate supported in the chamber with a curved edge thereof in contiguous relation with the curved inner wall of the casing adjacent the opening, the curved diffusion plate extending in a direction away from the opening in spaced overlying relation with a portion of the inner wall of the casing, means forming an orifice between the fluid inlet and the chamber, the orifice being located in said portion of the inner wall of the casing in substantial symmetrical relation with the longitudinal dimension of the curved diffusion plate and the orifice having a discharge opening on its chamber side for discharging a stream of fluid pressure into the chamber and onto the diffusion plate, valve means operatively associated with the orifice for controlling the flow of fluid through the discharge opening into the chamber, the flexible diaphragm being movable responsively to differential variations in pressure within and without the

chamber, a valve stem positioned in the chamber and having one end secured to the valve means and its other end operatively associated with the diaphragm for controlling the valve means responsively to movement of the diaphragm, and means forming an opening in the longitudinally curved diffusion plate for passage of the valve stem therethrough.

5. A breathing apparatus comprising a hollow casing including a curved inner wall defining a circular opening, a flexible diaphragm positioned in the opening and secured to the casing so that the casing and the diaphragm form a chamber, the casing having a fluid inlet adapted to be connected to a source of fluid under pressure and a fluid outlet in communication with the chamber, the flexible diaphragm being movable to within the chamber responsively to differential variations in pressure within and without the chamber, a hollow conical member supported in the chamber in symmetrical relation with the diaphragm and in spaced overlying relation with the inner wall of the casing with its large diameter end in contiguous relation with the curved inner wall adjacent the opening to form a support for the diaphragm upon movement of the diaphragm into the chamber, means forming an orifice between the fluid inlet and the chamber, the orifice having a discharge opening on its chamber side for discharging a stream of fluid into the chamber, valve means operatively associated with the orifice for controlling the flow of fluid through the discharge opening into the chamber, and a valve stem located in the chamber having one end secured to the valve means and the other end in operative relationship with the diaphragm so that movements of the diaphragm control the valve means, the hollow conical member including a portion formed of fluid impervious material overlying in spaced relation the orifice and a portion of the inner wall surrounding the orifice and being substantially symmetrically positioned with respect to the path of the stream of fluid discharged from the orifice, the portion of the hollow conical member formed of fluid impervious material having an opening therein for passage of the valve stem therethrough.

6. A breathing apparatus comprising a hollow casing including a curved inner wall defining a circular opening, a flexible diaphragm positioned in the opening and secured to the casing so that the casing and the diaphragm form a chamber, the casing having a fluid inlet adapted to be connected to a source of fluid under pressure and a fluid outlet in communication with the chamber, the flexible diaphragm being movable to within the chamber responsively to differential variations in pressure within and without the chamber, a hollow conical member formed of fluid impervious material supported in the chamber in symmetrical relation with the diaphragm and with its large diameter end in contiguous relation with the curved inner wall adjacent the opening to form a support for the diaphragm upon movement of the diaphragm into the chamber, a portion of the hollow conical member being in spaced overlying relation with a portion of the inner wall of the casing, means forming an orifice between the fluid inlet and the chamber, the orifice having a discharge opening on its chamber side for discharging a stream of fluid into the chamber, valve means operatively associated with the orifice for controlling the flow of fluid through the discharge opening into the chamber, a valve stem located in the chamber having one end secured to the valve means and another end in operative relation with the diaphragm so that movements of the diaphragm control the valve means, the orifice being located in said portion of the inner wall of the casing in substantial symmetrical relationship with the longitudinal dimension of said portion of the hollow conical member so that the stream of fluid discharged from the orifice impinges upon said portion of the hollow conical member, and said portion of the hollow conical member having an opening for the passage of the valve stem therethrough.

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