

## **Underwater safety**

In the light of hazards related to operations performed under water, a group of professional divers welcomed the adoption of the Act on executing underwater operations in 2003. The act makes the right to execute underwater operations dependent upon fulfilment of specific qualification criteria by divers, and requires the entrepreneurs who undertake these operations to secure an appropriate level of safety. The regulation of the Minister of Infrastructure on occupational safety and health during underwater operations, which followed the adoption of the above-mentioned act, brought OSH requirements closer to the actual level of technological advancement. The requirements relate, among others, to equipment of diving bases, technical checks, disinfection of diving equipment and the quality of breathing factors.

Water is the environment in which a human being has been forced to perform - in less or more favourable conditions - various operations for a long time. The basic precondition of effective underwater work is the provision of a technical ability to breathe.

### **Systems of diving and performing underwater operations**

These can be divided into hyperbaric (related to direct exposure of a diver's body to the influence of increased pressure) and normobaric (the body of a diver is not exposed to the influence of increased underwater pressure).

The selection of an appropriate diving system for particular underwater operations should take account of the following:

1. the choice between diving systems and systems not requiring the participation of divers;
2. in the case of diving systems - the choice between hyperbaric, normobaric and mixed systems;
3. the choice between autonomy and non-autonomy, i.e. verifying whether it is possible to perform operations away from the diving base or whether the base is essential directly on site;
4. the depth at which the operations are to be performed as the main criterion for applying a particular type of technology;
5. the reconnaissance of water environment in which the operations are to be performed with regard to its temperature, existing currents, clarity etc.

**Hyperbaric systems** are mainly implemented by means of scuba diving apparatus and transmission equipment (see the scheme).

In hyperbaric systems the key problem is decompression. In the world there do not exist standard universal charts for implementing these systems and scientific research in that field is still needed. Yet, owing to the time consuming process of diver's submerging and ascending and because of increased negative effect which the regular subjection to these processes has on a human body (after 40 min. of work at the depth of 80 metres decompression takes 6-8 hours and is followed by a compulsory 24-hour break) the so-called saturated diving is used, which is referred to as long-term diving in the act. It consists in the fact that in a decompression chamber with the capacity of 8 m<sup>3</sup>, under appropriate air

pressure - dependent upon the depth at which operations are to be performed – a group of divers is locked for the whole period of underwater operations which can take up to several weeks. During this time divers sleep, eat and relax in the chamber – all the time under pressure many times higher than the atmospheric pressure, in the mixture of gases quite different from air, usually in the mixture of helium and oxygen. The temperature maintained inside the chamber guarantees thermal comfort and the level of this comfort is dependent on the composition of the gaseous mixture.

Divers are transported under water by means of a diving bell. To perform work they exit the bell wearing wetsuits. They breathe a mixture of gases supplied from the surface by means of hoses (the mixture contains only several per cent of oxygen). Standard working time of one diver is 8 hours, including 4 hours under water and 4 hours of vigilance and operating the bell.

Besides a "residential" decompression chamber, the system of devices essential for saturated diving comprises a set of tanks with necessary gases, life support system as well as auxiliary and control equipment.

**Normobaric systems** are implemented in reinforced wetsuits, observational chambers, submarine vessels etc.

### **The influence of external factors**

Both sports activity and, in particular, performing underwater operations is connected with a number of hazards to life and health.

A substantial hazard for a diver is hypothermia which causes other side effects such as the quickening of a decompression incident, inefficient work of a diver, non-observance of OSH principles etc.

The most commonplace is decompression sickness (DCS). Its symptoms and intensity depend on the diving depth and the time spent under water. For the sake of simplicity it can be assumed that 12 meter depth in short-term diving and 6-7 meter depth in long-term diving with a quick ascent period does not trigger a decompression incident. Decompression sickness is defined as a number of pathological processes occurring in the organism as a result of improperly decreasing pressure – i.e. decompression. The mechanism of its occurrence consists in simultaneous increase in depth and hydrostatic pressure and the related increase in the solubility of gases (Henry's law). While ascending, along with decreasing depth and the related decrease in pressure, the solubility of gases in liquid becomes lower which in turn leads to oversaturation and bubble formation in the bloodstream. The deeper a man dives the greater is the solubility of gases – the larger amount of gas is dissolved. The longer is the exposition to increased pressure, the more gas is dissolved. Additionally, different tissues have different saturation and desaturation time – this relationship is the basis for implementing decompression.

The factors conducive to the occurrence of decompression sickness, besides the direct influence of external factors and factors resulting from applied technology are as follows:

- unsuitable general physical condition,
- excessive body weight,
- dehydration,
- presence of alcohol in blood,

- poor psychological condition of a diver.

While performing underwater operations we must consider the possibility of the following unfavourable changes occurring in the diver's organism:

- **hypothermia** experienced by a person performing underwater operations (the narrowing of blood vessels, obstructions in blood circuit),
- **decreased work ability** caused by physiological influence of high partial neutral gas pressures and harmful impurities and in the case of oxygen, either too high or too low pressures;
- **increased amount of gas dissolving in tissues as a result of physical effort** while remaining in higher pressure conditions,
- **decreased lung ventilation capacity** and gas exchange of the organism – due to higher density of the breathing gas and the necessity to use a breathing apparatus,
- **diseases caused by bacteria, influence of harmful impurities and unfavourable partial oxygen pressures in breathing mixtures** – while performing operations at large depths and remaining in higher pressure conditions.

### **Procedures, technologies and equipment**

Underwater operations which are conducted at a wide range almost always require individual selection of diving equipment, auxiliary equipment and a specific diving procedure (technology).

Decompression disease can be prevented by means of appropriately planned and implemented decompression. Regardless of whether a diver spends a dozen or so hours or several dozens of days under pressure, decompression is precisely the same and the divers' return to atmospheric pressure conditions requires decompression which takes about 1-1.5 hours for each meter of submersion (remaining in the pressure equal to its depth).

Efficient performance of underwater operations requires the minimization of a negative influence of water temperature upon body temperature of a diver. We can distinguish between two types of thermal protection: passive and active. The first one consists in eliminating loss of temperature by using appropriate layer of insulation. Active protection is to do with compensating for temperature loss by providing it from the outside.

A human being under water has diminished perceptive abilities. All of his senses function in a limited scope, they are disturbed (e.g. the sense of balance) or almost unusable (e.g. a sense of smell). That is why they need to be technologically enhanced in order for a human being to work effectively. Basic technical equipment consists of lighting systems, systems of underwater observation, communication etc.

Among the most needed support systems for divers one should mention effective and infallible communication system. The psychological research shows that what a man working under water values most is the ability to communicate via communication systems.

Underwater lightning ensures accurate orientation during submersion and correct performance of work; it additionally enhances the diver's feeling of security.

Even simple underwater operations require the use of appropriate tools. In many cases it is possible to perform work by hand, but this kind of activity is inefficient. These days even various underwater checks or inspections, although they can be conducted on the basis of a diver's visual observation, require the use of technical equipment for developing reliable

documentation. Probably one of the most universal tools supporting a diver's work are hydraulic tools and hand-held tools made of special materials (e.g. special bronzes). Besides that there exists a certain group of universal pneumatic tools. Other tools (such as e.g. measurement tools) require a special design – depending on the type of work which needs to be accomplished.

Technical support for the diving crew in case of emergency is of primary importance. Basic requirements in this area relate to securing a technical ability to assist those injured taking account of the necessity to evacuate divers under pressure. Here one should remember not only about technical abilities but also about psychological comfort. Technical support for the crew in itself, without approved and regularly practised procedures, will not ensure the adequate level of safety. Many emergency situations can take place during underwater operations (e.g. compression disease) which require the transportation of a diver to a health centre on land in order to provide him with medical care.

Ensuring safety during underwater operations is a process stretched over time and requires well-organized, systematic and planned actions. It is also by no means an exploited subject as it evolves along with scientific developments, and opinions in that field are different in different countries. This results from diving tradition, organization of a training system and technical resources as well as the level of health care in a given country.

Up to date practice related to supervision of occupational safety and health during underwater operations in District Labour Inspectorate of Gdańsk shows that although it is advisable for a labour inspector to be well-prepared for inspection activities, it is rather unreasonable to formulate a separate inspection topic concerning this issue.

### **Conclusive remarks**

Underwater operations are generally dominated by work performed at small depths up to 10 metres where technical requirements are not too high. Attention should be paid to the quality of a breathing factor, technical condition and hygienic facilities of a diver's work as well as his professional qualifications and health status. The need to obtain maritime or inshore administration's permit to perform underwater operations in a particular body of water and the requirement that an entrepreneur must hold a safety management system certificate, should successfully eliminate persons who do not have the required qualifications and experience. Good results with regard to identification of places where underwater operations were performed were obtained following the submission of a written request to Maritime Office in Gdynia and Słupsk and the Office of Inshore Navigation in Gdańsk for up-to-date information concerning permits for underwater operations issued by these bodies.

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