Dec. 10, 1968 YUJIRO YAMAMATO ET AL 3,415,245

NOISE-SUPPRESSION DIVING APPARATUS

Filed March 8, 1965 3 Sheets-Sheet 1

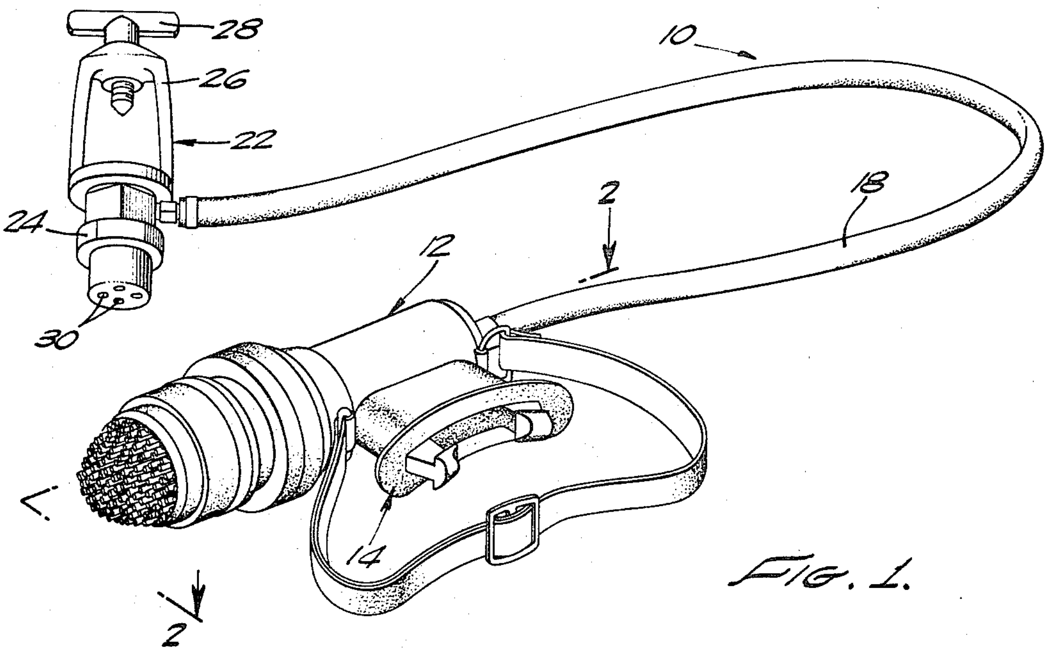

FIG. 1.

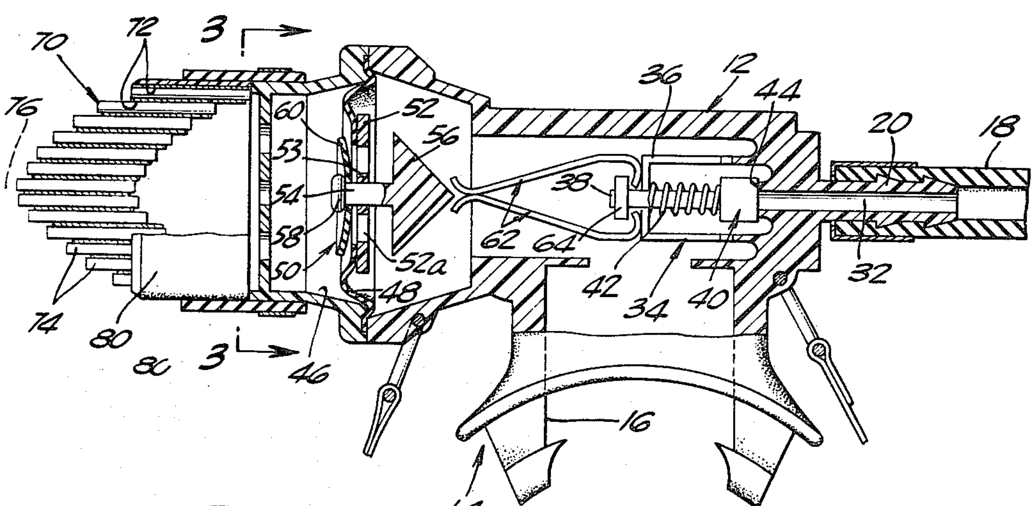

FIG. 2.

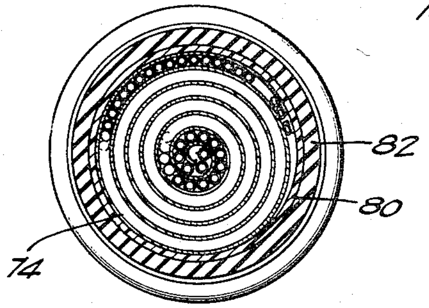

FIG. 3.

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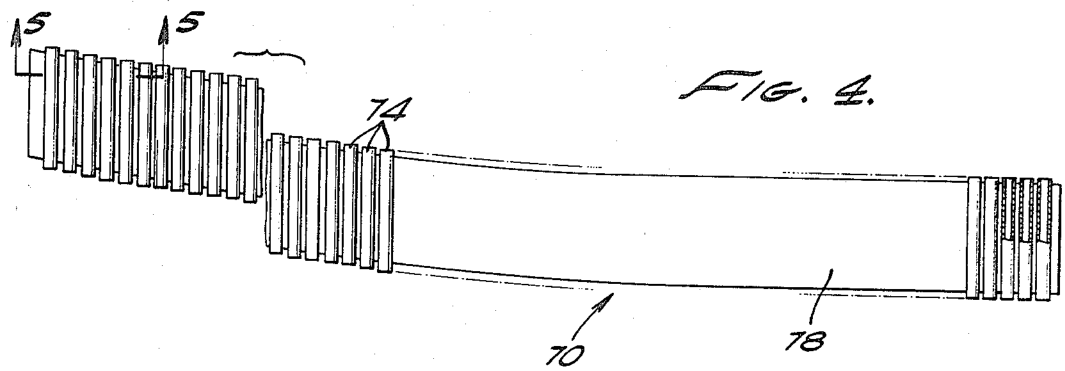


FIG. 4.

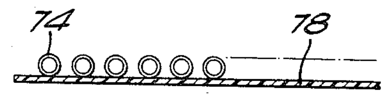


FIG. 5.

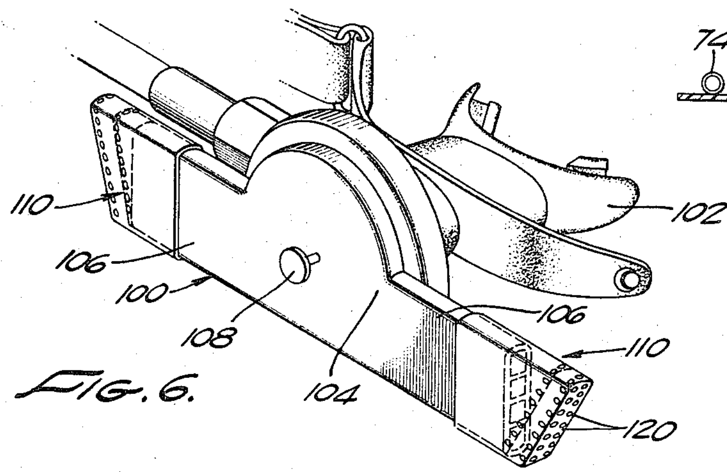


FIG. 6.

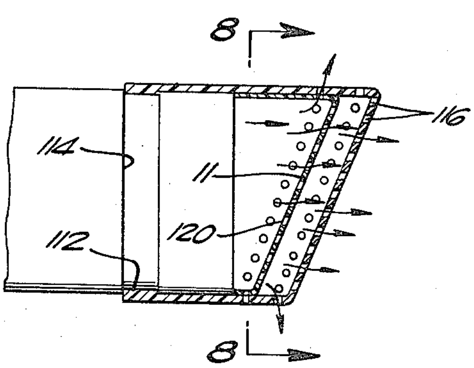
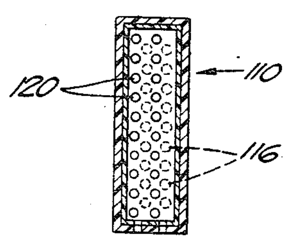


FIG. 7.

FIG. 8.



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NOISE-SUPPRESSION DIVING APPARATUS

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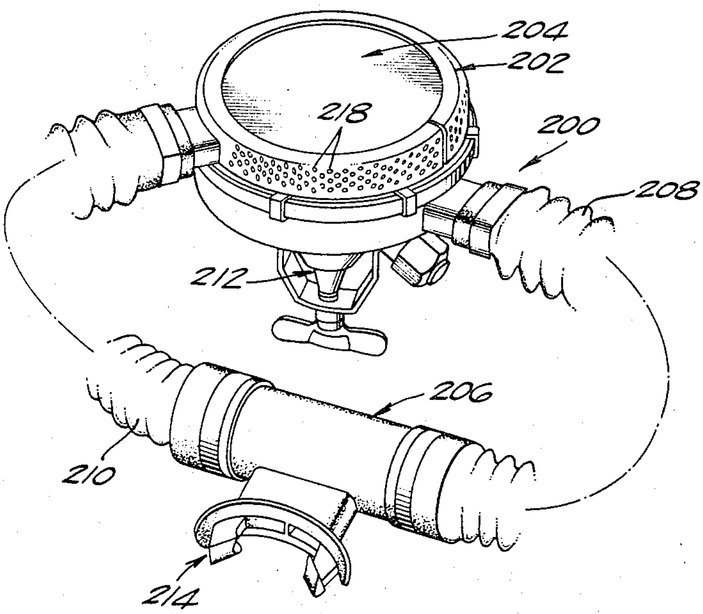


FIG. 9.

FIG. 10.

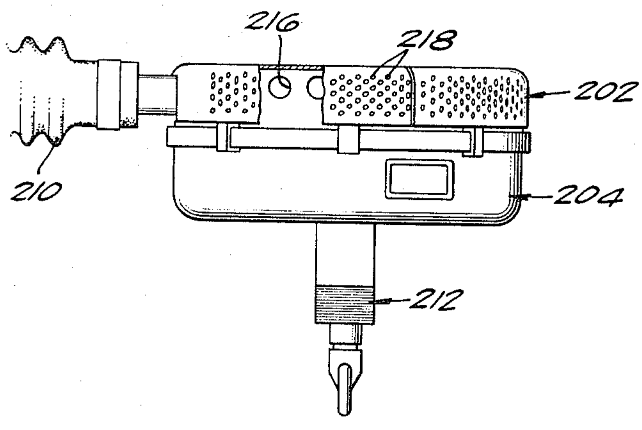
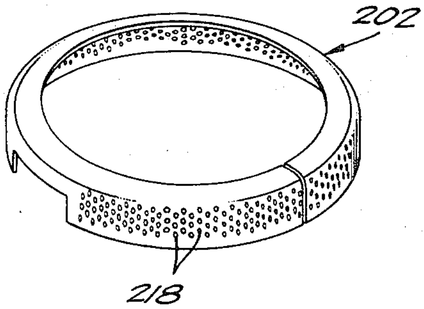


FIG. 11.



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NOISE-SUPPRESSION DIVING APPARATUS

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Filed Mar. 8, 1965, Ser. No. 437,968
8 Claims. (Cl. 128—147)

This invention relates generally to underwater breathing apparatus and has more particular reference to exhaust diffusers for minimizing the pressure fluctuations which normally occur in the breathing chamber of such apparatus during exhalation.

In recent years, underwater swimming has become an extremely popular sport which is widely practiced throughout the world. This increase in popularity of the sport has been due, primarily, to the development of relatively simple, light-weight, and reliable underwater breathing apparatus which may be safely used by both amateur and professional divers. Generally speaking, underwater breathing apparatus of this type comprises a breathing chamber which is equipped with either a mouthpiece or a face mask, and receives a breathable gas under a pressure slightly in excess of the ambient water pressure, and an exhaust passage through which expired air exhausts from the chamber to the surrounding water. If the breathing apparatus is equipped with a mouthpiece the latter is clenched between the diver's teeth and the diver may breathe only through his mouth. If the breathing apparatus is equipped with a face mask, the latter seals itself to the diver's face in such a way that the diver may breathe through both his mouth and his nose. Some types of underwater breathing apparatus of the kind under discussion are self-contained, that is to say, they are equipped with their own supplies of pressurized breathable gas. In this case, the breathable gas is stored under pressure in cylinders which are strapped to the diver's back and connected to the breathing chamber through an air supply hose. In other cases, the breathable gas is delivered to the diver from the surface through a long hose. Both of these types of underwater breathing apparatus include a demand pressure regulator which is responsive to the ambient water pressure and is effective to supply breathable gas to the breathing chamber at a pressure slightly in excess of the ambient water pressure at the depth to which the diver is submerged.

The existing underwater breathing apparatus of the kind under discussion possess one deficiency which this invention seeks to cure. To understand this deficiency, let us consider the actions which occur when a diver breathes underwater. Each time the diver inhales, the pressure in the breathing chamber is reduced to a level slightly below the ambient water pressure. This reduction in the chamber pressure results in closure of the exhalation valve by the ambient water pressure to prevent back flow of water into the chamber and in opening of the demand pressure regulating valve to supply breathable gas to the chamber. Each time the diver exhales, the chamber pressure is increased to a level slightly in excess of the ambient water pressure. This increase in chamber pressure reopens the exhalation valve to permit the expired air to exhaust into the surrounding water and recloses the demand pressure regulator valve to cut off the flow of breathable gas to the chamber. During each inhalation by the diver, the exhaust passage up to the exhalation valve fills with water. When the diver next exhales, the expired air emerging from the chamber forces the water out of the exhaust passage. When the exhausting expired air finally reaches the outer end of the exhaust passage, it commences to form a bubble in the surrounding water. The force of adhesion between the water and the wall of the exhaust passage and the force of cohesion between the water particles at the interface between the water and the expired air initially cause the bubble to adhere, in effect, to the wall of the exhaust passage. As a consequence, the bubble progressively increases in size as the expired air continues to exhaust through the passage. Eventually, the upward buoyant force on the bubble exceeds the force of adhesion between the water and the wall of the exhaust passage, whereupon the bubble abruptly breaks away and rises toward the surface. This abrupt release of the bubble results in a sudden back flow of water part way into the exhaust passage. Immediately thereafter, the exhausting expired air commences the formation of a new bubble, and the entire phenomenon is repeated. As a consequence of this alternate release of bubbles from the exhaust passage and back flow of water into the exhaust passage, there are created in the passage pressure fluctuations which are transmitted into the breathing chamber. Similar pressure fluctuations are experienced, for example, when air is blown through a straw immersed in a liquid. These pressure fluctuations, in turn, tend to interfere with normal breathing function of the diver during exhalation and to create vibration of the exhalation valve. While such effects of the pressure fluctuations are not detrimental to the extent of preventing use of the underwater breathing apparatus, they are, nevertheless, annoying to many divers.

The defects, discussed above, are particularly undesirable in the case of underwater breathing apparatus equipped with an underwater communication system. Thus, a recent development in the art has been an underwater communication system including a microphone which is situated to respond to the acoustic vibrations created when the diver speaks. It is apparent, of course, that when a diver speaks underwater, he exhales into the breathing chamber with the result that the pressure fluctuations created by intermittent release of bubbles from the exhaust passage of the breathing apparatus occur in the breathing chamber. It has been found by experience that these pressure fluctuations react adversely on the vocal cords of the diver in a manner which makes it very difficult, if not impossible, to understand his words. In addition, the vibration of the exhalation valve created by these pressure fluctuations produces a background noise which often obscures the diver's words. Even under ideal conditions, underwater communication is not too clear, particularly in those cases where the diver is required to speak through clenched teeth, as he must if the breathing apparatus is equipped with a mouthpiece. Accordingly, elimination of the defects under consideration is particularly important in underwater breathing apparatus which is used with an underwater communication system.

It is apparent at this point, therefore, that there is a definite need for improved underwater breathing apparatus which is not subject to the deficiencies discussed.

It is a general object of this invention to provide such improved underwater breathing apparatus.

A more specific object of the invention is to provide underwater breating apparatus embodying a diffuser of unique construction in the exhaust passage from the breathing chamber which is effective to minimize pressure fluctuations in the chamber and vibration of the exhalation valve to such an extent that they no longer interfere with the diver's normal breathing or underwater voice communications.

Another object of the invention is to provide exhaust diffusers for the purpose described which may be embodied in the existing underwater breathing apparatus without modification of such apparatus.

A further object of the invention is to provide exhaust diffusers for the purpose described which are relatively simple in construction, economical to manufacture, reliable in use, and otherwise ideally suited to their intended functions.

With these and other objects in view, the invention consists in the construction, arrangement and combination of the various parts of the invention, whereby the objects contemplated are attained, as hereinafter set forth, pointed out in the appended claims and illustrated in the accompanying drawings, wherein:

FIGURE 1 is a perspective view of a single hose underwater breathing apparatus embodying one form of the present exhaust diffuser;

FIGURE 2 is an enlarged section taken on line **2—2** in FIGURE 1;

FIGURE 3 is a section taken on line **3—3** in FIGURE 2;

FIGURE 4 is a view of the exhaust diffuser in the breathing apparatus in FIGURES 1 through 3, showing the diffuser unrolled;

FIGURE 5 is an enlarged section taken on line **5—5** in FIGURE 4;

FIGURE 6 is a perspective view of another type of single hose underwater breathing apparatus embodying modified exhaust diffusers according to the invention;

FIGURE 7 is an enlarged section through one of the exhaust diffusers in FIGURE 6;

FIGURE 8 is a section taken on line **8—8** in FIGURE 7;

FIGURE 9 is perspective view of a two hose underwater breathing apparatus embodying a further modified exhaust diffuser according to the invention;

FIGURE 10 is an enlarged side elevation, partly broken away, of the breathing chamber and exhaust diffuser in FIGURE 9; and

FIGURE 11 is a perspective view of the exhaust diffuser embodied in the underwater breathing apparatus of FIGURES 9 and 10.

Referring first to FIGURES 1–5, the basic underwater breathing apparatus **10** illustrated is conventional except for the present exhaust diffuser embodied therein. Accordingly, the apparatus will be described only in sufficient detail to enable a full and complete understanding of the invention. Underwater breathing apparatus **10** comprises a breathing chamber **12** having a mouthpiece **14**, the outer end of which is shaped to be clenched between the diver's teeth. Extending through the mouthpiece into the interior of the breathing chamber is a passage or opening **16** through which the diver inhales breathable gas from the chamber and exhales into the chamber. A breathable gas supply hose **18** has one end fixed to a nipple **20** extending from one end of the breathing chamber **12**. The opposite end of the supply hose is fixed to a fitting **22** adapted for connection to a cylinder (not shown) containing a supply of brethable gas under pressure. This gas cylinder is worn on the diver's back and is equipped with straps for securing the cylinder to the diver. Fitting **22** includes a valve housing **24** containing a pressure regulator (not shown). Extending from the inlet side of the valve housing, which side is uppermost in FIGURE 1, is a yoke **26**, mounting a clamp screw **28**. The valve housing **24** and clamp screw **28** are adapted to receive therebetween the supply head of the gas cylinder (not shown) in such a way that the supply head may be secured to and urged into sealing contact with the inlet side of the valve housing by threading the clamp screw against the head. When the gas cylinder is thus secured to the valve housing, an inlet port (not shown) in the inlet side of the housing communicates with an outlet port in the cylinder supply head. Breathable gas is thereby permitted to flow from the cylinder, through the pressure regulator in the valve housing **24** and the supply hose **18**, to the breathing chamber. The pressure regulator is effective to discharge the gas to the breathing chamber at a regulated pressure. In most cases, a diver carries a second gas cylinder which may be connected into the breathing system by flipping a valve when the first cylinder is empty. The pressure regulator is exposed to ambient water pressure through ports **30** in the valve housing **24** and is so constructed as to deliver the breathable gas to the supply hose **18** under a pressure slightly in excess of the ambient water pressure when the diver inhales.

Referring to FIGURE 2, it will be observed that the interior of the breathing chamber **12** communicates to the passage in the supply hose **18** through an inlet passage **32** in the wall of the chamber. Disposed within the breathing chamber, opposite the inner end of the inlet passage, is a check valve mechanism **45** which permits flow only in a direction from the supply hose **18** into the breathing chamber **12**. This check valve mechanism includes a supporting yoke **36** which is joined to the end wall of the breathing chamber and slidably supports the stem **38** of a check valve **40**. A spring **42** on the valve stem urges the valve to a closed position of engagement with a valve seat **44** surrounding the inlet passage **32**. It is apparent at this point, therefore, that the check valve **40** opens to permit flow of breathable gas from the supply hose **18** into the breathing chamber **12** and closes to prevent back flow into the supply hose.

At the opposite end of the breathing chamber **12** is an exhaust passage **46** which communicates the interior of the chamber to the surrounding medium. In the normal operational environment of the mask, of course, this surrounding medium is the water in which the mask is submerged. A flexible wall or diaphragm **48** extends across and is peripherally sealed to the wall of the exhaust passage **46** a distance inwardly from the outer end of the latter passage. The diaphragm has a central opening **50**. Bonded to the inner surface of the diaphragm, about its central opening **50** and overlying this opening, is a rigid plate **52** having openings **52*a*** and a central portion **53**. Extending through and frictionally fittted in the central portion **53** of the plate **52** is a stem **54** having a tapered wedge **56** at its inner end. On the outer end of the stem **54** is a bead **58**. A flexible check valve disc **60** is mounted on the stem **54** between the bead **58** and the diaphragm **48**. The diameter of this valve disc is somewhat larger than the diameter of the diaphragm opening **50**. It is apparent, therefore, that when the internal pressure of the breathing chamber **12** exceeds the external pressure of the surrounding medium, or water, the central portion of the diaphragm **48** is urged outwardly away from the breathing chamber and the outer edge of the check valve disc **60** is deflected outwardly away from the diaphragm, thereby to communicate the breathing chamber to the surrounding water through the diaphragm opening **50** and the exhaust passage **46**. When the ambient water pressure exceeds the internal chamber pressure, the outer edge of the valve disc is deflected into fluid sealing contact with the outer surface of the diaphragm about its central opening **50**, thereby to seal off the breathing chamber from the surrounding water, and the central portion of the diaphragm is urged inwardly toward the breathing chamber. As will be seen presently, the inlet check valve **40** is an inhalation valve which opens when the diver inhales and the exhaust check valve **60** is an exhalation valve which opens when the diver exhales.

Within the breathing chamber **12**, between the inhalation valve **40** and the exhalation valve **60**, are a pair of spring arms **62**. The right hand ends of these arms, as the latter are viewed in FIGURE 2, are bent inwardly to engage between the cross member of the inhalation valve supporting yoke **36** and a flange **64** rigid on the inner end of the inhalation valve stem **38**. The opposite ends of the arms **62** are bent inwardly toward one another to positions wherein these latter ends of the arms contact when the inhalation valve is closed and the diaphragm **48** occupies the position shown in FIGURE 2. The left hand extremities of the arms are bent outwardly away from one another. When the diaphragm **48** moves inwardly in response to a reduction in the internal breathing chamber pressure below the ambient water pressure, the tapered wedge **56** carried by the diaphragm is forced between the divergent left hand ends of the arms. When this occurs, the arms are rotated outwardly away from one another, about their right hand inturned ends as fulcrums, and these latter ends of the arms in effect pry the inhalation valve **40** away from its valve seat **44**. This is necessary to communicate the reduced pressure in the breathing chamber to the pressure regulator contained within the housing **24** of the fitting **22** and thereby effect opening of the inhalating valve to admit additional breathable gas to the chamber. When the diaphragm **48** moves outwardly in response to an increase in the breathing chamber pressure above the ambient water pressure, the inhalation valve spring **42** recloses the inhalation valve **40** and returns the arms **62** to their contacting positions of FIGURE 2.

The underwater breathing apparatus thus far described is conventional. In use, a diver grips the mouthpiece **14** between his teeth. When the diver exhales, the pressure in the breathing chamber **12** rises above the ambient water pressure with resultant closing of the pressure regulating valve and the inhalation valve **40** to cut off the flow of breathable gas into the breathing chamber. When the diver inhales, the pressure within the breathing chamber drops below the ambient water pressure with resultant closing of the exhalation valve **60** to prevent back flow of water into the breathing chamber and opening of the inhalation valve **40** and the pressure regulating valve to admit a new charge of breathable gas into the breathing chamber. As noted earlier, the expired air which emerges through the exhaust passage **46** when the diver exhales into the breathing chamber, forms bubbles at the outer end of the exhaust passage which intermittently break away from the exhaust passage and rise to the surface. As each bubble breaks away, there is a sudden inrush of water back into the exhaust passage. This alternate escape of bubbles from the exhaust passage and inrush of water back into the passage creates pressure fluctuations which are transmitted back into the breathing chamber **12**. Such pressure fluctuations in the chamber tend to interfere with normal breathing and cause vibration of the exhalation valve **60** in the breathing apparatus. These pressure fluctuations are quite pronounced for the reason that the bubbles which escape from the apparatus are relatively large. As a consequence, the interference to breathing and the valve vibration occasioned by such pressure fluctuations are annoying to many divers. From this standpoint alone, therefore, the elimination of the pressure fluctuations is extremely desirable.

As noted earlier, however, the pressure fluctuations and their attendant effects are particularly undesirable in underwater breathing apparatus which is used in connection with an underwater communication system. Even under ideal conditions, underwater voice communications are somewhat difficult to understand, particularly when the diver is required to speak through clenched teeth as he must when the breathing apparatus includes a mouthpiece. Accordingly, it is highly desirable if not absolutely essential to eliminate any interference with such underwater voice communications, such as the earlier discussed adverse reaction of the bubble induced pressure fluctuations on the vocal cords of the diver and the background noise produced by vibration of the exhalation valve **60**.

According to this invention, pressure fluctuations in the breathing chamber **12** occasioned by escape of expired air from the breathing mask into the surrounding water are minimized by placing a diffuser **70** in the outer end of the exhaust passage **46** of the breathing apparatus. This diffuser includes a multiplicity of restricted passages **72** through which the emerging expired air flows from the exhaust passage **46** into the surrounding water. It has been found that this exhaust diffuser is highly effective in reducing bubble induced pressure fluctuations in the chamber **12** to such an extent that they no longer adversely affect the diver's breathing or underwater voice transmissions. It is believed that the present exhaust diffuser is effective to reduce the pressure fluctuations in the breathing chamber for three reasons. First, in the existing underwater breathing apparatus, the effective cross-sectional area of the outer end of the exhaust passage, that is, the end of the exhaust passage through which the expired air emerges from the passage into the surrounding water, is relatively large and, as a consequence, the bubbles formed in the water by the emerging expired air are large. Accordingly, the mass of water which tends to flow back into the outer end of the exhaust passage following break away of each of these enlarged bubbles, and the resultant pressure fluctuation produced in the breathing chamber are correspondingly large. When the present diffuser **70** is placed in the exhaust passage the expired air emerges into the surrounding water through a multiplicity of relatively small diameter passages and the bubbles formed by the air emerging through each diffuser passage are relatively small. As a consequence, the mass of water which tends to flow back into the outer end of each diffuser passage following break away of each bubble therefrom, and the resultant pressure fluctuation created by such back flow are relatively small. Secondly, in the existing underwater breathing apparatus, the large bubbles formed by the emerging expired air tend to escape from the outer end of the exhaust passage one at a time, thereby producing in the breathing chamber very pronounced pressure fluctuations. When the present exhaust diffuser **70** is installed in the apparatus, the bubbles of expired air break away from the outer ends of the multiplicity of diffuser passages in random fashion, thereby resulting in a relatively high frequency low amplitude pressure fluctuation pattern, rather than in a low frequency, high amplitude pressure fluctuation pattern as in the existing breathing apparatus. In addition, because of the random nature of the pressure fluctuations created by the expired air escaping through the multiplicity of diffuser passages, these pressure fluctuations tend to cancel one another. Third, in the existing underwater breathing apparatus, the outer end of the exhaust passage has a single large opening to the surrounding water with the result that even though the expired air emerging through different portions of this opening may tend to form individual bubbles, those bubbles which emerge at the same instant of time tend to coalesce and form the relatively large bubbles referred to above. As noted, this results in pronounced, low frequency high amplitude pressure fluctuations in the breathing chamber. According to the preferred practice of the present invention, the outer ends of the diffuser passages are spaced in such a way as to eliminate the tendency of the bubbles emerging through each passage to combine or coalesce with the bubbles emerging through the adjacent passages and thereby form larger bubbles which would produce more pronounced pressure fluctuations in the breathing chamber.

To the above ends, the exhaust diffuser **70** in FIGURES 1, 2, and 3 comprises a bundle of small tubes **74** which are installed in the exhaust passage **46** in parallel relation to the central axis **76** of the exhaust passage and which define the restricted diffuser passages **72**. The inner ends of these tubes open to the exhaust passage. The outer ends of the tubes project beyond the outer end of the exhaust passage into the surrounding water. In addition, it will be observed that the outer ends of the tubes are spaced in the direction of he exhaust passage axis **76** in such manner that the outer end of each tube is axially spaced from the outer ends of its adjacent tubes. Thus, each time the diver inhales, the expired air emerging from the breathing chamber **12** flows from the exhaust passage **46**, through the diffuser tubes **74**, into the surrounding water and the air emerges from the outer end of each tube into the surrounding water as a string of small bubbles. Because of the axial spacing of the outer ends of the diffuser tubes, the tendency for the small bubbles emerging from each tube to coalesce with the small bubbles emerging from the adjacent tubes, prior to break away of the bubbles from the tubes, is substantially minimized or eliminated.

Referring to FIGURES 3, 4 and 5, it will be observed that the diffuser tubes **74** are adhesively bonded or otherwise secured to a strip **78** of flexible material in such manner that the tubes extend normal to the length of the strip and, therefore, in parallel relation to one another. The strip is then rolled into a coil which is adhesively bonded or otherwise secured within a retaining ring **80**. The retaining ring, in turn, is secured within a mounting ring **82** which is telescopically fitted over and secured in any convenient way to the outer end of the wall of the exhaust passage **46**. It, of course, will be understood that in the normal position of the breathing apparatus, the axis **76** of the exhaust passage is horizontal so that the outer ends of the diffuser tubes are normally horizontally staggered, as shown. This staggered relation of the tubes may be accomplished in either of two ways. For example, the diffuser tubes may be made of different length and secured to the strip **78** in such manner that the inner ends of the tubes are located substantially in a common plane normal to the axis **76** of the exhaust passage. Alternatively, the diffuser tubes may be of the same length and secured to the strip **78** in such manner that the outer ends of the tubes are axially offset, as illustrated. This latter method of constructing the diffuser is preferrred for the reason that diffser tubes of different length present differing resistances to the flow therethrough of the emerging expired air. Accordingly, there is a tendency, when the diffser tubes are of different length, for most of the air to flow through the shorter tubes. This has the effect of increasing the back pressure imposed by the diffuser. When all of the tubes have the same length, as illustrated in the drawings, the resistance to air flow through the tubes is substantially uniform with the result that the tendency for the emerging expired air to flow through some of the tubes and not others is substanially minimized or eliminated. It has been found that an exhaust diffuser according to the invention, wherein the diffuser tubes are of substantially the same length, creates no significant increase in back pressure.

Reference is now made to FIGURES 6 through 8 wherein there is illustrated a conventional single hose breathing apparatus **100** of modified design. Breathing apparatus **100** includes a mouthpiece **102** having a breathing passage (not shown) which opens into a breathing chamber (not shown) contained within a housing **104**. Leading from this housing are two exhaust ducts **106** containing exhaust passages which open through the outer ends of the ducts. Also contained within the housing **104** is an exhalation valve (not shown) which opens when the breathing chamber pressure exceeds the ambient water pressure and closes when the ambient water pressure exceeds the internal breathing chamber pressure, thereby to permit venting the expired air from the chamber into the surrounding water and prevent back flow of water into the chamber. Mounted on the housing **104** is a button **108** which may be depressed to manually open the check valve and thereby clear the breathing chamber.

Telescopically fitted over the outer end of each exhaust duct is a modified exhaust diffuser **110** according to this invention. Each exhaust diffuser comprises a sleeve constructed of plastic or other suitably rigid material which is proportioned to receive its respective exhaust duct. The diffusers may be secured to the exhaust ducts in any convenient way, as by providing the inner ends of the diffuser sleeves with internal shoulders **112** for engaging in external grooves **114** in the ducts. Extending across the outer end of each diffuser sleeve is a wall **116**. A second wall **118** extends across the interior of each diffuser sleeve in spaced and preferably substantially parallel relation to the outer wall **116**. The inner diffuser walls **118** may be secured in position in the diffuser sleeves in any convenient way. In the drawings, for example, each inner diffuser wall **118** comprises tha end wall of a sleeve which is proportioned to fit closely in its respective outer diffuser sleeve and is adhesively bonded or otherwise fixed in position in the latter sleeve. The inner and outer diffuser walls, **116**, **118**, are provided with a multiplicity of restricted ports or passages **120**. Preferably, the passages **120** in the outer diffuser walls **116** are offset relative to the passages **120** in their respective inner diffuser walls **118**. The side walls of each diffuser are formed with similar restricted ports or passages **120** in the region between the inner and outer diffuser walls **116**, **118**, and in the region just inwardly of the inner walls.

Each time the diver exhales, the exhalation valve (not shown) within the breathing chamber housing **104** opens to vent expired air from the chamber to the surrounding water through the exhaust ducts **106**. This expired air emerges into the surrounding water through the restricted passages **120** in the exhaust diffusers **110**. It is apparent that since each of these passages is substantially smaller in cross-sectional area than the exhaust passages in the exhaust ducts, the diffusers are effective to minimize the bubble induced pressure fluctuations in the breathing chamber for the same reasons as discussed earlier in connection with exhaust diffuser of FIGURES 1 through 5. It will be recalled that in the latter diffuser, the outer ends of the diffuser passages, in the normal position of the breathing apparatus, are horizontally offset to minimize coalescence into large bubbles of the relatively small bubbles emerging from the adjacent diffuser passages. In the modified exhaust diffusers **110** of FIGURES 6 through 8, this same desirable end is achieved by inclining the outer diffuser walls **116** at an acute angle relative to the normally horizontal axis of the exhaust ducts **106** as illustrated in the drawings, so that the adjacent diffuser passages **120** in the outer diffuser walls are horizontally offset in the normal position of the breathing apparatus.

Reference is now made to FIGURES 9–11 wherein reference numeral **200** denotes a conventional two hose underwater breathing apparatus equipped with a further modified exhaust diffuser **202** according to the invention. Breathing apparatus **200** comprises a rear pressure regulator and exhaust chamber **204** and a front breathing chamber **206**. Extending from the rear chamber to the front chamber is a supply hose **208**. Extending from the front chamber to the rear chamber is an exhaust hose **210**. The rear chamber has the usual means **212** for connection to a tank of breathable gas under pressure. The front chamber has a mouthpiece **214**.

When the diver inhales, breathable gas from the tank flows from the rear chamber **204** to the front chamber **206** through the supply hose **208**. When the diver exhales, the expired air flows from the front chamber to the rear chamber through the exhaust hose **210**. This expired air exhausts from the rear chamber into the surrounding water through exhaust passages on ports **216** in the wall of the rear chamber. It has been found that the air bubbles which are formed by the expired air emerging through the exhaust ports **216** are quite large and tend to create the undesirable pressure fluctuations referred to earlier.

The exhaust diffuser **202** reduces the size of these exhaust bubbles and causes random escape of the smaller bubbles from the exhaust ports **216**, thereby minimizing or eliminating the undesirably bubble-induced pressure fluctuations, as before. Exhaust diffuser **202** comprises a simple spring band which is perforated to provide a multiplicity of restricted passages **218**. The diffuser band is dimensioned so that it may be snapped over the rear chamber **204** to the position shown, wherein the perforated portion of the band overlies the exhaust ports **216**. The band is frictionally retained in position by virtue of the spring pressure of the band against the chamber wall. When the breathing apparatus is in use, the expired air emerges from the rear chamber through the restricted diffuser passages **218**, whereby bubble induced pressure fluctuations are minimized or effectively eliminated.

In typical exhaust diffusers according to the invention the restricted diffuser passages are on the order of .032 to .040 inch in diameter.

The invention has been disclosed herein in connection with underwater breathing apparatus of the self-contained type. It will be immediately apparent to those skilled in the art, however, that the invention may, as well, be utilized in underwater breathing apparatus which is supplied with breathable gas from the surface.

While the invention has herein been shown and described in what is conceived to be the most practical and preferred embodiment, it is recognized that departures may be made therefrom within the scope of the invention, which is not to be limited to the details disclosed herein but is to be accorded the full scope of the claims so as to embrace any and all equivalent devices.

Having described the invention, what is claimed as new in support of Letters Patent is:

1. In a single-hose underwater breathing apparatus, the combination comprising:

means defining a breathing chamber having an opening for communication to the mouth of a diver;

means defining an exhaust passage opening at one end to said chamber, and at its outer end communicating with the surrounding water;

an exhalation valve in said exhaust passage which permits flow of air through said passage only in the direction from said chamber to the surrounding water;

an exhaust diffuser having a plurality of elongated restricted passageways formed therein, each of said passageways being of substantially the same length and the outer ends of said passageways terminating at various different longitudinal positions;

and means securing said diffuser to the outer end of said exhaust passage means so that all of the air discharged from said exhaust passage flows through said diffuser, and upon reaching the end of respective ones of said passageways is immediately discharged into the surrounding water.

2. Apparatus as claimed in claim **1** wherein the outer ends of said passageways are arranged in a generally convex configuration so that even when the discharge of air is in a downward direction the plurality of small air bubbles discharged from respective ones of said passageways are not confined by said diffuser but rise upwardly in the surrounding water.

3. Apparatus as claimed in claim **1** wherein said diffuser is formed from a plurality of tubes that are secured to a flexible strip, the strip being rolled in a coil; said securing means including a cylindrical mounting ring which extends partially over the outer end of sad passage defining means and partly over the adjacent end of said exhaust diffuser.

4. In underwater breathing apparatus, the combination comprising:

an exhaust duct opening at one end to a mouthpiece compartment, said exhaust duct having an outer end;

and an exhaust diffuser consisting essentially of a double-bottomed cup;

the upper end of said diffuser cup being fitted around and secured to the outer end of said exhaust duct;

the two bottom walls of said diffuser cup being spaced apart in substantially parallel relationship and each having a plurality of small openings formed therein.

5. Apparatus as claimed in claim **4** wherein said exhaust duct is of substantially rectangular configuration, and wherein one side of said diffuser cup is of significantly greater depth than the other side so that air being exhausted from one side of said exhaust duct travels a significantly greater distance before encountering the diffuser openings than does the air exhausted from the other side of said exhaust duct.

6. Apparatus as claimed in claim **4** wherein the small openings in the two bottom walls of said diffuser cup are non-aligned, so that air passing through any one of at least certain small openings of the first bottom wall must be transversely deflected before passing through a small opening in the second bottom wall.

7. In a single-hose underwater breathing apparatus, the combination comprising:

means defining a breathing chamber having an opening for communication to the mouth of a diver;

means defining an exhaust passage opening at one end to said chamber and at its outer end communicating with the surrounding water;

an exhalation valve in said exhaust passage which permits flow of air through said passage only in the direction from said chamber to the surrounding water;

and an exhaust diffuser secured to the outer end of said exhaust passage means, said diffuser on its outlet end having a plurality of small openings of the order of 0.032 to 0.040 inch in diameter, said diffuser having a plurality of restricted openings on its inlet end, and said diffuser having a length which is very large compared to the diameter of said outlet openings whereby said diffuser adds a significant resistance load to the breathing circuit of the apparatus.

8. In a two-hose underwater breathing apparatus, the combination comprising:

means defining regulator including a substantially cylindrical air exhaust chamber, said air exhaust chamber having relatively large, circumferentially spaced exhaust ports formed in the circumferential wall thereof;

means for attaching an air hose at one circumferential point to the circumferential wall of said exhaust chamber;

and a cylindrical, resilient, exhaust diffuser band so dimensioned that it may be snapped over said exhaust chamber wall to be frictionally retained thereon, said diffuser band having a portion cut away to fit around said air hose attachment means, said diffuser band having a plurality of small openings formed therein whose diameter is of the order of 0.032 to 0.040 inch whereby air bubbles emerging from said exhaust ports are broken into a plurality of smaller bubbles before being disseminated into the surrounding water.

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