Proceedings
American Academy of Underwater Sciences
Diving For Science
2016

Editors
Lisa Lobel
Michael Lombardi

In: Lobel L.K., Lombardi, M.R. eds. Diving for Science 2016.
Proceedings of the American Academy of Underwater Sciences 35th Symposium.

Full-face Masks for Diving Applications: An Overview

Giorgio Caramanna[1*], Jouni Leinikki[2]

[1] GeoAqua Consulting, PO Box 2805, Vineyard Haven, MA 02568, USA
giorgio.caramanna@gmail.com
[2] Alleco Oy, Veneentekijäntie 4, Helsinki, Finland
[*] presenting and corresponding author

Abstract

Full-face masks are designed to cover a diver's face in a single volume, including the eyes, nose and mouth. These masks offer a higher degree of protection from the surrounding environment mostly in terms of enhanced thermal insulation during cold water or ice diving and some limited protection when diving in potentially polluted waters. Another important aspect of full-face masks is that they can be equipped with an underwater communication system that allows the divers to speak to each other and with the surface team. This latter characteristic is extremely useful when complex information needs to be shared as in the case of scientific diving operations and training. A full-face mask is a versatile piece of equipment that can be integrated in different diving configurations such as SCUBA, surface-supplied, tethered diving and rebreathers. There are a few specific safety issues that the divers need to address when using a full-face mask mostly because this system integrates both the mask and regulator into one single unit. As is for any piece of diving equipment, full-face masks need proper knowledge and training in diving procedures to be safely and proficiently used. There are a good number of different models available that, even though they share the same basic structure, are designed to fulfill different needs including recreational divers, technical divers, professional divers and the military.

Keywords: ice diving, polluted waters, scientific diving, training, underwater communicators

Introduction

The term "full-face" refers to a mask designed to cover a diver's face including eyes, nose and mouth in a single volume, differing from the traditional "half-mask" which covers only the eyes and nose. The full-face mask therefore offers a higher degree of protection but nevertheless the head and the eardrums remain exposed to the surrounding water and should be taken into consideration in specific circumstances such as when diving in polluted waters.

Using a full-face mask, the diver can breathe through the nose. Because a mouthpiece is not needed, it is possible to speak with other divers and the surface team when the full face is equipped with communicators. This characteristic enhances the overall safety of the dive and is a key feature for operations that require a complex exchange of information among the diving team members and/or between divers and the surface (Angelilli, 2012). In general, full-face masks are equipped with an on-demand second stage regulator, which is activated when the pressure inside the mask drops after the inhalation phase. The air is then vented outside through the regulator exhaust valve or, in some models, through a dedicated valve usually placed on the bottom of the mask frame. A few models can be equipped with a positive-pressure regulator that is able to maintain an inner pressure above that of the surrounding environment with a controlled continuous flow of breathing gas inside the mask. Using a full-face mask, a diver will continue to breathe even in the case of loss of consciousness, thereby increasing the chance of being successfully rescued (Mitchell et al., 2012; Pitkin A., 2003). In the event that a diver runs out of air, no water will enter into the lungs, which increases the probability of resuscitation.

Because the mask also includes a regulator, water should not enter and therefore the visor cannot be cleared by flooding the mask; instead, it must be defogged by another system such as a stream of fresh air circulating along appropriate paths. Usually, fresh air enters the mask from the visor base and flows along its surface before entering the oral-nasal mask. The exhaust air is then vented through the regulator baffles or a specific venting valve.

Scientific diving with a full-face mask

Scientific diving focuses mostly on data collection, deployment of scientific instruments, collecting samples and performing a variety of underwater experiments that often require a high degree of coordination between the divers and between divers and the surface. The possibility of vocal communication when using a full-face mask allows for exchanging even complex information faster than with any other underwater communication technique, which makes this diving gear especially useful for scientific divers. The collected information can easily be communicated to the surface team, making underwater recording procedures unnecessary and simplifying and reducing the diver's workload.
The use of a full-face enhances the safety and comfort of the diving activity mostly when such activity is performed in challenging environments such as cold, deep or polluted waters.

Cold water/ice diving
Scientific divers may be involved in underwater research activity requiring diving in very cold water or below the ice such as in polar studies, frozen lakes and high-latitude areas. Cold water and ice diving are demanding activities that expose the diver to stressful conditions both physically and mentally (Heine, 1996; Hendrick and Zaferes, 2003). Moreover, low temperatures may affect the performance of the diving gear, mostly regulators, leading to potential freezing of the first and second stage and causing free-flow. Free-flow under very cold temperatures is not only dangerous for the obvious reason of quickly consuming the breathing gas supply available, but also because the rapid gas expansion can further decrease the temperature (Joule-Thomson effect) generating extremely low values which can harm the diver who is breathing through the regulator.

When diving in very cold water, there are two main advantages for using a full-face: the diver's face has better thermal insulation, and the second stage is far less prone to freezing. If the full-face mask is to be removed in cold water, induced thermal shock may trigger the mammalian diving reflex leading to bradycardia, which can be potentially dangerous for the diver (Robinson, 2012).
It is important to ensure that before entering the water, the full-face and its second stage are maintained dry and insulated from the surrounding cold environment as much as possible until the very last moment. The diver should then wear the full-face and enter the water as soon as possible, refraining from breathing when still out of the water in order to reduce potential freezing of the second stage due to ice crystal formation from the moisture created by breathing. Therefore, correct functioning of the regulator should be checked with the diver's face below the water soon before starting the dive.

The choice of the first stage, generally not included in the full-face kit, should focus on a model designed for use in cold water and/or that can be equipped with an anti-freeze kit. Ice diving requires diving in an overhead environment where direct access to the surface is denied by the presence of ice; therefore, the diver must swim back to the entrance hole to exit. The use of a full-face equipped with communicators enhances the diver's safety, allowing a continuous exchange of information with the surface team and, when tethered diving is performed, with the tender (Sheldrake et al., 2011).

Moreover, if both diver and standby diver are equipped with communicators, they can talk to each other in case the standby diver is deployed facilitating rescue and support operations.

At the end of the dive, the full-face should be removed and placed in an insulated bag to avoid ice formation. If the mask freezes, it should be placed in a warm environment to allow the ice to melt. Pouring hot water on the mask as a deicing procedure should be avoided because the induced thermal shock could cause some components of the mask to break, such as the visor. The use of other defrosting liquids should be carefully assessed because their chemical composition could damage some of the components of the mask and/or its residuals may be harmful for the diver.
The mask should be completely dried before being used for the next dive. Using a mask that is still wet in very cold environments will very likely lead to icing issues.

Mixed gas diving
Mixed gas diving may be necessary for scientific divers in deep diving and when decompression gases are used (Kesling and Styron, 2006).If a full-face is used in mixed gas dives, it should be connected to a specific manifold that allows switching between the different gases. The advantage of a full-face is that the diver avoids swapping of the second stages when shifting from the bottom mix to the travel and deco mix, which is needed when changing breathing gas using a standard SCUBA configuration.

When using a communicator system, the diver will also be able to talk with the surface thereby improving safety during critical moments such as during long decompressions. A limitation of the use of communicators is the maximum depth at which these are rated; if the planned depth of the dive is below the suggested limits of the communicator device, it should not be used because it could be easily be damaged by pressure. The use of a full-face, mostly if coupled with a communication system, may increase the breathing gas usage; therefore, an accurate calculation of the necessary gas should be part of the pre-dive planning especially for deep dives (Robinson, 2012). The presence of helium in breathing gas causes a modification in the sound frequency with a shift towards high-pitched notes. As a consequence, clarity of speech is compromised and this should be taken into consideration when a communicator system is used (Tucker, 1986).

If the full-face is to be used with gases with an oxygen content higher than 40%, it should be cleaned and prepared to oxygen standard to avoid potential oxygen ignition; such cleaning and preparation should be performed by a trained technician and only if the procedure is approved by the full-face maker (Lang, 2006).

Polluted waters
Divers may be required to collect samples in areas where some degree of pollution is expected. The protection offered by a full-face, even if used with a dry hood connected to a dry suit, is limited because the mask could be dislodged and there is a potential of leaks from the watertight seal and other areas (Table 1; Amson, 1991; Barsky, 2007; Harris, 2009; Naval Sea Systems Command, 2004; Steigleman, 2002). The pollution must therefore not be of such a level to present a risk of death or serious disability should the diver become contaminated. The Association of Diving Contractors International standards allow the use of a full-face in waters where a level of contamination can cause short-term health effects but will not cause lasting injury, disability or death (ADCI, 2011). If high levels of dangerous contaminants are present, more efficient protective gear is needed such as a diving helmet, and special diving procedures should be followed.

Most full-face masks are equipped with an “on-demand” regulator which, if the sealing between the mask and the diver's face is breached, will free-flow generating an inner over-pressure that is able to prevent water from entering the mask. Using positive-pressure regulators can enhance protection from leaks inside the mask but requires the use of surface-supplied diving procedures, which are quite demanding in terms of logistics, cost and equipment, and also limit the diver's freedom of movement in the water. Moreover, water can enter the mask anyway if the breach is large or if the diver assumes some positions such as head-down; therefore, protection from pollution offered by the over-pressure effect is quite limited.

The first stage should be equipped with a protective membrane, such as that used in anti-freezing kits, so as to avoid ingression of polluted water within the inner mechanism since some pollutants (e.g. volatile compounds) could migrate within the regulator and contaminate the breathing gas. Pollutants may also penetrate the second stage regulator's membrane or exhaust valves and a number of chemicals can also seep through the fabric of a dry suit or penetrate the walls of hoses or the umbilical carrying the breathing gas, making diving in polluted water an extremely dangerous operation (Viking, 2001).

Decontamination procedures should be adopted once the diver is back on the surface and before removing the diving gear; this is to avoid the contaminants present on the external surface of diving gear from entering into contact with the diver's body. The decontamination wastes should also be correctly eliminated. The ground crew employed in decontamination procedures should wear appropriate protection to avoid being exposed to contaminants (EPA, 1997; Tulis and Langley, 1994). Decontamination procedures should be clearly described in the operation plan and the team should be trained in such procedures (Angelilli, 2012).

Diving in some types of water, such as in the presence of fluids of low pH and/or sulfur compounds (e.g. close to submarine geothermal vents or in volcanic lakes), will also affect the aging rate of diving gear and the full-face, leading to potential oxidation and corrosion of the metal parts; therefore, more frequent servicing of equipment and replacement of damaged parts, which means higher maintenance costs, is required.

Table 1. Potential points of contaminant ingression

Potential contaminants ingression points	Cause
Mask seal	Damaged seal, displaced mask
First stage	Use of a non-sealed first stage
Second stage membrane	Damaged, displaced or chemical permeability
Second stage exhaust valve	Damaged, displaced or chemical permeability
Atmospheric breathing valve	Not properly closed before diving
Communicator port	O-ring misplaced or damaged
Water drainage valve (some models)	Damaged, displaced or chemical permeability

Diving configurations with a full-face mask

Different diving configurations may be used with a full-face mask. In SCUBA mode, a secondary air source should be available. In surface supplied, a non-return valve along the umbilical and a bailout system are mandatory. In mixed gas diving, each cylinder may be equipped with a second stage as an extra safety measure. Each technique has its advantages and limits. Moreover, specific safety rules need to be followed depending on the diving configuration adopted.

SCUBA diving
In this case, the full-face mask is added to the standard SCUBA configuration maintaining freedom of movement that is typical of this diving technique.
When a full-face mask is used for SCUBA diving, some safety rules must be followed (Robinson, 2012; Barsky, 1994).

- Another independent air source, including at least a second stage (octopus), should be present.
- A spare half-mask should be carried and the diver should be proficient in removing the full-face and replacing it with the mask.

The full-face may also be connected through a manifold to another breathing gas source. This can be a bailout cylinder or, in case of deep and technical diving, multiple gas sources.
Using a wireless communicator can enhance the safety and proficiency of the divers allowing for discussion within the diving team and with the surface crew; the augmented breathing rate due to the use of vocal communication should be considered in planning adequate breathing gas availability.

Tethered diving
In this case, the diver is using SCUBA gear plus a tether connected to the surface and manned by a tender. Usually the diver is in water alone and a standby diver is ready to be deployed for assistance if needed. The tether is also a physical link between the diver and surface and can be used to quickly guide the standby diver if necessary. Some potential for entanglement is present but the risk can be well controlled by correct management of the tether by the tender and diver. Because the diver is alone in water, an appropriate breathing system redundancy is necessary in the form of an independent air source (Sheldrake, 2011).

The advantage of such a system is that along with the tether, it is possible to use a wired communicator that generally has better performance than the wireless. Moreover, by using this system the surface crew can continuously monitor the diver's breathing sound and therefore be aware of any anomaly in its rate. A common application of this procedure is in ice diving where the tether is a physical safe connection between the diver and the hole in the ice canopy, which is the only exit point (Leinikki, 2004).

Another application of tethered diving is in "Blue-water" diving where the divers operate in the open ocean. In this case, multiple divers are connected to a down line fixed to a surface float connected to the diving platform. The aim of using a physical connection for the divers is to assure that they will stay on station without the risk of drifting or going below the planned maximum depth. A standby diver will be in charge of supervising the working divers. Usually, rope signals are used between the divers (Haddock and Heine, 2005). In diving teams composed of divers from different nations, it is necessary to agree on the rope signals used, as they vary considerably between countries. In this situation, the use of full-face masks equipped with communicators would allow divers to talk providing advantages in terms of safety and quality of the scientific operation.

Surface-supplied diving
In surface-supplied diving, breathing gas is provided from the surface through an umbilical. The obvious advantage of this system is that the breathing gas supply is theoretically never-ending and the diver does not have to carry cylinders. Another advantage of this system is that the breathing mix is delivered and controlled by the surface team, allowing the diver to focus on the work task (Humphrey et al., 2011).

In the unlikely event of a failure of surface-supplied, a bailout cylinder with enough breathing gas for safe surfacing is carried with a harness which is also used to connect the umbilical and the communication wires.

When using a full-face, the second stage of the mask is connected to a manifold that accepts the main supply form the umbilical (this must have a non-return valve installed) and the bailout gas from the first stage on the bailout cylinder.

The logistics involved in this type of diving can be complex and require the deployment of expensive equipment and the presence of a well-trained surface team that should include at least a primary and standby divers, divers' tenders and one supervisor (Robinson, 2012).

Rebreather diving
The use of a full-face coupled with a rebreather may be considered when vocal communication between the diving team is unavoidable such as in some filming operations (Seymour, 2012). When using a full-face mask with a rebreather, the increased "dead space" in the breathing loop due to the larger volume of airspace within the mask should be considered; the use of oral-nasal inner mask or a two-section full-face with a detachable breathing pod can reduce this problem (Pyle, 1996). Changes in internal pressure due to the respiratory cycle may affect the integrity of the mask seal (Robinson, 2012). CCR-oxygen based is another field of application for full-face allowing for better airways protection in high-oxygen exposure (Butler, 2004). The Navy Experimental Diving Unit tested a full-face mask Kirby-Morgan M48 to be used with the "Viper", a shallow-water rebreather which utilizes 70% O_2 – 30% N_2 breathing mix. The mask's performance was considered satisfactory for use with the rebreather even though an increase of 29% in the respiratory effort of the rebreather was recorded (Stanek and Hedricks, 2003). This value is above the usual increase of 14% due to the use of a full-face and could be due to improper fitting of the oral-nasal mask (Warkander, 2010). If the diver were to become unconscious, wearing a full-face mask prevents water ingression both in the lungs and in the rebreather loop which increases the diver's safety even in extreme situations (Verdier, 2007). Some of full-face masks that are currently available on the market are certified to be used with a CCR.

Safety issues with a full-face mask

As for any piece of equipment, a full-face mask presents some issues that need to be addressed for its safe and proficient use (Barsky, 1994; Robinson, 2012)

Loss of communication
One of the main advantages in using a full-face is the possibility of talking with the diving team and the surface. If there is failure in the communication line, different approaches can be followed depending on the type of diving that the diver is performing:

- SCUBA: In this case, it is possible to continue the dive given that hand signals are feasible and that the communication loss is not affecting the underwater activity (e.g. if communicating is the only way for data collection during a scientific diving activity, the dive should be terminated).
- Tethered: In this case, pre-arranged rope signals can be used to maintain a degree of communication between the diver and the surface.
- Surface-supplied: In this kind of dive, communication between diver and surface is mandatory and if it is lost, the dive must be terminated.

Broken faceport
The visors of full-face masks are generally made of very strong material and shattering them is very unlikely to happen under normal diving conditions. Nevertheless, should this happen, it is a very serious issue. A full-face with a broken faceport will flood immediately making communication impossible and making breathing through the second stage regulator extremely difficult or unattainable. If this happens, the diver should replace the full-face with the spare mask and start breathing through the alternative air source, terminating the dive following a safe ascent to the surface.

Water ingression
In case of water ingression, the diver should assume a "chin up" position and press the second stage purge button. This action will start a free-flow of breathing gas within the mask pushing the water out through the exhaust system. This issue is generally not life threatening, but proper training is necessary in order to perform the dewatering operation quickly and proficiently. If the dive was in polluted water, the diver – having being exposed to contaminants – should go through an appropriate medical assessment.

Sharing breathing gas
The full-face can be equipped with a manifold and quick disconnection hoses so that one breathing gas source can be shared between two divers. A further alternative is the use of secondary regulators to be shared between the divers as in standard SCUBA configuration; in this case, the diver in need of breathing gas will replace the full face with the spare standard mask and breathe through the alternate regulator offered by the other diver. Specific training on these procedures is needed and the skills should be periodically reviewed. In a gas-sharing situation, the dive needs to be terminated following a controlled ascent. Sharing the full-face itself between divers is a very unlikely operation that would expose both divers to a very high level of risk; therefore, it should be avoided.

Increased gas consumption
When using a full-face mask, an increase in breathing gas usage is quite common. The main cause is often that a full-face is used with communicators and talking leads to higher breathing rates. Moreover, mostly during the ascending phase of the dive, some gas may escape from the watertight seal causing the regulator to undergo short free-flow bursts. The diver should therefore reassess the breathing rate when using the full-face in order to correctly plan breathing gas management.

Fogging
In order to avoid fogging of the faceport, the inside of the mask should be maintained as dry as possible. For this reason, it should be put on before entering the water. If the diver has to wait at the surface for a long time wearing the full-face, he/she will consume part of the breathing gas needed for the dive. In this case, two options are available: wait to put on the mask until when in the water and just before starting the dive, or add a specific port to the mask with a valve through which it is possible to breathe atmospheric air when on the surface. In the first case, attention should be given to avoid getting the inside of the mask wet. The second solution requires adding an atmosphere-breathing valve to the mask. The use of anti-fogging liquids is also an option, and for some models of full-face, it is the only option available.

Equalization
Because of the shape of the full-face, it is not possible to pinch the nose to equalize; depending on the model, different devices allow nostrils to be closed. For some divers the equalization procedure with a standard mask compared with a full-face is more difficult, but for others it is actually easier because of the free-nose breathing. Failure to equalize will lead to termination of the dive.

Changes in buoyancy
The larger volume of a full-face affects the diver's overall buoyancy; some models allow for small trimming ballasts to be added. Another issue is the potential seepage of breathing gas from the mask into the hood; this can be mitigated with good mask fitting and/or using vented hoods or puncturing small holes on the top of the hood to act as vents.

Full-face masks available on the market

A number of full-face masks are available on the market. Even though they share some common features, there are differences in their technical characteristics due not only to the producer's choices but also to the market (i.e. commercial, military, rescue, law enforcement, recreational divers) that they are intended for. The following is a description of some full-face masks that are currently available (Table 2).

Interspiro: Divator MKII
This system has been successfully tested by the US Navy Experimental Diving Unit – NEDU (Panama City, CA) to a maximum depth of 60 meters (197 ft) and water temperature of -1.7°C (29°F).

The full-face is available in four versions: Rubber black, Rubber grey, Silicon black, Silicon grey. The rubber models are more resistant to chemicals and tears, while the silicone models are more resistant to ozone, UV light, thermal extremes, and tend to fit small faces better since they are made smaller. The mask is held in place by a rubber head harness with stainless steel buckles. The visor is flat with side matte finish to avoid optical distortions. Small weights can be attached to the sides for buoyancy trimming. An inner oral-nasal mask with two one-way valves helps reduce CO_2 build-up and enhance the communication quality housing the microphoneAn equalizing pad is placed inside the oral-nasal mask and closes the nostrils when the mask is pushed upward towards the face. The pad can be moved in different positions to fit the diver's nose. The air from the regulator flows along the visor with a defogging effect before entering the oral-nasal mask and then the exhaust air is vented through the baffles of the second stage.

The second stage is a balanced on-demand regulator and it is available in a version generating positive pressure equivalent to 35 mm (1.38 in) of water. A switch allows the positive pressure to be turned off when taking the mask off to avoid free-flow. This feature is derived from the original use of this full-face, which was for breathing protection in smoke-filled environments. In diving applications this impedes external water ingression, which is useful if diving in contaminated environments. A one-way valve prevents water flooding of the inner regulator mechanism to avoid corrosion and reduce potential freezing when diving in cold water. The second stage is plugged into a central port below the visor and is held in place by a bayonet connection and a retaining plate that acts as plug for the microphone port when no communication system is used. The microphone has a similar plate to lock the regulator. The dedicated LP hose connection has a nut that needs to be hand-tightened; no tools are needed to do so.

The mask can be drained by pushing the purge button on the second stage and maintaining a chin-up position. A mask that is completely flooded can be drained in just a few seconds. In case of free-flow, it is still possible to breathe because the over-pressure is vented through the regulator's baffles and the face seal.

A HUD warning light can be clipped onto the right side of the visor giving a blink alert when the pressure inside the cylinders drops to 55 bar (798 psi) with a final continuous blinking at 10 bar (145 psi) before turning off (Barsky, 1994; Interspiro, 2007).

Kirby-Morgan: EXO-26

The EXO-26 full-face mask is available in two models: "original" and "balanced regulator" (EXO-26BR) and can be used in SCUBA or surface-supplied mode. The EXO-26BR has been tested and approved to be used with air (EN1221) to a maximum depth of 50 m (164 ft) and, when in surface-supplied mode, the maximum length of the umbilical is 183 m (600 ft) in no more than two sections with minimum diameter of 9.5 mm (3/8"). The mask meets or exceeds the requirements of HSE (UK), the US Navy and the US Coast Guard, and it is CE certified for use in Europe and also CR rated by the Dive Lab, Panama City, Florida, USA.

To reduce CO_2 build-up, the EXO-2BR has an inner oral-nasal mask that contains the microphone and equalizer, which is used to close nostrils.

Several models of wireless communicators can be used with the full-face in SCUBA mode; when in surface-supplied mode, wired communicators can be used with a general improved quality of sound. The earphone is included in a specific molded task, which is part of the sealing skirt of the mask. In surface-supplied mode, a bailout cylinder is mandatory to be connected to the manifold. The diver will be able to switch between the umbilical and the cylinder if the main supply is lost. A quick disconnecting fitting can be used to make it easier to separate the bailout system from the mask for storage or servicing. The first stage of the bailout bottle should be equipped with a pressure release valve to prevent build up of pressure in the connecting hose and in the manifold in case of leakage. A pressure gauge should also be connected to the bailout system.

The umbilical should have a one-way valve in line to avoid air from flowing out from the mask in case of umbilical failure. This is a very serious situation because the mask, following a quick drop in pressure, may squeeze the diver causing injury or even fatality.

In case of water leaking into the mask, the diver should terminate the dive. The regulator has a knob that can be set in a position causing free-flow thus displacing the incoming water and allowing the diver to have both hands free during surfacing. In case of massive flooding, the full-face mask can be drained by pushing the purge button on the second stage regulator; it takes about three seconds to completely empty the mask.

The mask should not be used in waters polluted by petroleum-derived chemicals because these can damage the mask frame leading to sudden failure of the full-face (Kirby-Morgan, 2013).

Kirby-Morgan: M48-MOD-1

The Kirby-Morgan M48-MOD-1 is a full-face mask based on the concept of an upper eye section, and a detachable lower section "pod" which contains the second stage regulator. The frame and pod are made of high impact plastic and the seal is made of silicone. The full-face is CE and CR rated and can be used with SCUBA, rebreather or surface-supplied configuration with air compliant with EN 12021 to a maximum depth of 50 m (164 ft) and minimum water temperature of 10°C (50°F) in SCUBA mode and 2.5°C (36.5°F) in surface-supplied mode. It is to be noted that surface-supply mode is not CE certified.

The eye section has the main design of a traditional binocular mask (which can be equipped with prescription lenses) and the visor is not outfitted with any defogging system therefore anti-fog liquids should be used on the lenses. This section has a tilt-to-purge valve; to clear water, the diver should attain a chin-up position, pull lightly on the bottom of the visor frame, activate the valve with the other hand and exhale from the nose.

The “pod” section is detachable even underwater and can then be drained using the purge button on the second stage; further residual water can be expelled through a valve placed under the chin.
A variety of regulators can be used with the full-face but they must be suitable to use with a mouthpiece specifically designed for the mask, which is a mouthpiece tube with a single lip at the end closest to the diver’s mouth and the following dimensions:

Length: 0.75 inch
Width: 1.25 inch
Height: 0.85 inch

Moreover, very high-flux regulators should not be used because, if the purge button is fully depressed or in case of free-flow, they could create a dangerous over-pressure inside the mask affecting the diver’s airway and lungs. Both wired and wireless communication systems can be connected to the full-face (Kirby-Morgan, 2014).

Poseidon: Atmosphere
The “Atmosphere” full-face mask is produced by Poseidon Diving Systems and meets or exceeds the requirements of the European Union standard EN 250:2000 for cold water diving. It is certified for underwater use with air (EN 12021) to a maximum depth of 50 m (164 ft). The mask has a flat visor that can be equipped with prescription lenses. On the frame supports, head-mounted torches or video cameras can be installed.

The “Atmosphere” is also able to accept most available communicator systems. The mask is fitted with a Poseidon X-stream as first stage and a specifically modified Jet-stream as second stage.

Like other Poseidon regulators, the one used with this full-face has a “pre-dive” switch to avoid free-flow at surface; the switch should then be moved to “dive” before submerging. These regulators work with a pilot valve and should be pressurized before entering the water including when they are rinsed; failing to do so may result in water entering through the second stage leading to flooding of the regulator with potential damage.

For equalization, the mask should be pushed upward allowing the inner plug to close the nostrils.
In case of flooding, the mask can be drained using the purge button on the second stage of the regulator while keeping the head in a “face down” position (Poseidon, 2000).

Draeger: Panorama Nova Dive
The “Panorama Nova Dive” full-face is produced by Draeger Safety AG & Co. which is specialized in a variety of gas management products and breathing equipment. This mask derives from a very similar model that was developed for breathing protection in low oxygen environments.

The mask has a flat visor that can be equipped with a dark shield for welding. To maintain a fog-free visor, defogging liquid should be used since no specific defogging airflow can be activated. The frame has two handles on the side to facilitate removal of the mask even when wearing thick gloves. The head harness can support the communication system’s earphones.

Three ports – one on the front and two on the sides – can be used to plug in up to three regulators or two regulators and the microphone of a communication system. When not in use, the ports are closed by plugs that, if removed at surface, allow atmospheric air to be breathed thereby saving diving gas. Specific quick connectors enable switching regulators underwater with minimal water ingress; this feature is useful when using stage and/or multi-gas cylinders.

A purge valve placed on the lower chin of the front of the mask is used for clearing water if needed without interfering with the regulator function.

An oral-nasal mask is fitted with a one-way valve to reduce build-up of CO_2. Two clips inside the oral-nasal mask, which can be activated from outside the full-face, are used for equalizing.

The “Panorama Nova Dive” can be used with SCUBA and rebreather systems that have the appropriate plug-in connectors and have been CE approved for this mask. When used with rebreathers, the oral-nasal mask is replaced by a mouthpiece. A special non-magnetic version of the full-face is available for military applications (Drager, 2002).

OTS: Guardian

The Ocean Technology Systems “Guardian” full-face mask has a very similar design to the Divator MKII mask. The mask has a silicone sealing that provides comfortable and effective contact with the diver’s face. The frame that surrounds the polycarbonate flat visor can hold the earphone cable when a communication system is used. A head harness holds the mask in place. An ambient breathing valve on the top right side of the mask allows the diver to breathe atmospheric air when at the surface to avoid wasting cylinder air.

The second stage of the regulator is specifically designed for the “Guardian”. It is plugged into the central lower part of the mask held by a locking mechanism that is activated by an internal button to make it easy to remove the regulators for cleaning and servicing and to ensure secure locking of the second stage. A standard LP hose connects the second stage to the first stage.

The air is vented from the second stage flowing against the visor with a defogging effect (same system adopted in the Interspiro MKII) before entering an oral-nasal mask and then exhaled through the regulator diaphragm. One-way valves prevent inhaled and exhaled air from being mixed thereby minimizing the build-up of CO_2. Inside the oral-nasal mask, a V-shaped equalizer block closes the nostrils when the mask is pushed up.

The full-face can be equipped with communicators; the microphone port is on the bottom part on the right side of the frame, and the head harness supports the earphones (OTS, 2009).

Ocean Reef: Neptune

Ocean Reef developed an interesting comprehensive system where the full-face mask is integrated with a series of accessories suited for a variety of applications. The “Neptune” full-face mask is available in two different versions: the "Neptune Space G-Divers" for advanced recreational divers and diving instructors, and a family of four different models focused on professional, military and commercial divers. The full-face is composed of a visor held by a frame and connected to a head harness. A specific feature of this mask is that the exhaust gas is vented through a valve placed on the chin of the mask and not through the regulator baffles. This valve also acts as drain for any water seeping into the mask. The valve itself can be set for venting on the right, left or both sides (minimal resistance) or can be closed when the diver is in a head-down position to avoid free-flow of the regulator.

An oral-nasal inner mask with one-way valves reduces the CO_2 accumulation and contains the equalizer block that closes the nostrils when the top of the visor is pushed towards the diver’s face.

The air inflowing the mask follows a specific path along the visor acting as defogging system before entering the oral-nasal mask. The "Neptune Space G-Divers" is available in two sizes and four colors; it can be equipped with a surface valve on the right side to breathe ambient air when at the surface. The dedicated second stage regulator can be equipped with a quick-connecting hose making it easier to separate the mask from the rest of the diving gear. The visor accepts optical lenses and an integrated LED light can be placed inside the top section of the visor fed from a battery with a three-hour burn time.

A wireless communication system is available with a push-to-talk microphone plugged into a dedicated port on the left side of the mask. A secondary regulator can be plugged into the port used for the ambient-air valve allowing for a redundancy of breathing gas sources.
The mask is CE certified for underwater activities in SCUBA mode and it is not intended for surface-supplied mode. The "pro" family of Neptune full-face masks has the same structure as the Neptune Space G-Divers but with some improved features. It is composed of the following four models:

- *Neptune Space*: for professional and commercial divers
- *Neptune Raptor*: to be used with enriched-oxygen gases up to 100% O_2
- *Neptune Predator*: stainless steel frame and anticorrosive cover for the second stage regulator
- *Neptune Iron*: for polluted water diving; has a stainless steel frame and anticorrosive cover for the second stage regulator; the exhaust valve, inhalation diaphragm, purge button and rubber seal are made to withstand exposure to contaminated waters.

The mask can be equipped with a diving data recorder that can be plugged into a computer for post-dive analysis. A HUD on the left side of the visor allows depth and tank pressure range to be monitored. A drinking bag can be connected with a tube entering the oral-nasal mask; a valve regulates the flow. The second stage can be connected to a manifold to accept two breathing gas sources such as two independent cylinders. The wireless communicator can be set to an automatic cycle where 30" of transmitting mode are followed by 20" of receiving mode and so on; this is useful for monitoring the diver who will be hands-free. A duplex wired communicator with 250 m of cable could be used and coupled with an underwater camera; this can operate together with a wireless communicator for redundancy. A special version of the wired communicator can be connected with a buoy that has a cellular phone. The pro masks can be used with surface-supplied air. A special version of the frame is available to enable the use of standard regulators plugged into the mask with dedicated adapters (Ocean Reef, 2010).

Apollo Military: Bio full-face
The "Bio" full-face mask produced by the Australian Apollo Military has a standard binocular visor designed to both minimize the internal volume and to maximize the field of vision.
A welding shield can be placed over the visor. It is possible for the diver to equalize by nose pinching, in the same way as using any other standard mask, due to the specific shape of the visor.
The mask structure and seal are made of nitrile rubber, which is oil-resistant and very resilient to heavy usage. On the top-right side of the visor, a valve operated by a push-button can flush air from the regulator within the mask with a defogging effect. The specifically designed second stage has a fully sealed system to prevent seepage from the exhaust valve thus protecting the diver from polluted waters. A quick disconnection coupling with a safety lock ensures a stable connection between the second stage and the mask. When diving in uncontaminated environments, a chin valve can be used for drainage in case of water entering the mask. On the left side of the mask, a surface-breathing valve allows the diver to breathe external air when at the surface.

The microphone of a communication system can be plugged into a port on the right side of the mask.

Brackets can support headlights on the top frame of the mask (Apollo Military, 2005).

Table 2. Comparative table of some key features of full-face masks

Model	Defogging	Diving mode	Regulator	Communicator
Divator MKII	Airflow	SCUBA Surface-supplied	Dedicated	Wireless Wired
Exo-26	n.a.	SCUBA Surface-supplied	Dedicated	Wireless Wired
M48-MOD-1	n.a.	SCUBA Surface-supplied Rebreather	Multiple choices	Wireless Wired
Atmosphere	Airflow	SCUBA	Dedicated	Wireless
Panorama Nova Dive	n.a.	SCUBA Rebreather	Multiple choices	Wireless
Guardian	Airflow	SCUBA	Dedicated	Wireless
Neptune G-Divers	Airflow	SCUBA	Dedicated	Wireless
Neptune "Pro"	Airflow	SCUBA Surface-supplied	Dedicated	Wireless Wired
Apollo Bio	Airflow on demand	SCUBA	Dedicated	Wireless

Conclusions

Full-face masks are valuable tools for a variety of diving environments and activities. The main advantage is that by using a full-face equipped with a communication system, it is possible to talk among the members of a diving team and between divers and surface crew. In several situations, where the exchange of information is a key factor, this capacity is of paramount importance allowing for safer and more proficient underwater activity.

Full-face masks provide a higher degree of protection from the surrounding environment than a standard half-mask and regulator mostly in terms of thermal insulation. Protection from polluted waters is limited and should be carefully assessed before diving. Diving with a full-face allows the diver to breathe naturally through the nose making the dive more comfortable and reducing stress on the jaw, which may occur during long dives. Moreover, in case of loss of consciousness, the diver will still be able to breathe thereby increasing the chances of successful rescue.

As for other diving equipment, acquiring skills and experience about the use of the mask, and especially regarding the bailout and emergency procedures, is mandatory for its safe and enjoyable use.

Acknowledgements

The anonymous reviewer is acknowledged for the useful comments and improvements to the manuscript.

Literature Cited

ADCI. 2011. *Consensus standards for commercial diving and underwater operations 6th edition*. Houston, TX.: Association of Diving Contractors International.

Amson, J.E. 1991. Protection of divers in waters that are contaminated with chemicals or pathogens. *Undersea Biomedical Research*, 18/3: 213-219.

Angelilli, K. 2012. *Public safety diving all the way to the bottom: for divers*. Parker, CO.: Outskirts Press.

Apollo Military. 2005. *Bio Full-face mask*. Sydney, Australia: Apollo Military.

Barsky, S.M. 1994. *Diving with the Divator MKII Full Face Mask*. Collins, CO.: Team Vision Inc.

Barsky, S.M. 2007. *Diving in high-risk environments*. Ventura, CA.: Hammerhead Press.

Butler, F.K. 2004. Closed-circuit oxygen diving in the U.S. Navy. *UHM,* 31/1: 3-20.

Drager. 2002. *Panorama Nova Dive*. Luebeck, Germany: Drager Safety AG & CO.

EPA. 1997. *Protocol for sanitizing AGA full-face masks*. Port Orchard, WA.: EPA, Region 10.

Haddock, S. and J. Heine. 2005. *Scientific Blue-water diving*. La Jolla CA.: University of California.

Harris, S. 2009. *Final report for the Micro Drysuit Decon*. Port Orchard, WA.: EPA, Region 10.

Heine, J.N. 1996. *Cold water diving: a guide to ice diving.* North Palm Beach, FL.: Best Publishing.

Hendrick, W. and A. Zaferes. 2003. *Ice diving operations.* Tulsa, OK.: PennWell.

Humphrey, A., S. Grossman, J. McBurney, and S. Sheldrake. 2011. *Use of surface-supplied gas for scientific diving*. In: Pollock, N.W. ed. Proceedings of the American Academy of Underwater Sciences 30th Symposium. Dauphin Island, AL.: AAUS.

Interspiro. 2007. *Divator MKII user manual*. Lidingo, Sweden: Interspiro.

Kirby-Morgan. 2013. *Operation and maintenance manual for the EXO Original and EXO Balanced Regulator Full-Face Mask*. Santa Barbara, CA.: Kirby-Morgan Dive System.

Kirby-Morgan. 2014. *M-48 MOD-1 User Guide*. Santa Barbara, CA.: Kirby-Morgan Dive System.

Kesling D. E., H. J. Styron. 2006. *Scientific diving operation with untethered open-circuit mixed gas scuba*. In: Lang, M. and N.E. Smith, eds.Proceedings of the Advanced Scientific Diving Workshop. Washington D.C.: Smithsonian Institution.

Lang, M. 2006. The state of oxygen-enriched air (nitrox). *Diving and Hyperbaric Medicine,* 36/2: 87-93.

Leinikki, J. 2004*. Diving in winter*. Helsinki, Finland.: Alleco.

Mitchel, S.J., M.H. Bennett, N. Bird, D.J. Doolette, G.W. Hobbs, E. Kay, R.E. Moon, T.S. Neuman, R.D. Vann, R. Walker, and H.A. Wyatt. 2012. Recommendations for the rescue of a submerged unresponsive compressed-gas diver. *UHM*, 12: 1099-1108.

Naval Sea Systems Command, 2004. *Guidance for diving in contaminated waters*. Washington D.C.: Direction of Commander: Naval Sea Systems Command.

Ocean Reef. 2010. *Neptune Space Predator full-face mask owner's manual*. San Marcos, CA.: OCEAN REEF Inc.

OTS. 2009. *Guardian full-face mask owner's manual*. Santa Ana, CA.: Ocean Technology Systems.

Pitkin, A. 2003. *Underwater expedition*. Warrell D., and S. Anderson eds. Royal Geographical Society Expedition Medicine. New York, NY.: Routledge.

Pyle, R., 1996. *A learner's guide to closed circuit rebreather operations*. Richardson D., Menduno M., Shreeves K. Eds. Proceedings of the rebreather forum 2.0. Redondo Beach, CA.: DSAT.

Poseidon. 2000. *Atmosphere Full-face mask user manual*. Västra Frölunda, Sweden: Poseidon Diving Systems.

Robinson, M. 2012. *The encyclopedia & guide to diving with a full-face mask*. San Bernardino, CA.: Trafford Publishing.

Seymour B. 2012. *U. S. National Park Service Perspective*. In: Lang, M and D. Steller, eds. Proceedings of the AAUS rebreather colloquium. Monterey CA.: American Academy of Underwater Sciences.

Sheldrake, S., R. Pedersen, C. Shulze, S. Donohue, and A. Humphrey. 2011. *Use of tethered SCUBA for scientific diving*. In: Pollock N.W. ed. Proceedings of the American Academy of Underwater Sciences 30th Symposium, Dauphin Island, AL.: American Academy of Underwater Sciences.

Stanek, S.J., and C.S. Hedricks. 2003. *Evaluation of the KMS48 full-face mask with the Viper very shallow water underwater breathing apparatus*. Panama City, FL.: Naval Diving Experimental Unit.

Steigleman, W.A. 2002. *Survey of current best practices for diving in contaminated water*. Panama City, FL. Navy Experimental Diving Unit.

Tucker, W.C. 1986. *Diver's handbook of underwater calculations*. Centreville, MA.: Cornell Maritime Press.

Tulis J.J., R.L Langley. 1994. *US EPA Standard operating protocol. Biohazards of diving operations and aquatic environments*. Environmental Protection Agency.

Verdier, C. 2007. Technical matters. *X-Ray*, 18: 77-80.

Viking. 2001. *Diving in contaminated water, 3rd Edition: Chemical and biological tests of Viking dry suits and accessories*. Portsmouth, UK .: Trelleborg Viking Inc.

Warkander, D. 2009. *Testing diver's underwater breathing apparatus: the U. S. Navy perspective*. In: Vann R.D, S.J. Mitchell, P.J. Denoble, T.G. Anthony, eds. Technical Diving Conference Proceedings. Durham, NC.: Divers Alert Network.