

EXHALATION VALVE FOR USE IN AN UNDERWATER BREATHING DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

[001] This application claims priority to United States Utility Patent Application Serial No. Unknown, entitled "Exhalation Valve For Use In An Underwater Breathing Device," which was filed on May 18, 2006. This application also claims priority to and the benefit of United States provisional patent application serial no. 60/683,477, entitled "Valves, Baffles, Shortened Snorkels, Stealth Snorkels, Snorkel Equipment Combined with Scuba Equipment," which was filed on May 21, 2005. This application also claims priority to and the benefit of United States provisional patent application serial no. 60/728,193, entitled "Snorkel Valve," which was filed on October 19, 2005. Each of these applications is hereby expressly incorporated by reference herein in its entirety.

BACKGROUND OF INVENTION

Field of Invention

[002] The present invention relates generally to an underwater breathing device and, in particular, to an exhalation valve for use in an underwater breathing device that is configured to produce positive end-expiratory pressure in the airway of a user.

Description of Related Art

[003] An underwater breathing device enables a user to continue breathing even after the user's mouth and/or nose is submerged in water. Some underwater breathing devices, such as scuba and snuba breathing devices, are configured to provide a submerged user with air from a compressed-air container. Other underwater breathing

devices, such as a convention snorkel, are configured to provide a user with air from the atmosphere.

[004] A convention snorkel generally includes a breathing conduit through which air can be inhaled from the atmosphere. The breathing conduit is typically configured with two ends. One end of the snorkel is intended to remain above the surface of the water. The other end of the snorkel is intended to be submerged under the surface of the water. The end of the inhalation conduit that is intended to be submerged generally includes a mouth piece. In practice the user inserts a portion of the mouthpiece into his mouth and thereby creates a seal between the user's airway and the breathing conduit. The user then submerges his mouth and the mouthpiece under water while maintaining the other end of the breathing conduit above the surface of the water, thereby enabling the user to inhale atmospheric air while submerged in water. At the same time, the breathing conduit enables the user to exhale through the user's mouth without breaking the seal between the user's mouth and the mouth piece. Generally, the air exhaled by a user exits the snorkel through the same breathing conduit through which the user inhales atmospheric air.

[005] One problem that a user can encounter while using a conventional snorkel is increased fatigue due to the compressive forces of the ambient water in which the user is submerged. During normal inhalation and exhalation, a user expends effort inflating and deflating his lungs. When a user is submerged in water, however, the compressive forces of the ambient water around the user's lungs force the user to expend more effort than usual in order to inflate his lungs and tend to cause the user to expend less effort than usual to deflate his lungs. This reduced-effort exhalation tends to cause a user to exhale faster than normal such that there is less time between each increased effort-inhalation, resulting in more frequent inhalation. More frequent

inhalation can cause the user to fatigue more quickly than during normal inhalation and exhalation, which can result in difficulty breathing due to a smaller functional lung capacity and the possibility of atelectasis, which is a failure of the lungs to expand completely.

[006] Another problem that a user can encounter while using a conventional snorkel is difficulty breathing due to water being present in the breathing conduit of the snorkel. Water can sometimes enter a conventional snorkel through one or both ends of the breathing conduit. This water can cause difficulty breathing when it accumulates to the point where the water interferes with the passage of air in the breathing conduit and/or the water is inhaled by the user. In addition, the presence of water in the breathing conduit of the snorkel can cause a distracting gurgling or bubbling noise as air passes by the water during inhalation and/or exhalation.

BRIEF SUMMARY OF INVENTION

[007] A need therefore exists for an underwater breathing device that eliminates or reduces some or all of the above-described problems.

[008] In accordance with a first aspect of the present invention, there is provided an exhalation valve for use in an underwater breathing device, the exhalation valve configured to produce positive end-expiratory pressure in the airway of a user of the underwater breathing device in order to reduce the overall work of underwater breathing, the exhalation valve comprising: a plate defining at least one chamber port and an exhalation port, the at least one chamber port being positioned opposite the exhalation port; and a flexible membrane that is sealable against a surface of the plate and is sized and positioned to be capable of sealing the exhalation, the flexible membrane comprising: a sealed position in which the flexible membrane seals the exhalation port such that substantially no air can flow between the at least one chamber port and the exhalation port, and an unsealed position in which the flexible membrane does not seal the exhalation port such that air can flow between the at least one chamber port and the exhalation port.

[009] In accordance with embodiments of the present invention, there is provided an exhalation valve that may include a plate that is substantially rigid and substantially disk-shaped. In addition, the exhalation port of the plate of the exhalation valve may be either oval-shaped or teardrop-shaped. Further, the flexible membrane of the exhalation valve may include a hinged region positioned so as to divide the exhalation port into two sides such that, when the flexible membrane bends along the hinged region, one side can become unsealed while the other side remains sealed. Moreover, the plate and/or the flexible membrane

of the exhalation valve may have a nub formed thereon that is positioned between the plate and the flexible membrane.

[010] In accordance with a second aspect of the present invention, there is provided an underwater breathing device configured to produce positive end-expiratory pressure in the airway of a user of the underwater breathing device in order to reduce the overall work of underwater breathing, the underwater breathing device comprising: a chamber including first and second openings, the chamber being configured such that when air is being exhaled through the first opening into the chamber in a manner that restricts air from simultaneously escaping through the first opening, there is no unrestricted passageway out of the chamber through which air can exit the underwater breathing device and, as a result, the exhaled air creates an exhalation pressure within the chamber; and a valve for restricting airflow between the chamber and the second opening, the valve comprising: a plate defining the at least one chamber port and the exhalation port, the at least one chamber port may be positioned opposite the exhalation port, the at least one chamber port and the exhalation port defining the second opening; and a flexible membrane that is sealable against a surface of the plate and may be sized and positioned to be capable of sealing the exhalation port, the flexible membrane being configured such that an opening force, comprising any exhalation pressure within the chamber, biases the valve in a first direction and a closing force biases the valve in a second direction, the first direction being substantially opposite the second direction, the flexible membrane comprising: a closed position in which the flexible membrane seals the exhalation port such that substantially no air is released from the chamber through the exhalation port, the flexible membrane being

disposed in the closed position when the opening force is less than or equal to the closing force; and an open position in which the flexible membrane does not seal the exhalation port such that air is released from the chamber through the exhalation port, the flexible membrane being disposed in the open position when the opening force exceeds the closing force.

[011] In accordance with embodiments of the present invention, there is provided an underwater breathing device may include a mouthpiece connected to the first opening. In addition, an underwater breathing device may include an exhalation conduit connected to the exhalation port. Further, an underwater breathing device may include an exhalation conduit divided by a septum which creates a first conduit and a second conduit. The second conduit is sized and positioned such that, when the underwater breathing device is in use, any water that enters the exhalation conduit tends to collect in the second conduit. Furthermore, the flexible membrane further may include a hinged region aligned with the septum such that, when the flexible membrane bends along the hinged region, the first conduit can become unsealed while the second conduit remains sealed. Moreover, the opening force required to bend the flexible membrane at the hinged region of the flexible membrane and thereby only unseal the first conduit is less than the opening force required to bend the flexible membrane such that both the first and the second conduits are unsealed. In addition, the closing force may include ambient water pressure when at least a portion of the underwater breathing device is submerged in water. Further, the opening force further may include a force created by a tension of an elastic string attached to the flexible membrane which biases the flexible membrane in substantially the first direction. Moreover, the tension of the elastic string, and the resulting opening force, may be manually adjustable.

[012] In accordance with alternate embodiments of the presents invention, there is provided an underwater breathing device configured to produce positive end-expiratory pressure in the airway of a user of the underwater breathing device. The positive end-expiratory pressure in the airway of the user may reduce the overall work of underwater breathing. The underwater breathing device may include a chamber and a valve. The chamber may include first and second openings. The chamber is preferably configured such that when air is being exhaled through the first opening into the chamber in a manner that restricts air from simultaneously escaping through the first opening, there is no unrestricted passageway out of the chamber through which air can exit the underwater breathing device and, as a result, the exhaled air creates an exhalation pressure within the chamber. The valve may function to restrict airflow between the chamber and the second opening. The valve may be configured such that any exhalation pressure within the chamber biases the valve in a first direction and a counter pressure biases the valve in a second direction. The first direction may be substantially opposite the second direction. The valve may have a closed position in which substantially no air is released from the chamber through the second opening. The valve can be disposed in the closed position when any exhalation pressure within the chamber is less than or equal to the counter pressure. The valve may also have an open position in which at least some air is released from the chamber through the second opening. The valve can be disposed in the open position when any exhalation pressure within the chamber exceeds the counter pressure.

[013] In accordance with further embodiments of the present invention, there is provided an underwater breathing device that includes a mouthpiece connected to the first opening. In addition, an underwater breathing device may include an exhalation conduit connected to the second opening. Also, the counter pressure may include ambient water pressure when at least a portion of the

underwater breathing device is submerged in water. Further, the counter pressure may also include one or more springs. Moreover, an underwater breathing device may also include a chamber with a third opening and where the valve further restricts airflow between the chamber and the third opening. The valve can further include a purge position in which at least some air is released from the chamber through the second opening and the third opening. The valve may be disposed in the purge position when any exhalation pressure within the chamber is distinctly greater than the counter pressure.

[014] These and other aspects, features and advantages of the present invention will become more fully apparent from the following detailed description of preferred embodiments.

BRIEF DESCRIPTION OF DRAWINGS

[015] The appended drawings contain figures of preferred embodiments to further clarify the above and other aspects, advantages and features of the present invention. It will be appreciated that these drawings depict only preferred embodiments of the invention and are not intended to limit its scope. The invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

[016] Figure 1A is a front view of an exemplary assembled snorkel;

[017] Figure 1B is a front exploded view of the snorkel of Figure 1A;

[018] Figure 2A is a top perspective view of the inhalation cap and the inhalation valve diaphragm member of the snorkel of Figures 1A and 1B, which together form an inhalation valve;

[019] Figure 2B is a transverse section view of the inhalation cap of the snorkel of Figures 1A and 1B showing the inhalation valve in open position such as occurs during inhalation;

[020] Figure 2C is a transverse sectional view of the inhalation cap of the snorkel of Figures 1A and 1B showing the inhalation valve in the closed position such as occurs during breath holding or exhalation

[021] Figure 3A is a transverse sectional view of the main tube of the snorkel of Figures 1A and 1B and its associated structures;

[022] Figure 3B shows the transverse sectional view of Figure 3A with the exhalation tube coursing within the main tube and mounting to the main tube's exhalation tube upper mount;

[023] Figure 3C shows the Ellipsoid Cross-Section of the lower end of the main tube of the snorkel of Figures 1A and 1B;

[024] Figure 3D is a transverse sectional view of the main tube of the snorkel of Figures 1A and 1B and its associated structures;

[025] Figure 4A is a side view of the ribbed flexible connecting tube of the snorkel of Figures 1A and 1B;

[026] Figure 4B is a sectional view of the connecting tube shown in Figure 4A;

[027] Figure 5A is an exploded side view of the junction with the mouthpiece, the exploded exhalation valve / purge valve assembly, and the purge cap of the snorkel of Figures 1A and 1B;

[028] Figure 5B is an exploded perspective view of the exhalation valve/purge valve assembly;

[029] Figure 5C is an exploded transverse sectional view of the exhalation valve / purge valve assembly;

[030] Figure 5D shows the top view of this exhalation valve / purge valve assembly;

[031] Figure 5E shows a collapsed transverse sectional view of the exhalation valve / purge valve assembly;

[032] Figure 6A is a transverse sectional view of the junction with the exhalation valve in closed position;

[033] Figure 6B is a transverse sectional view of the junction with the exhalation valve in open position as occurs in normal exhalation;

[034] Figure 6C is a sectional view of the junction with the rapid purge ports open as occurs during purging levels of exhalation;

[035] Figure 7A is a sectional view of an alternative exhalation valve/purge valve apparatus showing a compressible accordion-style wall. This wall has slits in the lower, outer accordion walls that are closed, unless the walls are fully distended as in a purge operation;

[036] Figure 7B is a sectional view similar to Figure 7A showing the exhalation valve in open position with the purge valve in the closed position;

[037] Figure 7C is a sectional view similar to Figure 7A showing both the exhalation valve and the purge valve open;

[038] Figure 8 is another cross-sectional view of an alternative exhalation valve / purge valve apparatus showing a dome that travels vertically and an externally positioned exhalation tube;

[039] Figure 9 is a transverse sectional view of the junction which houses the exhalation valve, as it is adapted to mount to a connecting tube, which in turn mounts to the exhalation vents or equivalent of a scuba regulator;

[040] Figure 10A is a sectional view of an alternative exhalation valve configuration in the closed position;

[041] Figure 10B is a sectional view of the exhalation valve configuration of Figure 10A in the open position;

[042] Figure 11A is a side view of a flexible membrane that can be used in the exhalation valve configuration of Figures 10A;

[043] Figure 11B is a perspective top view of the flexible membrane of Figure 11A;

[044] Figure 11C is a cross-sectional side view of a disk-shaped rigid piece that can be used in the exhalation valve configuration of Figure 10A;

[045] Figure 11D is a bottom view of the disk-shaped rigid piece of Figure 11C;

[046] Figure 12A is a sectional view of another alternative exhalation valve configuration with the valve in the closed position;

[047] Figure 12B is a sectional view of the exhalation valve configuration of Figure 12A with the valve in a partially open position;

[048] Figure 12C is a sectional view of the exhalation valve of Figure 12A with the valve in a fully open position;

[049] Figure 13A is a side view of a flexible membrane that can be used in the exhalation valve configuration of Figures 12A-12C;

[050] Figure 13B is a perspective top view of the flexible membrane of Figure 13A;

[051] Figure 13C is a cross-sectional side view of a disk-shaped rigid piece that can be used in the exhalation valve configuration of Figures 12A-12C;

[052] Figure 13D is a bottom view of the disk-shaped rigid piece of Figure 13C;
and

[053] Figure 14 is a cross sectional view of an exemplary tension knob.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[054] This invention is generally directed towards an exhalation valve for use in an underwater breathing device. The exhalation valve that is configured to produce positive end-expiratory pressure in the airway of a user of the underwater breathing device. The principles of the present invention, however, are not limited to underwater breathing devices. It will be understood that, in light of the present disclosure, the structures disclosed herein can be successfully used in connection with any device that is intended to produce positive end-expiratory pressure in the airway of a user.

[055] Additionally, to assist in the description of the exhalation valve, words such as top, bottom, front, rear, right, left and side are used to describe the accompanying figures, which are not necessarily drawn to scale. It will be appreciated, however, that the present invention can be located in a variety of desired positions within an underwater breathing device or other device—including various angles, sideways and even upside down. A detailed description of the exhalation valve for use in an underwater breathing device now follows.

[056] As discussed below and shown in the accompanying figures, the exhalation valve may be used in connection with an underwater breathing device such as a scuba or snuba regulator, or a snorkel. For example, the exhalation valve may function in connection with an inhalation valve of a snorkel, or the exhalation valve may be combined with the inhalation valve. The exhalation valve may be placed at the top or the bottom of the breathing conduit of a snorkel, whether the snorkel includes only a single breathing conduit, or includes both an inhalation conduit and an exhalation conduit. The exhalation valve is generally configured to open when the user of the snorkel exhales to allow the exhaled air to exit the snorkel. The exhalation

valve is also generally configured to close when the user of the snorkel is not exhaling, as during inhalation or between breaths. Where the snorkel includes both an inhalation and an exhalation conduit, the closed exhalation valve may prevent exhaled air from the exhalation conduit from passing back into the inhalation tube, thereby channeling the exhaled air through the proper exhalation tube.

[057] Turning now to Figures 1A and 1B, an exemplary snorkel 1 is disclosed. In generally, the snorkel 1 facilitate inhalation through an inhalation conduit to the mouthpiece of the user, and exhalation goes from the mouthpiece to an exhalation conduit from which exhaled air exits the snorkel. The snorkel 1 includes an inhalation valve and an exhalation valve. The snorkel 1 also includes a purge valve which shares part of its structure with the exhalation valve. When the snorkel 1 is in use, atmospheric air flows one-way into the inhalation valve and through the inhalation conduit to the mouthpiece where it is inhaled by the user. The air that is subsequently exhaled by the user then flows through the exhalation valve and through the exhalation conduit where the exhaled air exits the snorkel. Exhaled air can also exit the snorkel 1 through the purge valve. Additional details regarding exemplary structures for the inhalation valve, the inhalation conduit, the mouthpiece, the exhalation valve, the exhalation conduit, and the purge valve now follows.

[058] The snorkel 1 includes several major structural elements including an inhalation cap 7, a main tube 13, a connecting tube 19, a mouthpiece 54, a junction 22 which houses a chamber 23, an exhalation conduit 48, and a purge reservoir 27. At the lower end of the snorkel 1 is the purge cap 50. Near the upper end of the main tube 13 is the exhalation conduit exit port 16 where the exhaled air normally exits the snorkel 1.

[059] In greater detail, Figure 1B discloses the inhalation cap 7, an inhalation valve diaphragm member 10, the main tube 13, the connecting tube 19, and the junction 22. A combined sealing assembly 6 includes a combined sealing member 30, a rigid support disk 36, and a convoluted membrane 40, which serves to flexibly mount the active components of the exhalation valve which is a functional component of the combined sealing assembly 6 acting against a sealing ring 47 of an exhalation tube lower mount 44. The exhalation tube 48 mounts to the upper aspect of this structure as shown. The exhalation tube 48 then courses up the central chambers of the snorkel 1 until it mounts at its upper end by sandwiching between the main tube 13 and a hollow exhalation tube mounting plug 49. The exhalation tube lower mount 44 is connected to the junction 22 by a supporting structure 46 which on a top down view resembles spokes extending out to an outer rim. Therefore, this supporting structure 46 does not impede fluid / air movement across it, e.g., from top to bottom. The purge cap 50 screws onto the junction 22 and thereby secures the combined sealing assembly 6 where its convoluted membrane 40 attaches between these two structures. Importantly, the junction 22 houses the chamber 23 where exhalation pressure is maintained by the combination of the inhalation valve and the exhalation valve. The lower most portion of the chamber 23 within the junction 22 is referred to as the purge reservoir 27 as this is where splash / flood water would first accumulate.

[060] Figure 2A shows the inhalation cap 7, some thru-passages 8, and the inhalation valve diaphragm member 10, which taken together form the inhalation valve. The inhalation valve diaphragm member 10 has an optional partial thickness groove 12 across its diameter and is centrally anchored at its central hole 11 by the inhalation valve anchor 9 that is shown in Figure 2B and Figure 2C.

[061] Figure 2B shows a transverse sectional view of the inhalation cap 7 and the deformed shape of the inhalation valve diaphragm member 10, representative of the valve in its open position as occurs during inhalation. All inhaled air passes through the thru-passages 8 of the inhalation cap 7 to enter the snorkel 1. Therefore the inhalation cap can be considered the first member of the inhalation conduit. The inhalation valve diaphragm member 10 is very flexible and easily deforms to minimize any contribution to airway resistance in the inhalation conduit. The optional partial thickness groove 12 across its diameter allows this valve to function as a more efficient butterfly-style valve. Additionally, the inhalation cap 7 is sized such that the thru-passages 8 combine in area to similarly minimize their contribution to airway resistance even at rapid inhalation flow rates. The internal threads 55 of the inhalation cap 7 are shown and mate with corresponding threads on the main tube 13 as described in Figure 3A.

[062] Figure 2C is similar to Figure 2B, but shows the inhalation valve diaphragm member 10 in its flattened shape as occurs while not inhaling. The inhalation valve diaphragm member 10 naturally, but gently, assumes this flat shape when no pressure gradient exists across the valve in order to minimize the closing sounds that would be experienced if the valve did not flatten until forcefully closed. Then, as exhalation occurs, the valve remains tightly closed as the pressure acting on the exhalation valve (described in Figures 6A, 6B, and 6C) at the bottom of the snorkel 1 propagates within the snorkel 1 to provide the closing pressure for this inhalation valve. As long as the snorkel 1 is generally oriented in the normal use position (i.e., with the inhalation valve higher than the exhalation valve), and the user is not actively inhaling, this pressure will be adequate to prevent water from entering the snorkel 1 via the inhalation cap 7.

[063] Figure 3A shows a transverse sectional view of the main tube 13 and its related structures. The inhalation cap 7 mounts to the top end of the main tube 13 with a mating set of internal threads 55 and external threads 56 on their respective components. The represented structures of the inhalation valve are as described above for Figure 2B and Figure 2C. The main tube's central channel 14 directly receives inhaled air from the inhalation valve and therefore becomes the second functional member of the inhalation conduit, wherein the inhalation conduit is defined to be the network of tubes and other hollow structures through which inhaled air sequentially passes. The exhalation tube upper mount 15 is integral with the main tube 13 and provides a circular outer wall against which the upper end of the exhalation tube 48 is sandwiched by the hollow exhalation tube mounting plug 49. This design effectively eliminates a potential air leak between the exhalation conduit 48 and the inhalation conduit of the snorkel 1 that could otherwise be problematic as the exhalation conduit 48 passes through this wall of the inhalation conduit. The exhalation conduit exit port 16 is an opening in the inhalation conduit through which the exhalation conduit 48 exits the snorkel 1. The main tube 13 has an ellipsoid cross-section 17 at its lower end to reduce hydrodynamic drag while swimming and it transitions to a circular cross-section 18 at its upper end to allow the inhalation cap 7 to screw-mount. The lower end of the main tube 13 mounts to the flexible connecting tube 19 with the ribs on main tube 57 mating with the grooves in connecting tube 58.

[064] Figure 3B shows the circular cross-section 18 of the upper end of the main tube 13 and Figure 3C shows the ellipsoid cross-section 17 of the lower end of the main tube 13. Figure 3D is identical to Figure 3A except that it also shows the exhalation tube 48 as it courses through the main tube 13.

[065] Figure 4A is a side view of the ribbed flexible connecting tube 19. The outer ribs 21 provide radial support for the tube, while still allowing it to be flexible and bend. This bending provides improved comfort while the snorkel 1 is being worn, particularly if other diving gear is also concurrently being used.

[066] Figure 4B is a transverse sectional view of the ribbed flexible connecting tube 19 that is also described in Figure 4A. Now shown is the central channel 20 of this tube, which is the third functional member of the inhalation conduit. Further revealed herein are the upper grooves 58 of the connecting tube 19 that mate with corresponding ribs 57 on the main tube 13 (shown in Figure 3A) and the lower grooves 59 of the connecting tube 19 that mate with ribs 60 on the junction 22 (shown in Figure 5A)

[067] Figure 5A is an exploded side view of the junction 22 and its related structures. In particular, three mounts are integral to the junction 22 including the connecting tube mount 24 with its attachment ribs 60, the mouthpiece mount 25 with its attachment ribs 61, and the purge cap mount 29 with its external threads 64.

[068] The junction 22 houses a small volume chamber 23, which receives inhaled air from the central channel 20 of the connecting tube 19 (shown in Figure 4B), thereby becoming the fourth functional member of the inhalation conduit. In other embodiments, the chamber might not be a functional member of the inhalation conduit. This chamber 23 receives exhaled air from the mouthpiece 54. This chamber 23 is pressurized during exhalation and functionally provides the counter pressure to the user's airways. The lower region of the chamber 23 is more specifically referred to as the purge reservoir 27, as any captured water accumulates here first.

[069] The junction 22 also houses the functional exhalation valve and purge valve. In the preferred embodiment, these two valves share three structural elements

which, taken together, are simply referred to as the combined sealing assembly 6. The structures of this assembly are depicted for the preferred embodiment in Figures 6A through 6C, while examples of alternative embodiments of the exhalation valve and the purge valve are shown separately in Figures 7 and 8.

[070] The exhalation tube lower mount 44 is statically attached, via its spoke and rim-like supporting structure 46, to the junction 22 at the junction's snap mount for exhalation tube lower mount 44 (which is shown in Figures 6A, 6B, and 6C). The exhalation tube lower mount 44 additionally provides the sealing ring 47 for the exhalation valve. Inasmuch as this exhalation tube lower mount 44 directs exhaled air from the chamber 23 to the exhalation tube 48 (also referred to as exhalation conduit 48). The exhalation valve is comprised of elements of the combined sealing assembly 6 and the sealing ring 47, which items are described in more detail in Figures 6A, 6B, and 6C.

[071] Figure 5A also shows the purge cap 50 which screws onto the junction 22 at the corresponding mount. The purge cap 50 also is shown with the purge cap perforations 52 which allow water pressure to act on the exhalation valve and provides an exit for water that is purged across the purge valve. Figure 5B is an exploded perspective view of the combined sealing assembly 6. This assembly comprises the silicon rubber combined sealing member 30, the rigid support disk 36, and the flexible convoluted membrane 40.

[072] The combined sealing member 30, which is a one-part structure, provides the exhalation valve sealing member 31 and the purge valve sealing member 32. In the preferred embodiment, the exhalation valve sealing member 31 is dome-shaped in order to very gradually open exit flow and reduce vibration as exhaled air escapes across the exhalation valve when just minimally open. Other shapes that could

similarly result in dampening include teardrop or cone. The contiguous purge valve sealing member 32 notably has dampening ribs 33 that project out radially in various lengths from the underside of the purge valve sealing member 32 and serves to reduce or eliminate the buzz that would otherwise occur while purging. The combined sealing member 30 also has an attachment groove 34 around its midsection that provides secure attachment to the rigid support disk 36. The hollow region 35 allows the combined sealing member 30 to be compressed for assembly purposes, and provides a recess mount for an optional spring 68 (Figure 6A) that could further refine the exhalation airway pressure 65 if modification is desired in the future.

[073] The rigid support disk 36 provides several functions: It supports the combined sealing member 30 that allows the exhalation valve sealing member 31 to form a stable seal with the sealing ring 47 (shown in Figure 6A, Figure 6B, and Figure 6C); it provides a broad surface against which the ambient water pressure 66 (depicted in Figure 6A, Figure 6B, and Figure 6C) acts to balance the desired exhalation airway pressure 65 (depicted in Figure 6A, Figure 6B, and Figure 6C) within the snorkel 1; it supports the purge valve sealing member 32 to maintain proximity with the sealing surface of same disk; and it provides a smooth, rigid surface against which the purge valve sealing member 32 can seal. The rapid purge channels 39 in the rigid support disk 36 are closed by the purge valve sealing member 32, except during active purging operations when airway pressure 65 reaches a sufficient threshold for them to open for very rapid purge, taking full advantage of the higher exhalation airway pressures 65 which are maintained within the snorkel 1. The central hole 37 in the rigid support disk 36 supports the combined sealing member 30 at said member's attachment groove 34. The outer groove 38 of the rigid support disk

36 provides mounting attachment to the central anchor 41 of the flexible convoluted membrane 40.

[074] The convoluted membrane 40 is a flexible, annular structure that has transverse sectional convolutions to allow axial travel of the rigid support disk 36 and the combined sealing member 30. This functionally allows the exhalation valve sealing member 31 to appropriately open and close its seal against the sealing ring 47 (shown in Figure 6A, Figure 6B, and Figure 6C), thereby utilizing the ambient water pressure 66 to modulate the user's immersed and submersed exhalation rates. The convoluted membrane 40 has a central anchor 41 for secure attachment to the rigid support disk 36 and a peripheral anchor 42 for secure mounting in the space defined by the convoluted membrane junction groove 28 (of the unction 22 described separately in Figure 6A) and the corresponding convoluted membrane purge cap groove 51 (of the purge cap 50 described separately in Figure 6A). The screw mount of the purge cap 50 onto the unction 22 slightly compresses this peripheral anchor 42, which beneficially creates a seal to prevent water from entering the snorkel 1, and helps to lock the threads of the purge cap mount 29.

[075] Figure 5C is a transverse sectional view of the parts shown in Figure 5B. Figure 5D is top view of the Combined sealing assembly 6 as comprised by the parts of Figure 5B. Figure 5E is a transverse sectional view of the combined sealing assembly 6 as comprised by the parts of Figure 5C.

[076] Figure 6A is a transverse sectional view of the unction 22 with the exhalation valve in closed position. Numerous items identified in this figure are described in detail in Figure 5A and Figure 5B. Of note, the user's airway pressure 65, which acts on the combined sealing assembly 6 from above, is inadequate to overcome the inward compressing force that the ambient water pressure 66 produces

from below. Therefore, the exhalation valve sealing member 31 assumes tight closure against the sealing ring 47 and exhalation flow is prevented. The convoluted membrane 40 assumes a transverse sectional shape that is compatible with the rigid support disk 36 being at its upper end of axial travel. Also shown is an optional mechanical spring 68 which could be used to further refine the counter pressure upon exhalation that is achieved.

[077] Figure 6B is a transverse sectional view of the unction 22 with the exhalation valve in open position. This figure is very similar to that of Figure 5C, except that Figure 5D depicts the condition of normal exhalation in which the user's airway pressure 65 exceeds ambient water pressure 66, thereby exerting a net downward force on the Combined sealing assembly 6, removing the exhalation valve sealing member 31 from its sealing position against the sealing ring 47. Flow arrows 67 depict the direction of airflow through the chamber 23, across the exhalation valve, and into the exhalation tube 48, from whence it is channeled to exit the snorkel 1. The convoluted membrane 40 assumes a transverse sectional shape that is compatible with the rigid support disk 36 being near its lower end of axial travel.

[078] Figure 6C is a transverse sectional view of the unction 22 with the purge valve in open position. Note that the exhalation valve is also in open position, because the airway pressure 65 required for purging is excessive for normal exhalation. As per Figure 6A and Figure 6B, the description of many items shown in this figure is deferred to their descriptions in Figure 5A and Figure 5B. Note that the purge valve sealing member 32 is separated from the rigid support disk 36, thereby allowing the contents of the snorkel 1 to be expelled through the rapid purge channels 39. The purge valve sealing member 32 has a bias for closure molded into its shape such that the airway pressure 65 must be distinctly greater than the ambient water pressure 66

in order for the purge valve sealing member 32 to become displaced from the rigid support disk 36. The convoluted membrane 40 assumes a transverse sectional shape that is compatible with the rigid support disk 36 being at its lowest end of travel.

[079] Figure 7A is a sectional view of an alternative embodiment of the snorkel 1 that replaces the three parts of the combined sealing assembly 6 with one single molded flexible rubber part, the flexible sealing member 69. In doing so, the junction 75, the purge cap 76, and the exhalation tube lower mount 77 are all modified for this alternative embodiment. This flexible sealing member 69 has a sealing member anchor 70 along its circumference that secures this member to the junction 75 and the purge cap 76 in similar fashion to the peripheral anchor 42 previously described for the preferred embodiment. The flexible sealing member 69 also has a sealing dome 73 component that provides the functionality of the exhalation valve sealing member 31 previously described for the preferred embodiment. The rigid support disk 36 of the preferred embodiment has been eliminated. An optional rigid ring 74 may be placed within the deeper folds of the accordion wall 71 for additional mechanical support. Purge operations are facilitated by a series of small purge slits 72 in the outer folds of accordion wall 71 which remain closed due to the molded shape of the wall and the compressive forces of ambient water, until the airway pressure 65 is adequate to fully distend the accordion wall 71, thereby opening these purge slits 72 in a fashion similar to duck bill valves.

[080] Figure 7B is the alternative embodiment of Figure 7A in a condition of normal exhalation as is the condition of the preferred embodiment in Figure 6B, in which the airway pressure 65 is adequate for exhalation, but inadequate for rapid purge operation. The sealing dome 73 has separated from the exhalation tube sealing ring 47 allowing exhaled air to exit the snorkel 1 as shown by the flow arrows 75

[081] Figure 7C is the alternative embodiment of Figure 7A in a condition of purge operation as is the condition of the preferred embodiment in Figure 6C, in which the airway pressure 65 exceeds the threshold pressure for purging. Purge slits 72 are now evident in the lower, outer silicon rubber (or otherwise flexible) accordion wall 71. These purge slits 72 open with sufficient pressure to provide excellent purge capability, but otherwise generally remain closed for normal exhalation activities.

[082] Figure 8 reveals another embodiment of the snorkel 1 that now features a significantly modified design of the junction 78 that similarly contains a chamber 80 for counter pressure, but has an exhalation exit port 83 near the bottom of the snorkel 1, an external exhalation tube mount 84, and an external exhalation tube. The moving element which provides counter pressure for our desired positive end-expiratory pressure is the sealing cup 81 which travels coaxially and is supported laterally by a sealing cup rigid support. As the forces of airway pressure 65 in the chamber overcome the forces of ambient water pressure 66, the sealing cup 81 separates from the o-ring seal 82, allowing air to escape into the space above the perimeter of the sealing cup 81, which is then vented to the external exhalation tube 86 via the external exhalation tube mount 85. A sliding seal 87 helps maintain dryness within the snorkel.

[083] Figure 9 is a transverse sectional view of the enclosing structures of the exhalation valve as is modified to attach, via a non-collapsible air tube, to the exhalation vent on a typical scuba regulator. This invention, in effect, becomes an "exhalation regulator" for scuba diving purposes, as it functions to regulate the exhalation rate of the scuba diver. The device may be worn at mouth or chest level, depending on the comfort of the user. The junction 88 has been shortened from the preferred embodiment (described in Figures 5A thru 5D and Figures 6A thru 6C) for this alternative embodiment as it may be adapted for scuba or snuba purposes.

Furthermore, the mouthpiece mount 25 of the preferred snorkel 1 embodiment has been eliminated as this is not necessary for scuba. The exhalation vent from the separate scuba regulator attaches via a connecting tube 94 to the ribbed 90 connecting tube mount 89. The exhalation tube 92 has been significantly shortened and the exhalation conduit exit port 95 has been moved to the junction 88. The chamber 93 importantly continues to serve as a counter pressure chamber to accomplish the improved exhalation pressures as described herein. Figure 9 also includes a transverse sectional view of the exhalation valve and related structures as described in Figure 6B and as adapted to mount to the exhalation vent on a scuba regulator or snuba equipment. The exhalation tube 48 of Figure 9 is significantly shortened and exits from the junction 22 through a sidewall in the junction 22.

[084] As disclosed in Figures 10A and 10B, a snorkel 100 includes an alternative exhalation valve configuration. The snorkel 100 is configured to include many of the same components as the snorkel 1 of Figures 1A and 1B, including an inhalation valve, a main tube, a connecting tube, and a mouthpiece. Although these components are not shown in Figures 10A and 10B, it is understood that snorkel 100 is configured to function with these components in place as disclosed in Figures 1A and 1B. The snorkel 100 includes an inhalation conduit 102. The outside of the inhalation conduit 102 includes ribs 104 to which a connecting tube and a main tube can be attached, as shown in Figures 1A and 1B. Air enters the inhalation tube through an inhalation valve that is a one-way valve which allows air to flow into the inhalation conduit 102 but not out of the inhalation conduit 102, as disclosed elsewhere herein. After air enters into the inhalation conduit 102 through the one-way inhalation valve, the air enters the chamber 106 and can subsequently be inhaled by a user through a first opening 108. A mouthpiece can be connected to the first opening

108 using ribs 110 to facilitate the inhalation and exhalation of air by the user. After air is inhaled through the first opening 108, the user can subsequently exhale air through the first opening 108 and back into the chamber 106. Since the inhalation valve through which air entered the inhalation conduit 102 is a one-way valve, air that is exhaled into the chamber can not exit the snorkel 100 through the inhalation conduit 102. Instead, the exhaled air builds up in the chamber 106 creating an exhalation pressure in the chamber 106.

[085] The exemplary snorkel 100 also includes a valve plate 120 and a flexible membrane 120, which together form an exhalation valve. The valve plate 120 includes an exhalation port 132. The valve plate 120 also includes two chamber ports 134, as illustrated in Figure 11D. A flexible membrane 130 is attached to the edges of valve plate 120 and functions to seal the exhalation port 132 when the flexible membrane 130 is in the closed position, as disclosed in Figure 10A.

[086] The chamber ports 134 are positioned opposite the exhalation port 132. In this context and in the claims, the phrase "the at least one chamber port being positioned opposite the exhalation port" is defined as the exhalation port being positioned on substantially one side of the valve plate 120, and the at least one chamber port being positioned on substantially the other side of the valve plate 120. Continuing with this definition, although this definition includes a situation, such as shown in Figures 11D and 13D, where there is some overlap of the chamber ports with the exhalation port, such that the chamber ports partially surround the exhalation port, this definition does not include a situation where the chamber ports surround or substantially around the exhalation port, such as is shown in rigid support disk 36 of Figures 5B and 5D. This definition allows the flexible membrane 130 to gradually

peal away from the valve plate 120 beginning on the side of the flexible membrane 130 that is positioned directly underneath the chamber ports.

[087] Also disclosed in Figures 10A and 10B is an exhalation conduit lower mount 122 which forms part of an exhalation conduit 128. An exhalation tube 124 attaches to the exhalation conduit lower mount 122 at ribs 126.

[088] When the snorkel 100 is submerged in water, the ambient water pressure of the water surrounding the snorkel 100 pushes the flexible membrane 130 against the valve plate 120, thus sealing the exhalation port 132. When a user exhales into the chamber 106, the exhalation pressure that builds up inside the chamber 106 creates an opening force 140 which acts on the flexible membrane 130 through the chamber ports 134 of the valve plate 120. This opening force 140 biases the flexible membrane 130 in a first direction. At the same time, the ambient water pressure of the water surrounding the submerged snorkel 100 acts as a closing force 150 which biases the flexible membrane 130 in a second direction. The first direction of the opening force 140 is substantially opposite the second direction of the closing force 150.

[089] As disclosed in Figure 10A, when the closing force 150 is greater than or equal to the opening force 140, the flexible membrane 130 seals the exhalation port 132 such that substantially no air is released from the chamber 106 through the exhalation port 132. As disclosed in Figure 10B, however, when the opening force 140 exceeds the closing force 150, the flexible membrane 130 does not seal the exhalation port 132 and exhaled air 142 is released from the chamber 106 into the exhalation conduit 128. Once the exhaled air 142 reaches the exhalation conduit 128, the exhaled air 142 is released from the snorkel 100.

[090] As disclosed in Figures 11A and 11B, the flexible membrane 130 can optionally include protrusions 138 which are integrally formed in the flexible

membrane 130 and serve to dampen the impact of the flexible membrane 130 closing against the valve plate 134 to decrease the noise that can be involved with the closing of the flexible membrane 130 against the valve plate 120. As disclosed in Figures 11C and 11D, the valve plate 120 can also optionally include protrusions 136 which are integrally formed in the valve plate 120 and have substantially the same function as the protrusions 138. The exhalation port 132 of the valve plate 120 can also optionally be formed in a teardrop shape in order to allow the size of the unsealed portion of the exhalation port 132 to initially be very small and to gradually grow larger as the flexible membrane 130 peels away from the valve plate 120. Figure 11D discloses two chamber ports 134 defined in the valve plate 120, only one chamber port is possible, as is more than two chamber ports.

[091] As disclosed in Figure 12A-12C, a snorkel 200 includes another alternative exhalation valve configuration. The snorkel 200 is identical to the snorkel 100 of Figures 10A and 10B, except that the valve plate 120 and the flexible membrane 130 has been replaced with a different valve plate 160 and a different flexible membrane 180. The air flows through the snorkel 200 in a similar fashion as through snorkel 100, including the fact that exhaled air becomes trapped in chamber 106, thereby creating an exhalation pressure within chamber 106.

[092] The exemplary snorkel 200 also includes a valve plate 160 and a flexible membrane 180, which together form an exhalation valve. The valve plate 160 includes an exhalation port that is divided into an overlying exhalation port 170 and an underlying exhalation port 172. The valve plate also includes three chamber ports 166, as illustrated in Figure 13D. A flexible membrane 180 is attached to the edges of valve plate 160 and functions to seal the upper exhalation port 170 and the lower exhalation port 172 when the flexible membrane 180 is in the closed position, as

disclosed in Figure 12A. Also disclosed in Figure 10A and 10B is an exhalation conduit lower mount 162 which forms part of an exhalation conduit 128. The exhalation conduit lower mount 162 is divided by a septum 168 that creates an overlying conduit 174 corresponding to the underlying exhalation port 170 and an underlying conduit 176 corresponding to the underlying exhalation port 172. An exhalation tube 124 attaches to the exhalation conduit lower mount 162 at ribs 164. The underlying conduit 176 is sized and positioned such that, when the snorkel 200 is in use, any water that enters the exhalation conduit 128 tends to collect in the underlying conduit 176. Similarly, when water condenses along the inside surface of the exhalation conduit 128, it will tend to run down the inside surface and collect in the underlying conduit 176. The underlying conduit 176 functions, therefore, to trap water that enters the exhalation conduit 128.

[093] When the snorkel 200 is submerged in water, the ambient water pressure of the water surrounding the snorkel 200 pushes the flexible membrane 180 against the valve plate 120, thus sealing the overlying exhalation port 170 and the underlying exhalation port 172. When a user exhales into the chamber 106, the exhalation pressure that builds up inside the chamber 106 creates an opening force 140 which acts on the flexible membrane 180 through the chamber ports 166 of the valve plate 160. This opening force 140 biases the flexible membrane 180 in a first direction. At the same time, the ambient water pressure of the water surrounding the submerged snorkel 200 acts as a closing force 150 which biases the flexible membrane 180 in a second direction. The first direction of the opening force 140 is substantially opposite the second direction of the closing force 150.

[094] As disclosed in Figure 12A, when the closing force 150 is greater than or equal to the opening force 140, the flexible membrane 180 seals the exhalation port

132 such that substantially no air is released from the chamber 106 through the exhalation port 132. As disclosed in Figure 12B, however, when the opening force 140 exceeds the closing force 150, the flexible membrane 180 does not seal the overlying exhalation port 170 and the exhaled air 142 is released from the chamber 106 into the overlying conduit 174 of the exhalation conduit 128. Once the exhaled air 142 reaches the exhalation conduit 128, the exhaled air 142 is released from the snorkel 200.

[095] The flexible membrane 180 includes a hinged region 182. The hinged region 182 can be integrally formed in the flexible membrane 180 by making the hinged region 182 thinner than the surrounding regions of the flexible membrane 180. When assembled into snorkel 200, the hinged region 182 aligns with the septum 168 such that, when the flexible membrane 180 bends along the hinged region 182, as disclosed in Figure 12B, the overlying conduit 174 can become unsealed while the underlying conduit 176 remains sealed. The opening force 140 required to bend the flexible membrane 180 at the hinged region 182 is less than the opening force 140 required to bend the flexible membrane 180 such that both the overlying port 170 and the underlying ports 172 are unsealed, as disclosed in Figure 12C.

[096] This difference in the lesser opening force required to unseal the overlying exhalation port 170 and the greater opening force required to unseal the underlying exhalation port 172 allows a user of the snorkel 200 to exhale normally through the overlying exhalation port 170 without unsealing the underlying exhalation port 172. Since any water that enters the exhalation conduit 128 tends to collect in the underlying conduit 176, this aspect of the exhalation valve of the snorkel 200 allows a user to exhale with minimal liquid in the path of the exhaled air leaving the snorkel. This aspect of the exhalation valve also allows a user to periodically and intentionally

exhale more forcefully than normal in order to cause the opening force 140 to be great enough to unseal both the overlying exhalation port 170 as well as the underlying exhalation port 172. When this occurs, any fluid trapped in the underlying conduit 176 will be forced up the exhalation conduit 128 and out of the snorkel 200 by the forcefully exhaled air, thereby clearing the exhalation conduit 128 of unwanted fluid.

[097] As disclosed both in Figures 12A – 12C as well as in Figures 13A and 13B, the flexible membrane 180 can optionally include protrusions 184 and 186 which are integrally formed in the flexible membrane 180 and serve to dampen the impact of the flexible membrane 180 when closing against the valve plate 160. This dampening functions to decrease the noise that can be involved with the closing of the flexible membrane 180 against the valve plate 160. More particularly, the protrusion 184 is sized and configured to make contact with the septum 168 so that as the flexible membrane 180 closes and seals against the underlying exhalation port 172, the protrusion 184 absorbs the impact of the closing action by deforming slightly. This impact absorption results in less noise than without the presence of the protrusion 184. The protrusion 186 serves a similar function with respect to the inside wall of the overlying exhalation port 170.

[098] As disclosed in Figures 13C and 13D, the overlying exhalation port 170 and the underlying exhalation port 172 together form an oval shaped opening in the valve plate 160, although other shapes are possible. Figure 11D discloses three chamber ports 166 defined in the valve plate 160. The function of chamber ports 166 could be served by a single chamber port or by more than two chamber ports.

[099] As disclosed in Figures 14, a snorkel 200 having an exhalation valve with an adjustable tension includes a knob 202 and a barrel 204 around which an elastic string 206 can be wound. The elastic string 206 is attached to a flexible membrane

208. The structure and function of flexible membrane 202 can similar to the structure and function of the flexible membranes 130 and 180 of Figures 10A – 13D, or similar to other flexible membrane disclosed herein. The elastic string 206 is held substantially perpendicular to the flexible membrane 208 by the sides of a hole 210.

[0100] As the knob 202 is turned one direction, the elastic string 206 winds around the barrel 204, thus creating tension of the elastic string 206. Since the elastic string 206 is attached to the flexible membrane 208, the tension of the elastic string 206 biases the flexible membrane 208 in substantially the same direction as the exhalation pressure within the snorkel 200, and thus contributes to the opening force 140 acting on the flexible membrane 208. Thus, as the tension on the elastic string 206 increases, the exhalation pressure that is required to unseal the flexible membrane 208 decreases. Conversely, as the knob 202 is turned in the opposite direction, the elastic string 206 unwinds from around the barrel 204, thus decreasing the tension of the elastic string 206 and the resulting force 140 acting on the flexible membrane 208. Thus, the snorkel 200 includes knob 200 that allows a user to manually adjust the tension of the flexible membrane 208.

[0101] Although this invention has been described in terms of certain preferred embodiments, other embodiments apparent to those of ordinary skill in the art are also within the scope of this invention. Accordingly, the scope of the invention is intended to be defined only by the claims which follow.

CLAIMS

What is claimed is:

1. An exhalation valve for use in an underwater breathing device, the exhalation valve configured to produce positive end-expiratory pressure in the airway of a user of the underwater breathing device in order to reduce the overall work of underwater breathing, the exhalation valve comprising:

a plate defining at least one chamber port and an exhalation port, the at least one chamber port being positioned opposite the exhalation port; and

a flexible membrane that is sealable against a surface of the plate and is sized and positioned to be capable of sealing the exhalation port, the flexible membrane comprising:

a sealed position in which the flexible membrane seals the exhalation port such that substantially no air can flow between the at least one chamber port and the exhalation port; and

an unsealed position in which the flexible membrane does not seal the exhalation port such that air can flow between the at least one chamber port and the exhalation port.

2. The exhalation valve as recited in claim 1, wherein the plate is substantially rigid and substantially disk-shaped.

3. The exhalation valve as recited in claim 1, wherein the exhalation port is one of oval-shaped or teardrop-shaped.

4. The exhalation valve as recited in claim 1, wherein the flexible membrane further comprises a hinged region positioned so as to divide the exhalation port into two sides such that, when the flexible membrane bends along the hinged region, one side can become unsealed while the other side remains sealed.

5. The exhalation valve as recited in claim 1, further comprising at least one protrusion positioned between the plate and the flexible membrane and formed on the plate and/or the flexible membrane.

6. An underwater breathing device configured to produce positive end-expiratory pressure in the airway of a user of the underwater breathing device in order to reduce the overall work of underwater breathing, the underwater breathing device comprising:

a chamber including first and second openings, the chamber being configured such that when air is being exhaled through the first opening into the chamber in a manner that restricts air from simultaneously escaping through the first opening, there is no unrestricted passageway out of the chamber through which air can exit the underwater breathing device and, as a result, the exhaled air creates an exhalation pressure within the chamber; and

a valve for restricting airflow between the chamber and the second opening, the valve comprising:

a plate defining the at least one chamber port and the exhalation port, the at least one chamber port being positioned opposite the exhalation port, the at least one chamber port and the exhalation port defining the second opening; and

a flexible membrane that is sealable against a surface of the plate and is sized and positioned to be capable of sealing the exhalation port, the flexible membrane being configured such that an opening force, comprising any exhalation pressure within the chamber, biases the valve in a first direction and a closing force biases the valve in a second direction, the first direction being substantially opposite the second direction, the flexible membrane comprising:

a closed position in which the flexible membrane seals the exhalation port such that substantially no air is released

from the chamber through the exhalation port; the flexible membrane being disposed in the closed position when the opening force is less than or equal to the closing force; and

an open position in which the flexible membrane does not seal the exhalation port such that air is released from the chamber through the exhalation port, the flexible membrane being disposed in the open position when the opening force exceeds the closing force.

7. The underwater breathing device as recited in claim 6, further comprising a mouthpiece connected to the first opening.

8. The underwater breathing device as recited in claim 6, further comprising an exhalation conduit connected to the exhalation port.

9. The underwater breathing device as recited in claim 8, wherein the exhalation conduit is divided by a septum which creates a first conduit and a second conduit, the second conduit being sized and positioned such that, when the underwater breathing device is in use, any water that enters the exhalation conduit tends to collect in the second conduit.

10. The underwater breathing device as recited in claim 9, wherein the flexible membrane further comprises a hinged region aligned with the septum such that, when the flexible membrane bends along the hinged region, the first conduit can become unsealed while the second conduit remains sealed.

11. The underwater breathing device as recited in claim 10, wherein the opening force required to bend the flexible membrane at the hinged region of the flexible membrane and thereby only unseal the first conduit is less than the opening force required to bend the flexible membrane such that both the first and the second conduits are unsealed.

12. The underwater breathing device as recited in claim 6, wherein the closing force includes ambient water pressure when at least a portion of the underwater breathing device is submerged in water.

13. The underwater breathing device as recited in claim 6, wherein the opening force further includes a force created by a tension of an elastic string attached to the flexible membrane which biases the flexible membrane in substantially the first direction.

14. The underwater breathing device as recited in claim 13, wherein the tension of the elastic string, and the resulting opening force, is manually adjustable.