LOSS OF TECHNICAL AND FUNCTIONAL PROPERTIES OF ELEMENTS OF DIVING EQUIPMENT WHILST IN USE

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ABSTRACT

The author undertakes to systematise and compare various types of losses of the technical and functional properties of equipment related to diving with other areas of human activity in which technical equipment is used. The basis for this is the extensive literature describing, inter alia, the issues of wear and tear of machine parts, their damage, failures, etc. a phenomena occurring in the "life" of virtually every technical object. The specificity of diving techniques makes it a relatively little analysed segment of activity from the perspective of exploitation. Based on the analysis of publications and own materials, the author has reviewed and matched them in terms of similarity of loss of technical and functional properties of various elements of diving technology in relation to the divisions and criteria used in generally understood utilisation.
Keywords: Mechanical engineering, operation of diving technology, damage to diving equipment and hyperbaric facilities.

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INTRODUCTION

DEFINITIONS

With time, all technical devices and facilities lose their initial use value starting from the moment the manufacturing process ends and the exploitation begins, until they are completely withdrawn from use. It should be noted that during this time a continuous deterioration of their technical condition occurs. This is a natural, progressive process even with correct use and maintenance. [1]. The rate of change, in terms of technical parameters, depends primarily on the intensity of their use, as well as the quality of maintenance procedures. Other aspects, such as technical progress or economic conditions, are also important.

Loss of technical and functional properties of technical facilities is affected by a number of very different processes resulting from the impact of environmental conditions, as well as those arising in the object itself. They may occur gradually or abruptly. The gradual character of the reduction (degradation) of the functional value is based on the influence of ageing processes over a longer period of time. On the other hand, rapid loss of their value usually takes place suddenly and unpredictably in the majority of cases.

In the literature related to the subject of exploitation, we find a number of terms describing types and states of loss of technical and functional properties of technical objects. In the author's opinion, the most important of them include:

Physical ageing understood as physical processes causing irreversible changes in functional properties of technical objects. They usually begin at the moment the object is put into operation. They depend on a variety of factors acting on it both from the outside and from the inside. External factors include e.g. the influence of the atmosphere, water environment and other supporting technical equipment, etc. Internal factors, on the other hand, include mechanical, mechanical-physical and mechanical-chemical processes occurring primarily during use and storage [2]. They cause aging damage lasting over time. They result in a gradual loss of physical properties due to the destructive influence of the environment and changes occurring in the technical object itself.

Wear and tear as a process causing deterioration over time of the technical condition and usability of a technical object. It is an inherent phenomenon accompanying all technical devices. In the extreme case, wear and tear makes it impossible to operate the equipment properly. It generally progresses "gradually" in the period from the introduction into service until the object's complete decommissioning. It is important that during the life of a technical object timely maintenance is carried out according to the instructions and recommendations of the manufacturer. When used properly, a technical object should not pose significant problems, and the wear process should be "normal" (gradual) and result mainly from the specific application and the influence of environmental conditions known to the user. This means that a slow loss of technical and functional properties of a technical object is a result of natural physical aging.

Malfunction is a poorly defined term. Literature provides such synonyms as: defect, irregularity in the machine, minor fault in the device or minor failure or "lighter" form of failure. There are also opinions, in which the authors state that a malfunction may develop into a failure. When analysing this concept on the basis of various sources, one should conclude that a defect most often results in a short-term inoperability of a technical object. In technical terms, a defect should be treated as a disturbance in the operation of a technical object without causing a significant limitation in its use and without affecting the operation of the whole. Generally, it can be removed in a relatively short period of time and the technical usability of a technical object can be restored without excessive financial outlays.

Damage is one of the major events accompanying the process of use of a technical object. Most often, it is defined as a random event in which a technical object undergoes a temporary or permanent loss of its technical and functional properties. It means entering into a period of partial or complete loss of capacity to perform its functions, failing to maintain proper operating parameters in accordance with the technical documentation [3]. It is an involuntary event. It may occur suddenly, as a result of exceeding permissible, limiting operating parameters, or gradually, as a result of regular aging of a technical object in the process of utilisation. Damage is often called or associated with **Failure**. The term has virtually the same meaning and is similarly defined. One of the elements that differentiate them is, inter alia, the extent of the consequences of their occurrence [1]. When a failure occurs, the extent of the failure can be more extensive and severe compared to the occurrence of damage.

Destruction is a practically complete, irreversible deprivation of the technical and functional properties of a technical object to perform its function. It occurs under the influence of the energy transmitted by it. The state of destruction leads to a situation in which it is impossible to restore the object for use and further operation. The technical object, as a single object or as one of the whole, must be removed and replaced with a new one.

In order to identify and describe the mechanisms of loss of technical and functional properties of technical objects, numerous classifications and divisions are used, depending on the adopted criteria. They are often significantly differentiated and connected with specific branches of equipment and technologies applied in them.

Based on the analysis of the numerous criteria presented in publications, it can be observed that many of them are relatively convergent with respect to one another. The authors present similar definitions and descriptions. On this basis, it is possible to make a selection of significant and general definitions and descriptions, which sufficiently characterise the loss of technical and functional properties of technical objects, regardless of their purpose, functionality, specificity of use, etc.

Important definitions and descriptions, in the author's opinion, include:

1. Classification according to the main causes of damage [3]:

a) structural resulting from errors in the design and construction of a technical object, most often when extreme loads are not taken into account, i.e. the values that significantly exceed the nominal loads, directly leading to damage;
b) manufacture (technological) arising as a result of errors and inaccuracies of manufacturing processes (technological), e.g. inadequate dimensions (dimensional tolerance), defects of materials used to create a technical object (raw materials), incorrect mechanical or thermal processing, etc.;
c) operational resulting from failure to observe the required operating principles of a technical object, from the effects of external factors that are incompatible with the conditions of use of a specific object, which, in consequence, leads to the loss of usable parameters, weakening and premature wear of an object and/or exceeding the limit state;
d) ageing and wear accompanying the processes of the technical object's operation and being the result of progressive, irreversible changes leading to deterioration of durability and interoperability of particular elements.

2. Classification by type of destruction or damage to technical objects [2,3]:

a) mechanical**,** further divided into:
- geometric due to shape, shape errors, workmanship, machining class, etc.;
- kinematic caused by type of motion, speed, etc.;
- dynamic resulting from the type of load, forces applied, unit pressures, etc.;

b) material resulting from the selection of materials for components, their technical properties, quality, as well as materials that enable inter-operation (e.g. lubrication, etc.);
c) environmental (including chemical) effects caused by internal or external influences from the immediate environment of the component(s) such as humidity, fumes, chemicals, etc. and/or the natural environment such as marine and inland waterways and others; they cause various types of corrosion, aging of rubber, coatings, insulations, etc., acting beyond the control of the operator;
d) thermal caused by various events including a significant increase or decrease of temperature in the technical object itself, as well as resulting from the environment, and having a destructive impact on each stage of operation of the technical object;
e) electrical caused by static electricity, electro-corrosion, etc.

3. Classification of damage in terms of its impact on the operation of the technical object [4]:

a) critical which exclude the possibility of further use of the object;
b) major which require immediate action to restore the object to usable condition;
c) minor which occur when action to restore the object's serviceability is delayed;
d) negligible, the effect of which on the performance of the object may be disregarded.

According to [4] it may be assumed that "minor" and "negligible" is a **malfunction**, while "critical" and "major" is a **damage**.

DIVING TECHNIQUE

One of the definitions describes diving as the entirety of activities related to the presence of a person under water or in an atmosphere with increased pressure (the so-called hyperbaric conditions) in diving gear, allowing the person to perform underwater work and return to conditions present at the surface [5].

It should be noted that diving, understood as performing work in an aquatic environment, is a specific area of human activity. It is associated with relatively high risk and a number of dangerous situations for health and life.

Underwater human activities, depending on the type of diving and technology used, require specific undertakings in organisational, technical and medical aspects. In technical terms, this means the application and use of a relatively large number of diverse technical objects in terms of construction. They must be characterised by high quality and special properties, necessitated by the water environment, variable pressure and highly varied environmental conditions. These factors, in addition to a number of others, determine the manner of selecting diving technologies appropriate to the situation, in which the most adequate, safe and technically justified equipment will be used.

According to the Polish defence standard [6] diving technique are the technical systems and equipment used to conduct and secure diving. In the literature there are a number of different classifications of diving techniques, understood as a specific set (resource) of technical objects (equipment, devices) forming systems, depending on the adopted criterion of reference. In each of these one can distinguish specific, characteristic types of equipment used in specific dives. Diving techniques can generally be divided into two main groups:

a) diving equipment,
b) technical equipment and hyperbaric facilities included in diving systems.

The first group consists of technical equipment and devices worn directly on the diver's body. It consists of an autonomous or other type of gas supply device, dry suits, head protection, warming and protective clothing, footwear or flippers, buoyancy compensators, weight belts, frames, signal ropes, knives, tools and accessories [6].

The second group includes:

a) devices or sets of technical devices together with equipment which enable a diver(s) to stay safely under increased pressure, whether in a surface or underwater environment,
b) all technical components of diving systems structurally connected and interoperating with one another in order to enable effective performance of specific tasks in accordance with the adopted technology,
c) hyperbaric facilities understood as technical facilities designed and intended for use by a human being (diver) with a space (volume) in which a specific positive pressure is maintained.

CORROSION

The analysed cases of loss of technical and functional properties of diving technology allowed to group them and allocate them to the criteria and divisions used in the literature. The first observation was that in many respects their mechanisms are similar to those occurring in activities other than diving.

Another was the fact that the primary cause of the loss of technical and functional properties of diving equipment were events of an operational nature. Within this group various types of damage occurred. Wear and tear caused by corrosion phenomena accounted for the largest number of cases. This is primarily due to the direct impact of different types of water environments (fluids) on the equipment used and the technical and hyperbaric equipment immersed in them. In particular, the technology used in sea environments with varying degrees of salinity favours the development of corrosion foci. An additional element overlapping the corrosion processes was mechanical damage causing, amongst others, destruction of protective coatings, which were conducive to their initiation.

In the professional literature many types of corrosion are described, which are characterised according to accepted criteria. Generally, the corrosion is described as a process of destruction of metals under the influence of chemical or electrochemical reaction with the ambient environment. It proceeds with different intensity depending on the circumstances of technical object use, taking into account their composition and structure. Therefore, in the author's opinion, the important mechanism of corrosion processes in diving equipment are, among others, its two types [1]:

Chemical corrosion causing deterioration of metals by the action of dry gases or liquids that do not conduct electricity. The corrosion layer is formed by adsorption of gas, which is then dissociated by affinity with the metal or by temperature increase.

Electrochemical corrosion resulting in the destruction of a metal due to contact with water or a solution, which may form a conductive electrolyte between local cells located on the surface of the metal. The formation of cells is favoured by impurities present in metals and the heterogeneity of their chemical composition and structure.

The majority of metals used in generally understood technique are subject to corrosion. The destruction occurring as a result of its action accompanies the operation of the vast majority of technical objects. The losses caused by corrosion significantly exceed the effects of mechanical wear.

Fig. 1,2 and 3 show examples of damage to diving equipment and elements of diving equipment supporting operational diving exposures caused by corrosion processes.

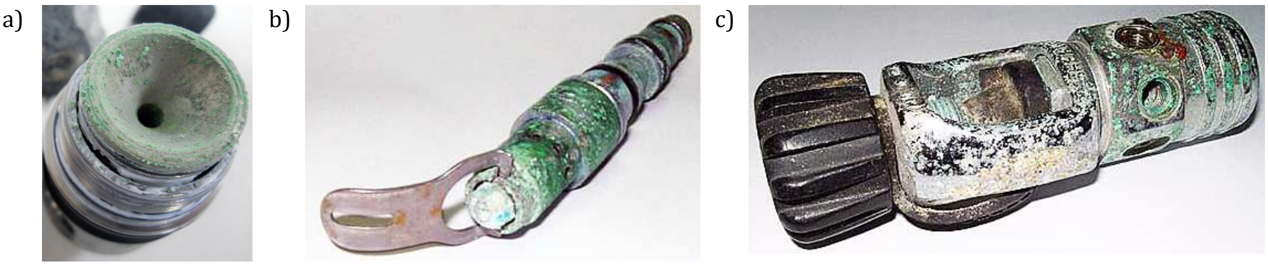


Fig. 1 Examples of deterioration of diving technology elements caused by corrosion processes:
a) corrosion of the 1st stage of the breathing apparatus caused by seawater [7];
b), c) 2nd stage reduction valve and 1st stage reduction of the breathing apparatus [8].

Fig. 2 Examples of deterioration of diving technology elements caused by corrosion processes:
a) cover for the soda lime container of the CO_2 scrubber installed in the hyperbaric chamber;
b) stop valve of the diving supply cylinder is covered with rust [7];
(c) the bottom part of a diver's gas cylinder [9].

a) b) c)

Fig. 3 Examples of deterioration of diving technology elements caused by corrosion processes:
a) the container of the decompression chamber air supply system at 150 bar;
b) electrochemical corrosion;
of the electrical passage through the shell of the decompression chamber caused by the presence of various types of metals;
c) the bottom of a decompression chamber.

MECHANICAL DAMAGE

The second large group in which a loss of technical and functional properties occurred to diving equipment as a result of its operation included mechanical damage.

Mechanical damage, also referred to as mechanical wear, is a process based on mutual mechanical impacts on the components from which technical objects are built. The basis of these processes is usually a certain form of increased load and movement of components. They may originate from the internal and external environment such as impacts, abrasions, crushing, contamination, etc. as well as from inter-operation with another structural element. These situations usually lead to excessive friction, looseness, excessive pressures, wear, change of shape, properties of the object and a number of other.

The analysed cases of loss of technical and functional properties of diving equipment, taking into account the criterion of their type and manner of occurrence, indicated, inter alia:

a) incorrect assembly of inter-operating structural elements,
b) interference of structural components due to contamination and lack of proper maintenance and failure to follow manufacturer's operating procedures,
c) mechanical damage to the surface of elements of technical objects,
d) mechanical damage to the flexible coupling elements of the equipment,
e) loss of tightness of structural elements of devices.

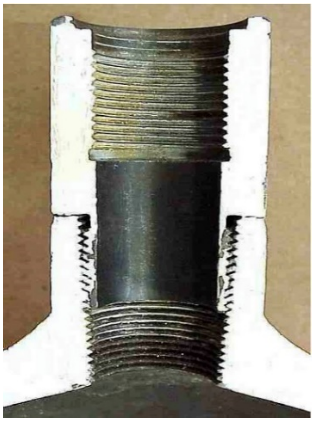
INCORRECT ASSEMBLY

Fig. 4 shows examples of improper assembly and fitting of interoperating elements of diving equipment. The first illustrates the damage caused by screwing a cylindrical adapter with a parallel thread into the neck of a diving supply cylinder with a tapered thread. This type of situation poses a risk of the mounted element being pulled out of the cylinder neck. It usually occurs as a result of a visual mistake in evaluating the type of thread or failure of routine. This results in conditions of very serious risk to health and possibly life for the person using or operating it. The next example shows damage to the thread of the LP port in the 1st stage head of a breathing apparatus. It occurred as a result of repeated, improper screwing of the flexible medium-pressure hose end into the head. Lack of alignment during this operation led to damage of the thread in the head and accumulation of metal filings inside it. The last example shows the mechanical fitting and insertion of the filter into the 1st stage of the breathing apparatus. As a result of grinding a part of the filter, which is made of soft material, the active filtering surface in the path of the breathing gas flow from the supply source to the breathing apparatus was reduced [9].

CONTAMINATION

Contamination of diving equipment in the form of sand residues, organic sludge, oil sludge, and combinations thereof is most often the result of negligent maintenance procedures. Typically, it occurs as a result of leaving equipment wet and unwashed for long periods of time, as well as storage in a humid, warm environment. These conditions effectively reduce performance parameters and may interfere with the cooperation between components. The visible effect is the increase in friction between parts, their difficult inter-operation, disturbances in the flow of breathing gas, etc.

Fig. 5 shows examples of contamination of components of a 2nd stage of a breathing apparatus.

a)

b)

c)


Fig. 4 Examples of incorrect assembly of interoperating components of diving equipment:
a) screwing a cylindrical adapter with a parallel thread into the neck of a diving supply cylinder with a tapered thread [10];
b) damage to the thread of the LP port in the 1st stage head of the breathing apparatus as a result of incorrect screwing in;
c) grinding of a part of the first stage filter of a breathing apparatus, reducing its quality and efficiency [11].

a)

b)


Fig. 5 Examples of contamination of a 2nd stage of a breathing apparatus [8,12].

PHYSICAL IMPACT

These are events originating from the mutual, physical interaction of various structural elements functionally related to one another, as well as extraneous, unrelated ones originating from the immediate environment. They result in, amongst other things, abrasions, scratches, dents, bends, local cracks, breaks and a number of other occurrences. They are often located on the surfaces of technical objects protected with protective coatings, such as paint, chromium plating, galvanisation, etc. They may occur both outside and inside the element of diving technology. The loss of these protective features is particularly conducive to the appearance of various types of corrosion foci. This group of damages includes also all defects distorting the geometry of the object, causing deterioration of interoperability with other elements or even making such interoperability impossible.

Fig. 6 shows examples of mechanical damage resulting from physical impact.

a)

b)

c)

d)


Fig. 6 Examples of mechanical damage to components caused by physical impact:
a) air tank; b) diving helmet [13];
c) local chromium coating loss on a breathing apparatus component [14];
d) damage to O-ring sealing seat [15];

FLEXIBLE CONNECTIONS

Flexible connections are an indispensable element linking certain diving equipment components into a functional, interoperable whole. They are widely used both in diving equipment and in hyperbaric facilities. They are flexible pipes adapted to work in different environments and under different pressures. Their construction is based on flexible materials such as thermoplastic polyether-polyurethane with a reinforcing plastic or metal braid and often covered with an outer rubber coating. Another type of conduits used are those made of Teflon and flexible metal conduits made of corrugated pipes. Both types are usually placed in stainless steel braids [16].

Flexible connections represent a group of diving technology components, in which the main cause of loss of technical and functional properties is aging. Manufacturers recommend that, when used normally, braided hoses be replaced every five years [17]. They have a limited life span regardless of the external appearance of the braid and the rubber sheath. This is due, among other things, to the fact that certain materials used in their production have a tendency to degrade as a result of hydrolysis. Cyclic overheating and cooling, occurring during diving, promotes degradation consisting in crystallisation of the material of the inner part of the hose (lining). As a result, "crystals" are formed which obstruct the flow of breathing gas and move towards the 2nd stage of the breathing apparatus [17,18].

Elastic joints, as a part of diving technology, are also subject to purely mechanical damage. These include local abrasion, cracks, breaks in the continuity of the material, tears or abrasion and/or cracks in the external protective coating, e.g. rubber. Other typical forms of damage observed include corrosion of metal, crimped ends of hoses (connectors) which enable their connection with other structural elements.

Fig. 7 shows examples of damage to flexible connections used in diving breathing apparatus.

a) b) c)

Fig. 7. Examples of damage to flexible connections used in diving breathing apparatuses:
a) interior of breathing hose with visible crystals from the lining [18];
b) supply hose damaged on the inside [7];
c) rupture of the outer rubber coating of the supply hose [14].

LOSS OF TIGHTNESS

The loss of tightness usually occurs in static or dynamic separable joints. It is usually caused by a disruption of the interoperation between the connected parts and the seal placed between them. Usually it does not cause an immediate loss of capacity for further use. However, it lowers the technical and functional parameters over time, which, in consequence, may lead to dangerous events. This condition requires taking decisive maintenance actions.

Based on the criterion of use, there are fixed and movable types of seals. The first type includes those in which the connected components remain motionless relative to each other, e.g. a shut-off valve screwed into the neck of a gas tank. In the case of moving connections, the mating parts are sealed by one of many types of seals. Especially widely used in diving technology is the O-ring seal. It is used both in equipment and diving systems.

Depending on the material used and how they are used, they are subject to damage. Typical failures include aging, drying and cracking, resulting in a loss of tightness. In addition, inadequate lubrication and excessively rough surfaces of sealing elements further complicate the process. A frequent cause is also the "pulling" of the O-ring material between mating parts during improperly conducted assembly.

Other sealing methods such as Teflon tapes are also used. They are mainly used for fixed connections. The incorrect sealing method leads to leaks. In all cases, a defective seal should be replaced with a new one.

Fig. 8 shows examples of loss of tightness of diving equipment components.

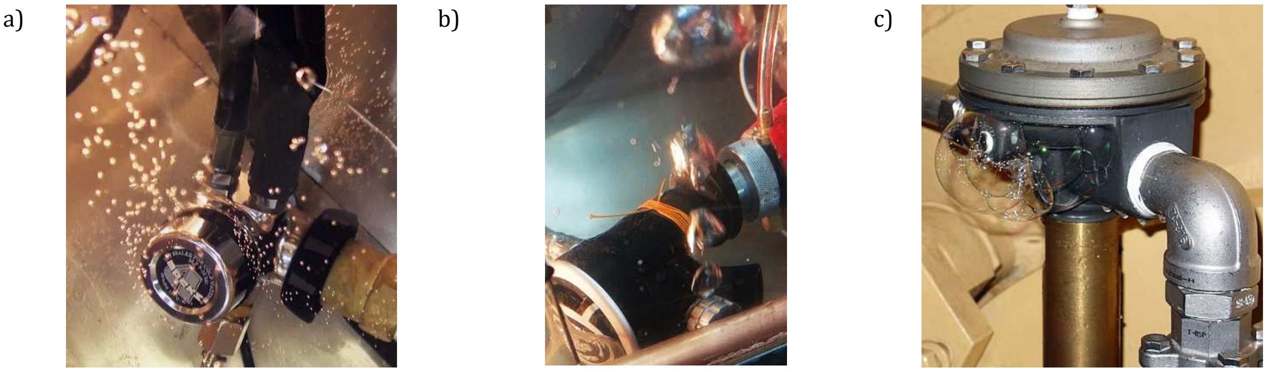


Fig. 8 Examples of loss of tightness of elements of diving equipment:
a) 1st stage of a breathing apparatus - O-ring sealing;
b) 2nd stage regulating knobs of breathing apparatus - O-ring sealing;
c) pressure regulator in the integrated breathing system in a decompression chamber - sealing with Teflon tape.

DAMAGE

The processes of use of diving technology involve cases of its damage. In general, two states occur: destruction in the normal process of use or as a result of a violent event. In both cases it is irreversible. Certain components or complete devices cannot be repaired and must be replaced by new ones.

Fig. 9 shows the destruction of diving equipment components in the normal process of use.

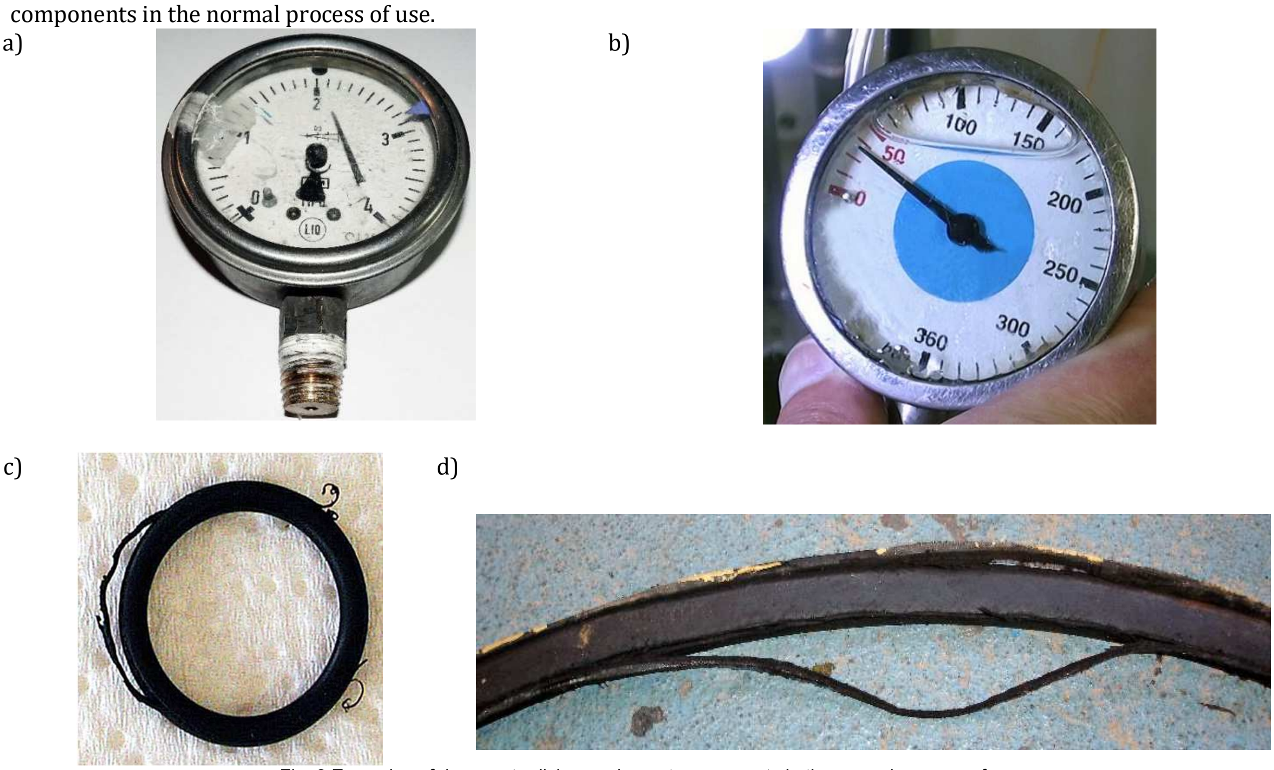


Fig. 9 Examples of damage to diving equipment components in the normal process of use:
a) pressure gauge from the air supply system of the decompression chamber deteriorated after long-term operation;
b) a flooded manometer for measuring the pressure in the breathing apparatus supply tube; c) O-ring seal in a breathing apparatus [19];
d) seal from the decompression chamber entrance after long-term use.

Rapid deterioration processes are particularly characteristic for diving equipment that operates in a high oxygen environment. These include oxygen supply systems as well as semi-closed and closed circuit breathing devices (rebreathers). This issue is related to two concepts, which at the same time are fundamental rules, the disregarding of which leads to very dangerous incidents. These are:

Oxygen cleanliness meaning the minimum acceptable level of cleanliness of the diving equipment, oxygen system or its elements ensuring safe use under oxygen conditions [6].

A clean component is a part of a system that is completely cleaned or has cleaned surfaces that have been subjected to examination and maintain the appropriate allowable level of contamination [6]. This means absence in oxygen installations and systems of contaminants such as fibers, grease, oil, dust, filings, burrs, bumps, particles, etc., where they might act as a fuel source or ignition spark.

Oxygen compability refers to the selection of materials that can work together in the environment of pure oxygen and gas mixtures with high oxygen content without causing ignition or rapid wear. The criteria for the use of specific materials such as minimum flash point, specific heat and thermal conductivity are important. Oxygen-compatible materials are such materials as stainless steels, brasses, which do not generate electrostatic charges, lubricants and seals adapted to work with oxygen, etc. [16]. The values of oxygen flow velocities in installations and devices, and geometric shapes of structural elements are also of great significance.

Fig. 10 shows the damage to the diving technique components resulting from a sudden event.

c)

d)

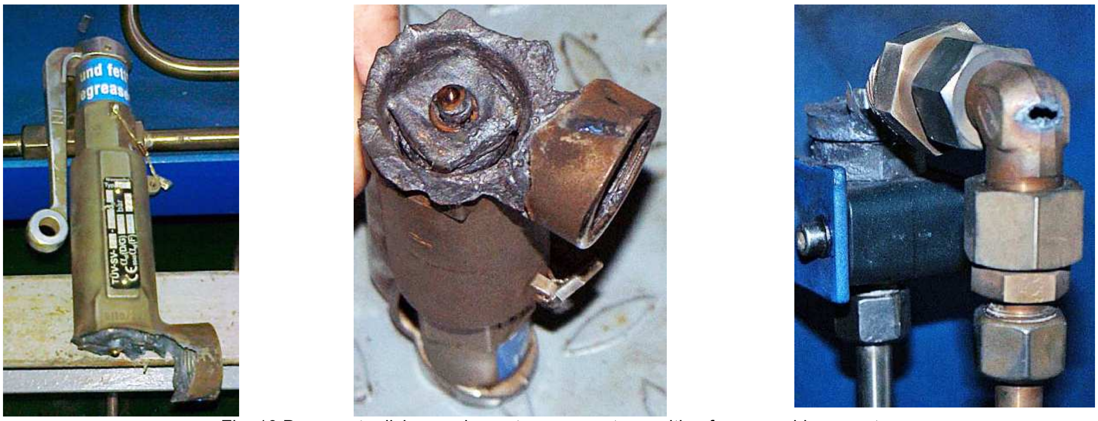


Fig. 10 Damage to diving equipment components resulting from a sudden event:
a) b) fires in rebreather type diving apparatus [20,21];
c) body and head of the shut-off valve in the oxygen pumping system;
d) safety valve from the oxygen supply installation to a decompression chamber [photo by Krzysztof Czermak].

W określonych sytuacjach zniszczenie może mieć również pozytywny charakter. Dotyczy to stosowania prób niszczących elementów techniki nurkowej. Charakter tych działań ma podłoże przede wszystkim badawcze i poznawcze. Podstawowym ich celem jest sprawdzenie granicznych, maksymalnych możliwości pracy pojedynczej części i/lub ich współpracy w konkretnym rozwiązaniu technicznym. Są one niezbędne do zapewnienia możliwie najwyższych standardów bezpieczeństwa konstrukcji techniki nurkowej udostępnianej potencjalnym użytkownikom.

Na rys. 11 pokazano przykłady prób niszczących elementów techniki nurkowej.

In certain situations, destruction can also be positive in nature. This applies to the use of destructive testing of elements of diving equipment. The nature of these activities is primarily exploratory and diagnostic.

Their primary purpose is to test the maximum limit possibilities of operation of a single part and/or their cooperation in a specific technical solution. They are necessary to ensure the highest possible standards of safety of the diving equipment design made available to the potential users.

Fig. 11 shows examples of destructive testing of elements of diving equipment.

a)

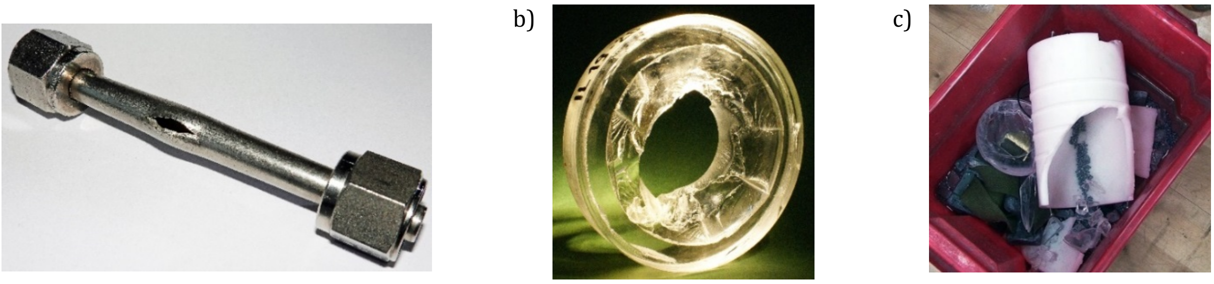


Fig. 11 Examples of destructive testing of elements of diving equipment:
a) a fragment of a gas installation feeding a decompression chamber, pressurized to 60 MPa;
b) Acrylic glass from a decompression chamber window destroyed at a pressure of approx. 25 MPa;
c) film camera housing destroyed by the pressure of an underwater environment corresponding to the value of about 3 MPa.

CONSTRUCTION FAULTS

Manufacturers of diving technology strive to create and produce products at the highest possible level. An important role in this process is played by classification societies, certification bodies, etc., which certify these products for use. Buyers of diving technology, being aware of the dangers of diving, when possible, purchase equipment with the highest safety standards. Therefore, the loss of technical usable properties of diving equipment due to evident design errors is a rare case. Nevertheless, such cases do occur.

Fig. 12 shows examples of components used in diving technology with faulty designs. In both cases, a material of insufficient thickness was provided during construction. As a consequence, the container used to protect the computer from the water environment in the decompression chamber was crushed. The second element was the threaded part of the safety valve screwed into the diving air service tank. The diameter of the thread core in relation to the inner diameter of the valve passage was too small. As a result of variable pressure over time, material fatigue occurred and a crack was formed in the core diameter. This resulted in leakage and a danger that the valve could be torn out from its seat.

a)

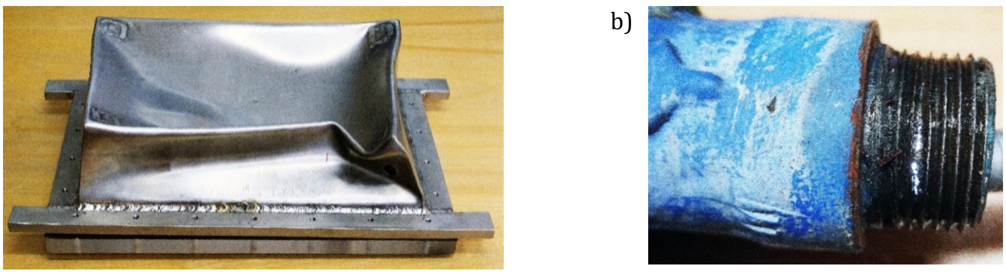


Fig. 12 Examples of faulty components used in diving equipment systems:
a) pressure container for computerised exercise testing station;
b) threaded part of the safety valve installed in the seat of the air service tank.

FREEZING

A non-typical type of loss of technical and usable properties of certain elements of diving equipment are freezes. They are mainly caused by the Joule-Thompson effect. This condition can lead to a blockage of the gas flow in the diving equipment and supply installations. Unblocking the flow occurs after "thawing". Open circuit breathing apparatus is particularly susceptible to this effect. It should be noted that the freezing of the apparatus is very dangerous and carries a high risk of a serious diving accident.

From a technical point of view, this is generally a short-term situation. The effect completely prevents normal operation, most often of the second stage pressure-reducing valve, and leads to a free flow of air from the supply cylinders. It is difficult to determine unequivocally whether a temporary freeze is a malfunction or damage or another form of loss of operational efficiency. It does not cause permanent damage to the device, and after the specified time has passed the apparatus (element, device) continues to operate as intended.

Fig. 13 shows examples of freezing of elements of diving equipment.

a)

b)

Fig. 13 Examples of freezing of elements of diving equipment:
a) 2nd stage of a breathing apparatus used in water with a temperature of approx. 4 ^{O}C;
b) filter integrated in the shut-off valve of the exhaust system of a decompression chamber.

CASE

Unusual and at the same time "amusing" was the case of loss of technical and functional properties presented in photo 14. The object was a flexible, high-pressure hose supplying breathing gas in a diving installation. On its external side, the manufacturer covered the metal braid with a flexible material. After connecting the components of the installation with the hose in question and supplying gas pressure, a "gas bubble" was formed. The flexible hose showed no signs of leakage or damage at the site of the bubble that would require immediate replacement. An outside inspection suggested that a small leak may have occurred in one of the two metal fittings crimped on the ends of the hose connected on the higher-pressure side. Gas had penetrated the spaces in the metal braid and delaminated the flexible braid at its weakest connection point.

The question was whether the incident should be classified as a defect or damage?

Fig. 14 A case of delamination of a braid made of plastic from a metal braid of a pressurised, flexible diving system hose.

CONCLUSIONS

This article certainly did not exhaust all the aspects related to the presented topic. This is due to the fact that the generally understood utilisation of technical objects as an important human activity is a very extensive and often complex issue.

Based on the review of publications and collected materials, as well as their analysis, the following conclusions can be drawn:

- The mechanisms of loss of technical properties of diving equipment, for the most part, do not differ from those occur-ring in other fields of technology not related to diving equipment and hyperbaric facilities. They also fit into the divi-sions and criteria used in the field of technical operation. Open circuit diving breathing apparatus is an exception. Under certain conditions, temporary disruptions of their primary service function due to the freezing process are possible. These events occur in real time and may cause danger to the health and even the life of the diver.
- An important element which differentiates diving equipment from other, non-diving technical objects, is, among others, its use under increased, variable pressure of gas and in water environment. It is directly in these conditions that the human-diver operates. Therefore, the equipment and devices used to carry out the diver's work underwater must be characterised by high quality workmanship, efficiency of operation and maximum safety of use. This dictates the use of appropriate construction materials, equipment, components and many other elements of good work-manship, as well as resistance to the external environment. Not without significance is also the destructive influence of time on diving equipment, which should be reasonably extended for them. This means that it is necessary to achieve greater resistance of diving equipment to all forms of reduction of their technical and operational values in time.
- Mobile diving equipment, i.e. not permanently tied to a specific location, is affected by its relocation to different geo-graphical positions. Locating complete diving systems in a changing atmospheric as well as aquatic environment pro-duces favourable conditions for reducing the technical and functional values of almost all its components.
- The largest number of analysed cases clearly indicated that the deterioration of diving equipment was caused primarily by different types of corrosion. The second most numerous group of cases were those of reduction and loss of technical efficiency as a result of operational processes.
- In a number of cases indications were found that the cause of damage was improper use and maintenance of diving equipment. The main cause of these situations was the failure to follow the manufacturer's recommendations regarding the instructions for use and theindicated inspection and repair periods.
- A frequent and inappropriate behaviour of the users is performing these activities themselves. This means lack of use of specialised repair facilities with technical infrastructure and properly trained personnel. Negligence in handling the diving technology after its use, improperly performed maintenance, storage and warehousing were also significant.
- Ongoing technical progress and technologies emerging along with it indicates that changes take place in diving equip-ment as well. A large role is played by new types of construction materials, which will replace those currently used. An example are diving air tanks made of composite materials. They practically eliminate the corrosion problem occurring in steel structures used thus far. However, along with them appeared a different type of damage, which include their rupture.

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