



**Technical Coordination for Workplace Safety of the Regions
and Autonomous Provinces**

Physical Agents Thematic Group

Operational Guidelines for the Prevention of Risks from Physical Agents pursuant to Legislative Decree 81/08

Part 8: HYPERBARIC ATMOSPHERES

in collaboration with:



**INAIL – National Institute
for Workers' Compensation**



Higher Institute of Health

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A.1. What is meant by the risk of exposure to hyperbaric atmospheres?

A work activity exposes workers to hyperbaric risk if the pressure of the inhaled gas mixture exceeds ambient pressure at sea level.

Work activities that expose workers to hyperbaric risk come in various types, and each has specific aspects of such exposure that distinguish it from other types. As a result of these differences, this document will be divided—where such differences occur—into as many subsections as there are distinct types of hyperbaric work activities.

1. SHALLOW- and DEEP-WATER DIVERS:

Shallow-water divers operate at depths ranging from a few meters to 50 meters, primarily on dives that end with an ascent upon completion of work, and sometimes on saturation dives. Their tasks involve supporting extraction activities for the submerged portion of the facility: assembling parts of the drill rig, welding, inspecting welds, etc.

Deep-water divers perform the same tasks, but at depths ranging from 50 to 300 meters. The work is carried out under saturation conditions: once the divers have been pressurized to the operating depth, they remain in that state for approximately 28 working days, and they spend their rest time in a hyperbaric chamber on the support vessel, working in shifts of eight hours, followed by eight hours of rest and eight hours of support for the team in the water—though these schedules may be adjusted based on operational needs. Teams typically consist of two divers, while a shift comprises three teams. They work using an umbilical line and a helmet, which allow them to communicate with the support crew and the surface. Deep-water divers receive thermal support via hot water from the surface and work with helium-oxygen mixtures (heliox). The work requires moderate physical exertion. Surface support is on-site, has all necessary equipment, and is equipped with an *on-site* multi-person hyperbaric chamber.

The **local service diver**, also known as a **harbor diver**, is the go-to professional for small- and medium-scale port work and ship repairs in the harbor. Their duties typically involve working underwater to install and repair bridges, piers, and harbor embankment foundations, inspecting ship hulls and underwater installations to detect any damage and perform minor repairs, assessing the condition of shipwrecks, clearing underwater obstacles, drilling holes for explosives underwater, conducting dives related to rescue, recovery, or search operations for drowning victims, and coordinating other workers. They work primarily in the water using an umbilical line and a full-face mask to communicate with the surface. The work requires moderate physical exertion. Surface support is on-site, equipped with all necessary gear, and connected via 112 to emergency medical services and a hyperbaric chamber near the dive site.

2. **SCIENTIFIC DIVING:** Archaeologists and underwater researchers conduct archaeological and scientific surveys that cannot be carried out without the specific expertise of a professional diver. The personnel involved come from a wide variety of backgrounds and often have recreational diving training: students, doctoral candidates, researchers, and professors. Dives are primarily solo dives using an air tank, a wetsuit, and a standard mask (without surface communication). Dives often require the use of specialized equipment (snorkels, penetrometers, lift bags, etc.), but the physical exertion is modest. No more than two dives are conducted per day, usually within the safety decompression limits. Surface support is provided at varying distances of two hours or more; it does not always have all the necessary equipment and is not equipped with a multi-person hyperbaric chamber.

3. **STATE DIVING UNITS:** Divers from State Diving Units perform a variety of services but are generally tasked with resolving situations caused by natural or human factors. The risks associated with these activities can be very high (rescue, mine clearance, narcotics searches, sampling of toxic and/or harmful substances, etc.). The work is primarily carried out through solo dives using air or binary mixtures (nitrogen-oxygen binary mixtures, i.e., oxygen-enriched

air) or ternary mixtures, usually within 50 meters, and may require moderate to high physical exertion. Deeper dives may also be conducted using specialized equipment. No more than two dives are performed per day. Dry suits and full-face masks with surface communication are used. Surface support is provided at zero distance, is equipped with all necessary gear, and is sometimes equipped with a multi-person hyperbaric chamber with medical and paramedical personnel *on site*.

4. **PROFESSIONAL FISHING, CORAL HARVESTERS, FISH FARMING:** This category encompasses two distinct subcategories. One includes divers who provide support for offshore aquaculture operations, while the other consists of so-called “coral harvesters.” Coral harvesters primarily engage in the deep-sea harvesting of coral and other species. This category is on the verge of extinction because no region is renewing permits, and when divers cease operations, there is a lack of new recruits. Surface support for coral divers is provided from a considerable distance, as they often dive alone to avoid revealing coral-rich sites; they rarely possess all the necessary equipment and, at times, rely on a single-person, low-pressure hyperbaric chamber on the support vessel. Fish farming workers, on the other hand, are steadily increasing in number due to the growing prevalence of these activities. Their work consists of repairing nets or assisting with the harvest of the catch. They make frequent solo dives daily during the harvest season, at relatively shallow depths (maximum 20–30 meters), using open-circuit scuba gear, and for durations of less than 40 minutes. They are not regulated by any national law (some regions, such as Tuscany, are in the process of establishing regulations), and their professional training varies considerably across the country. Given the nature of their work, specific training like that of an Operator Technical Diver (OTS) would seem necessary, but without saturation diving or deep-water diving. They typically engage in moderate-intensity physical activity using lightweight equipment without communication with the surface. This aspect entails a significant increase in risk, as they must ascend to the surface to communicate, thereby exposing themselves to multiple decompression risks. Fish farming divers have varying levels of surface support, while emergency response and medical assistance in the event of an accident are entrusted to the National Health Service (SSN).
5. **RECREATIONAL DIVING WORKERS:** Workers in this sector are divided into **dive guides** and **dive instructors**. The instructor’s role is to train the student in all the procedures that will ensure their safety while underwater. The dive guide/escort is responsible for taking a self-sufficient diver underwater and ensuring their safety, but above all their enjoyment, by leading them to where the dive is most interesting and accessible. They work primarily with pressurized atmospheric air tanks, have no means of communicating with the surface, and are far from rescue services. Dives are typically single dives but may be repeated up to three or four times a day during the summer season. Some use binary nitrogen-oxygen mixtures (oxygen-enriched air) and rebreathers; more rarely, they use Heliair (helium-enriched air). The work requires little physical exertion. Surface support is available at a distance of 2 hours or more; it does not always have all the necessary equipment and is not equipped with a multi-person hyperbaric chamber.
6. **CAISSON WORKERS AND MECHANIZED EXCAVATION (TBM):** Caisson workers are those who perform maintenance on the machine that carries out mechanical excavation, or who directly perform excavation operations inside a compressed-air caisson. The caisson is a watertight container resting on the seabed or on the head of the tunnel boring machine, which forms a seal with the tunnel it is excavating. Since it would naturally tend to flood, water is kept out by pumping compressed air into it at a pressure corresponding to the working depth below the of the groundwater table. They are used in civil engineering: tunnels (road, subway, or rail), mines, port construction, and bridge construction. They work in a dry environment and breathe pressurized ambient air. The work requires significant physical exertion. Surface support is

provided on-site, has all necessary equipment, and includes a multi-person hyperbaric chamber *on-site* (Presidential Decree 321/56).

7. **HYPERBARIC OXYGEN THERAPY:** The medical specialties related to hyperbaric oxygen therapy are currently: Anesthesiology and Resuscitation, Anesthesiology and Resuscitation with a Hyperbaric Focus, and Sports Medicine for Swimming and Underwater Activities. The Second-Level Master's Degree in Underwater and Hyperbaric Medicine is recognized as a qualification. The residency program no longer exists following the entry into force of European regulations on medical specializations. Hyperbaric technicians never enter the hyperbaric chamber and may only be pressurized inside it to resolve technical issues, preferably without patients present, while physicians and nurses are pressurized inside the chamber when they need to assist patients. Since 1998, the gas mixture used for pressurization in the hyperbaric chamber has been exclusively breathable air, while oxygen is administered via on-demand or continuous oral-nasal masks. In some cases, oxygen is administered through individual helmets that are sealed off from the chamber. Only one helmet is permitted per hyperbaric oxygen therapy session.

A.2. How should one proceed in the case of work involving hyperbaric risk?

With regard to hyperbaric environments, for which there is no specific section in **Legislative Decree No. 81/08, as amended**, a risk assessment must be conducted, and preventive and protective measures must be adopted, in accordance with **Article 181 of the same decree**, which specifies that the risk assessment for all physical agents must be such as to “identify and adopt appropriate preventive and protective measures,” with “particular reference to standards of good engineering practice and best practices” (see FAQ C.1).

A.3. What health and safety effects are to be prevented?

The health and safety effects directly attributable to exposure to hyperbaric atmospheres are:

1. Oxygen (O₂) toxicity occurs as a result of breathing air with a high pO₂ for extended periods; there are pO₂/duration tables to assess potential oxygen toxicity (see the NOAA Diving Manual, for example). Damage occurs in the lungs or the nervous system; the latter occurs exclusively in a hyperbaric environment. The outcome is a fatal accident.
2. Narcosis caused by increased pressure of the inhaled gas. The damage is neurological. The outcome can be fatal.
3. Traumatic pneumothorax caused by a rapid change in pressure. The damage affects the lungs, heart, and peritoneum. The outcome can be fatal.
4. Gastrointestinal overdistension: occurs due to a rapid change in intestinal gas pressure. It is not usually the cause of fatal accidents.
5. Barotrauma (ear, mask, paranasal sinuses, teeth): caused by rapid pressure changes affecting air-filled cavities. It is not usually the cause of fatal accidents.
6. Arterial gas embolism (AGE) is caused by a rapid change in pressure within the lungs, resulting in rupture of the alveolar-capillary membrane and cardiovascular and neurological damage. The outcome can be fatal.
7. Decompression sickness (DCS): This is caused by changes in the partial pressure of the inert gas and occurs due to errors in decompression or for unrelated causes (e.g., right-to-left shunt). The outcome can be fatal.
8. Dysbaric osteonecrosis: This is caused by changes in the partial pressure of inert gas within the bone. It differs from aseptic avascular osteonecrosis in that its progression is gradual and delayed over time. The outcome may be disabling (requiring prosthetics) but is not fatal.

9. High-pressure nervous syndrome. This is caused by changes in the pO_2 of the inert gas, particularly helium, and is directly related to the rate of compression. It typically occurs at absolute pressures exceeding 13 ATA. The damage is neurological and psychiatric. The outcome can be fatal.

Other effects, not directly caused by pressure changes but whose occurrence in a hyperbaric environment can increase the risk, include:

Diving syndrome (drowning).

1. Hypoxia: occurs because of reduced partial pressure ($pO_2 < 0.16$ bar) of oxygen in the breathing mixture. It causes a loss of consciousness that can lead to fatal events.
2. CO poisoning: occurs due to the presence of carbon monoxide in the mixture. It causes damage to the cardiovascular and nervous systems and can lead to a fatal incident.
3. Hypercapnia (CO_2) occurs due to excessive pCO_2 in the breathing mixture. It causes fatigue, headache, and other neurological and otolaryngological (ENT) symptoms and can lead to a fatal accident.

A.4. Who is particularly at risk?

By way of example, but not limited to, these include individuals with any of the following conditions:

- a) Allergies
- b) Previous hyperbaric problems: DCS, barotrauma
- c) Pregnancy
- d) Dermatological or skin conditions
- e) Brain disorders
- f) History of fainting, collapse, or dizziness; motion sickness; migraine
- g) Psychiatric disorders
- h) Drug addiction (within the past three years) or alcohol dependence
- i) Ear, Nose, and Throat (ENT) conditions
- j) Lung disorders and pneumothorax
- k) Previous surgeries on the lungs, heart, chest, or head
- l) Cardiac and circulatory disorders
- m) Metabolic and hormonal disorders
- n) Kidney or urinary disorders
- o) Osteoarticular disorders

A.5. Which healthcare professionals conduct occupational health surveillance?

Legislative Decree 81/08 stipulates that occupational health surveillance is the responsibility of the occupational physician (OP), who, in specific cases, may request support from a specialist physician, who in this case is a hyperbaric physician (HP). The role of the hyperbaric physician can be summarized as follows: a physician specializing in swimming and diving medicine or a physician holding a Level II master's degree in underwater and hyperbaric medicine. The role of the HP was introduced into Italian law by UNI 11366 of 2010 (currently under revision) and by the Decree-Law of January 24, 2012: "Urgent Provisions for Competition, Infrastructure Development, and Competitiveness," better known as the "liberalization decree," which, in Article 16, paragraph 2, establishes that the activities "*referred to in Article 53 of Presidential Decree No. 886 of May 24, 1979, shall be carried out in accordance with applicable regulations and the rules of good practice set forth in the UNI 11366 standard.*" This reference therefore confers binding force on the UNI 11366 standard.

A.6. What are the possible criteria to follow for periodic health examinations of exposed workers?

The answer to this question requires a necessary introduction explaining the inconsistencies and legal obligations in effect at the time of drafting this document.

There is no sector-specific reference standard that encompasses all the various relevant sectors, such as offshore, inshore, shallow-water, deep-water, saturation diving, fish farming, scientific diving, etc. (Note that the UNI 11366 standard is mandatory in the mining sector but serves only as a guideline for all other sectors lacking a specific UNI standard). It is important to note, in fact, that the UNI 11366 standard serves as the regulatory reference text for the issuance of ordinances by Port Authorities regarding safety in underwater work within port areas and the territory falling under their jurisdiction. Therefore, it becomes “mandatory” by virtue of Port Authority ordinances. The only regulatory references currently in effect regarding the medical assessment of workers’ fitness for duty are Legislative Decree 81/08 (assessment by the Occupational Physician) and the Ministerial Decree of the Ministry of the Merchant Marine dated January 13, 1979, published in the Official Gazette No. 47 of February 16, 1979, concerning the medical examinations required for eligibility to be registered in the Registry of Local Service Divers.

The latter, in particular, refers to the medical fitness examinations required by the Port Authorities Offices where Local Service Divers are registered; these divers are almost always O.T.S. personnel operating in the waters of the Maritime District in which they are registered: These divers are, for the most part, employed by companies operating within the district or, in any case, within the territory of the State in both maritime and inland territorial waters.

The competent authority for this fitness certification is the Port’s Maritime Health Service, which bases its assessments for the performance of professional diving activities on the examinations referred to in the Ministerial Decree. This fitness certification is limited solely to professional diving activities and does not, however, consider other non-diving work activities, such as those performed on the surface at the end of a dive shift; the latter fall under the jurisdiction of the designated Occupational Physician.

Not all operators undergo these examinations at the Maritime Health Service, as not all operators are registered in the Local Service Divers’ Registry; this registry is mandatory for conducting activities in compartmentalized maritime waters or similarly regulated areas.

Consequently, many operators do not undergo these examinations, leaving the determination of fitness for specific duties to the Occupational Physician: when seeking regulatory references for specific diagnostic assessments, the physician typically consults the decree from the Ministry of Transportation.

In light of the foregoing, it is the opinion of the rapporteurs of this Working Group that the contents of the ministerial document referenced for fitness assessments are obsolete and not up to date with the current situation: the recent COVID-19 pandemic, for example, requires specific post-infection screenings not covered by the reference list, yet equally essential for verifying a worker’s fitness to perform professional diving activities.

It is considered good practice for the various categories of employees to undergo medical examinations based on their specific risk assessments and the sectors in which they work.

If the Maritime Health Service does not certify medical fitness or fitness for the specific job, based on the regulations in effect at the time of the worker's examination, it is recommended—for the purposes of any fitness assessment by the Occupational Physician—to follow the guidelines in Table 1, attached at the end of the FAQs: this list can help ensure more comprehensive health monitoring. These guidelines must be considered in the risk assessment document to evaluate the impact on the specific worksite and/or the company.

C.1. What sources can be used to assess exposure to hyperbaric atmospheres?

Legislation regarding hyperbaric activities is evolving. A compilation of best practices can be found, in part, on the Physical Agents Portal (PAF) in the hyperbaric section. Some UNI standards are still being developed for scientific and archaeological diving as well as for professional diving. [Note: In the following, the term “diving” is also used to refer to operations in a dry environment. In the following, “diver” and “hyperbaric worker” (such as those involved in tunneling) are considered equivalent.]

Non-exhaustive list of available sources (not all are freely available):

1. Diving in Industrial Applications (Shallow and Deep Water): Legislative Decree No. 624 of November 25, 1996; Presidential Decree No. 886 of May 24, 1979; Law No. 27 of March 24, 2012 (Art. 16); UNI 11366 (currently renewal by UNI); IMCA - International Code of Practice for Offshore Diving; EDTC - GUIDANCE ON SAFE WORKING PRACTICES IN COMMERCIAL DIVING; HSE – L103 Commercial Diving Projects Offshore: Diving at Work Regulations 1997.
2. Divers in local (port) service: Ministerial Decree of January 13, 1979, Ministerial Decree of March 31, 1981, and Ministerial Decree of February 2, 1982; HSE – L104 Commercial Diving Projects Inland/Inshore: Diving at Work Regulations 1997.
3. Caisson workers: Presidential Decree 321/56: Regulations for the prevention of accidents and occupational health in compressed-air caissons.
4. Medical evaluation of divers: Balduzzi Decree (for recreational diving).
5. Archaeological and Scientific Diving (including videographers): ISPRA Guidelines; UNI standard currently being drafted; HSE – L 106 Media Diving Projects: Diving at Work Regulations 1997; HSE L 107 Scientific and Archaeological Diving Projects: Diving at Work Regulations 1997; NOAA Diving Manual: Diving for Science and Technology, 6th ed.; CMAS Standard for Scientific Divers; Woods Hole Oceanographic Institution: Diving Safety Manual, Revision 3.2; CNR – Safety Procedures for Underwater Activities for Scientific Research.
6. Divers in Government Agencies: NATO - ALLIED GUIDE TO DIVING OPERATIONS.
7. Professional spearfishing: Ministerial Decree of October 20, 1986.
8. Recreational diving: HSE – L105 Recreational Diving Projects: Diving at Work Regulations 1997;
9. Giancarlo D'Adamo et al., PRACTICAL LEGAL TRAINING FOR DIVING GUIDES AND INSTRUCTORS.
10. ISPESL: Guidelines – The Safe Management of Multi-Person Hyperbaric Chambers in a Clinical Setting (2017).

There are excellent manuals available for the categories mentioned above. We cite:

- U.S. Navy Diving Manual (ver. 7, 2016).
- NOAA Diving Manual: Diving for Science and Technology, 6th ed.
- www.edtc.org
- www.dmac-diving.org
- https://www.portaleagentifisici.it/fo_iperbariche_index.php?lg=IT

C.2. What criteria or methods can be used to assess the operational management of exposure to hyperbaric atmospheres?

The logical sequence for conducting a risk assessment of hyperbaric activities alone should be as follows for all types of exposure:

- 1) Medical fitness
- 2) Selection of the breathing gas mixture
- 3) Selection of the decompression table and related procedures
- 4) Adequacy of operator training in the selected techniques
- 5) Technological aspects (equipment required for the dive)
- 6) Other concurrent risk factors (physical, chemical, biological risks)
- 7) MEDEVAC
- 8) Human factors

This exposure assessment must be supplemented by a broader risk assessment covering all other characteristics of the work environment (e.g., poor visibility, currents, water traffic, etc.). Finally, other physical, chemical, and biological agents that may be present during the diving operation must also be considered.

About medical fitness and fitness for the specific job, refer to sections A.5. and A.6. Verification of their continued validity must be conducted considering the dates of the diving sessions; in fact, the absence of a valid medical fitness can increase the likelihood of an accident.

The choice of breathing gas mixture will be based on the operating depth, duration of exposure, and the availability of sufficiently reliable decompression tables. (The tables selected must be specified in the risk assessment.) The following table showing the probability of an accident in relation to the partial pressures of the inhaled gases serves to account for the effects these gases may have on the human body. In fact, since partial pressures increase in proportion to external pressure, certain critical factors must be considered. An increase in pO_2 raises the probability of oxygen toxicity, while an increase in pN_2 raises the probability of nitrogen narcosis. The presence of impurities in the breathing mixture, particularly pCO_2 , increases the probability of an intoxication-related incident in proportion to the operating depth.

The probability factor differs between dives in water and in a hyperbaric chamber. Table

for evaluating the partial pressures of respiratory gases

	green	yellow	red
pO_2 (bar)	1.3*	1.6/2.8**	above
pN_2 (bar)	3.16	4.74	above
pHe (bar)	as needed to reach the PA		
pCO_2 (ppm)	400	2000	above

* In the case of repetitive dives or dives over several consecutive days: reduce to 1.2 bar.

** in water/in a hyperbaric chamber

Decompression tables, which specify the procedures for reducing external pressure in such a way as to allow the inhaled inert gas to desaturate gradually enough, are indexed by the inhaled gas mixture, depth, and duration of the dive. These tables are based on models that approximate the behavior of the human body during the saturation/desaturation process in a way that does not account for interindividual differences. There are many tables and subsequent versions of the same tables. For example, the U.S. Navy tables (U.S. Navy Decompression Tables) have existed since 1956 and have undergone seven new editions, the latest of which was published in 2016. Although these tables are reliable, the simple fact that, over time, they have significantly increased decompression times for the same mixture, depth, and duration suggests that the subject has not yet reached a state of stability. Therefore, the choice of tables represents one of the most significant risk assessment decisions for

the purposes of prevention and safety in diving. This choice is not quantified in terms of probability of occurrence, but it can be assumed that more well-tested tables are safer than those that are less well-tested. The U.S. Navy tables (2016 US Navy tables) also provide a method for calculating the probability of a decompression accident occurring. In addition to this, certain factors that generally affect the probability of occurrence must be taken into account, as listed in the following table. If more than two of the indicated factors are present simultaneously, the probability of a decompression accident increases.

Factors Indicating Increased Decompression Stress: More Than Two Factors Simultaneously

Decompression risk	low	high
Total dive time (min)	< 70	> 70
Total decompression time (min)	< 30	> 30
Post-dive exertion (within 20 minutes of exiting the water)	No exertion	Physical exertion*
Repeated dives (interval < 2 hours)	no	yes
Dives on multiple consecutive days	no	yes
Altitude change or flight < 12 hours per single dive < 24 hours for repetitive dives	no	yes

* e.g., exiting the water while wearing diving gear

For example, if you make a very long dive (> 70') and want to take a flight immediately afterward (less than 12 hours after the end of the dive), the probability of a decompression accident is high. The choice of tables used serves as an indicator of safety and risk assessment, but it is not independent of other aspects of health and safety prevention, which must therefore be considered.

These aspects include:

- activities performed during diving/compression;
- technical equipment (regulators, BCDs, depth gauges, wetsuits, helmets, communication devices, etc.) to ensure redundancy that guarantees safety;
- maintenance of hyperbaric equipment (regularity and frequency of maintenance);
- surface support (number of personnel and training);
- comprehensiveness and response times of medical assistance;
- availability of a medical emergency and patient evacuation plan (MEDEVAC);
- prior diving training;
- technical diving training.

About human factors, it is important to note that physical and mental health affect the safety of underwater work. To ensure that divers do not endanger themselves or their dive partners, it is recommended that they undergo both a medical fitness evaluation and a job-specific fitness assessment—which evaluates health at the time of the examination—as well as pay attention to human factors, which encompass those aspects that affect health during the performance of the work. Human factors include physical aspects (knowledge of or adherence to healthy nutrition to avoid excessive thinness or obesity), cognitive (being aware of one's medical conditions, informing project managers about the use of prescription and over-the-counter medications, managing stress), social relationships (relationships with colleagues, the company, family, and society), cultural factors (behaviors such as the use of tobacco, steroids, and protein shakes for weight loss), and emotional factors (such as financial stability).

Probability

Value	Probability	Description
1	Extremely unlikely	There are no known incidents within the organization (frequency: zero events). The event may not be known to all staff. It has occurred internationally but is extremely rare (≤ 3 events per year)
2	Unlikely	The event may occur due to a combination of several independent and unlikely causes (frequency ≤ 1 event per year). The event is generally known to all staff. It has occurred internationally but only in rare circumstances (≤ 10 events per year)
3	Possible	The event may occur due to a combination of several independent and probable causes (frequency ≤ 10 events per year). Staff are aware of the event. The frequency at the international level is ≤ 100 events per year
4	Likely	The event can occur without the combination of several causes, although not automatically or directly (frequency ≤ 20 events/year). The event is well known to all staff. It occurs frequently internationally (> 100 events/year)
5	Highly likely	The event can occur directly and automatically (frequency ≥ 20 events/year). The event causes concern, and staff know it can happen easily

Severity →		<i>Negligible</i>	<i>Mild</i>	<i>Moderate</i>	<i>Serious</i>	<i>Very serious</i>
Probability ↓		1	2	3	4	5
Extremely unlikely	1	1 LOW	2 LOW	3 LOW	4 LOW	5 MEDIUM
Unlikely	2	2 LOW	4 LOW	6 MEDIUM	8 MEDIUM	10 MEDIUM
Possible	3	3 LOW	6 MEDIUM	9 MEDIUM	12 MEDIUM	15 HIGH
Probable	4	4 LOW	8 MEDIUM	12 MEDIUM	16 HIGH	20 HIGH
Highly likely	5	5 MEDIUM	10 MEDIUM	15 HIGH	20 HIGH	25 HIGH

Gravity:

Value	Severity	Injury	Environmental Impact	Property Damage
1	Negligible	Minimal health consequences. May require first aid, on-site medical treatment, or reduced work duties without resulting in missed shifts or days of absence.	Minimal impact. The affected area is limited to where the event occurred. Normal conditions are restored without human intervention and within a short period of time (< 1 week).	Damage limited to equipment and facilities, which can be repaired through routine maintenance.
2	Mild	Minor health consequences. Absence from work (LTI) lasting 1 to 40 days.	Minor impact. The affected area is limited to the construction site. The previous conditions are restored through human intervention, without external protection agencies.	Minor damage to equipment, repairable on-site. Damage to the facility requiring short-term, localized repairs. Damage < €50,000
3	Moderate	Significant injury. Partial disability or significant health consequences Absence from work (LTI) exceeding 40 days.	Moderate impact. The affected area extends within 500 m of the construction site. The previous conditions are restored through intervention by environmental protection agencies.	Damage to equipment requires repairs of medium duration. Damage to the facility requiring intervention/restoration. Damage between €50,000 and 500,000
4	Serious	Very serious injury. Death or severe permanent disability of a person. Inability to return to work.	Serious impact. The affected area extends to the regional level. Requires intervention by environmental protection services. Violation of environmental regulations.	Significant damage to equipment and facilities requiring long-term repairs. The facility sustains structural damage. Damages between €500,000 and 2 million.
5	Very serious	Multiple fatalities. The event may result in terminal occupational illness or death for more than one person.	Very serious impact. The affected area extends to the national or international level. Serious violations of environmental regulation.	Loss of important facilities or equipment. Site completely damaged and unusable. Damages > €2 million.

The Designated Leader must coordinate with NUE 112/118 to arrange for the emergency transfer of the injured person, who must be transported as quickly as possible to the nearest hyperbaric center in a clinical setting. The patient must receive normobaric oxygen administration during the time between recovery and transport to the hyperbaric chamber.

The Designated Leader must specify the methods and timelines for the patient's transport and treatment, considering the worst foreseeable marine weather conditions.

D.1. What technical and organizational measures should be adopted following the assessment of risks associated with hyperbaric environments?

Having refined the assumptions outlined in the previous tables for the various risk factors, the

response involves eliminating or mitigating the unfavorable scores identified in those tables.

The risk assessment should be tailored to each type of hyperbaric work described in A.1.

Under the supervision and responsibility of the employer of the operating company, emergency procedures and a plan for the assistance, the recovery and transport of an injured diver, to be implemented in accordance with current health protocols, to a clinical facility whose operational status during the relevant period and response times must be verified prior to conducting the dives; Alternatively, the company must maintain, on the support vessel or in the immediate vicinity, a suitably equipped and furnished hyperbaric chamber, staffed by a hyperbaric physician and/or personnel qualified to operate the chamber and authorized to perform therapeutic treatments under medical supervision; the hyperbaric chamber, in addition to complying with current relevant regulations, must be large enough to accommodate a cot and allow medical personnel to provide care to the injured person.

D.2. In which cases is specific information or training required? What should the content include?

Training and information on the specific equipment used must always be provided, as well as on the operational procedures selected for the particular dive. In any case where a well-defined organizational structure has been established, training on that structure is necessary to ensure that individual workers' behaviors are optimally aligned with the organization itself. In practice, this applies in all cases.

Training on risks arising from work activities (which is distinct from the professional qualifications that must already be possessed) must address the decisions made by the Safety Employer regarding:

- 1) Medical fitness (the employer must inform staff that they must maintain good health and adequate nutrition/hydration)
- 2) Appropriate breathing mixture
- 3) decompression table—the company may choose which one to use but must inform the worker
- 4) Operational equipment (regarding both equipment and procedures)
- 5) coordination among the various teams and between the teams and the surface
- 6) MEDEVAC (medical evacuation: medical transport of the injured person)

In addition, situations must be included where other risk factors occur in conjunction with the dive, such as in cases of concurrent physical, chemical, or biological hazards, which require the use of specialized equipment or medical care in a hyperbaric environment.

In general, the information must cover the objectives of the dive, the methods for achieving them, and the equipment needed to perform the operations required to meet those objectives.

D.3. Under what conditions might the risk of exposure be increased?

Factors that can increase the risk include weather conditions, sea state, and currents. Inadequate diving training for operators; unsuitable, poorly maintained, or obsolete equipment; breathing mixtures unsuitable for the depth; impaired general health or emotional/cognitive state; limited or absent specific information; negligence in planning; low or high water temperature; diving at high altitude; repetitive dives; any medical conditions the diver has experienced as a result of recent dives, exceptional physical exertion during the dive, excessive distance from the hyperbaric chamber (more than two to four hours), failure to update specific training—including in prevention and first aid—and polluted waters.

D.4. How should the Technical Report supporting the hyperbaric risk assessment document be structured, and what should it include?

The Technical Report must be organized according to the following topics:

- 1) company name;
- 2) identification of the employer, the Occupational Health and Safety Employer (RSPP) and the Workers' Safety Representative (RLS), the occupational physician, and/or the hyperbaric physician;
- 3) description of the activity to be carried out: objectives, personnel (including any teams), technical resources, and planned procedures;
- 4) hyperbaric risk analysis: breathing mixture, decompression tables, equipment and support resources, teams and their coordination, MEDEVAC, interaction with the National Health Service (SSN) or autonomous response capability (*on-site* hyperbaric chamber, establishment and location of a medical facility near the worksite for the management of critically ill patients, in the event that on-site management is not possible); see the tables in section C.2;
- 5) Work Process Risk Analysis (Operational Safety Plan)
- 6) possible interaction between different risk factors;
- 7) if multiple companies are involved, a DUVRI (risk assessment of interfering activities) must also be provided.

D.5. What assessment methods are appropriate for evaluating other physical risks in a hyperbaric environment?

Certain diving activities may expose workers to other physical risk factors such as noise (use of a diving bell), vibrations (use of pneumatic tools), ionizing radiation (inspections of weld integrity), optical radiation (ultraviolet radiation from welding/oxy-electric cutting), ultrasound, electrical hazards, and risks of mechanical trauma. These factors must be assessed while considering the different environmental conditions resulting from being in the water. In addition to physical risk factors, biological and chemical risk factors should also be considered for work environments where they are relevant.

In projects involving multiple vessels, it is necessary to establish a coordination system to prevent accidents between different operators and vessels.

E.1. Under Legislative Decree 81/2008, in accordance with which references must the risk assessment for hyperbaric atmospheres be conducted?

The risk assessment for exposure to hyperbaric atmospheres must be conducted in accordance with Article 181 of Legislative Decree 81/2008, which stipulates that the employer—as clearly indicated in paragraph 1 of Article 28—must assess all risks arising from exposure to physical agents. Since Title VIII does not include a specific chapter on hyperbaric atmospheres, the regulations require consideration of the provisions of the entire Chapter I—namely, the purpose of the risk assessment, which must be such as to identify and implement appropriate prevention and protection measures (Section D), with particular reference to rules of good engineering practice and best practices, as outlined in Sections C and D (Article 182, paragraph 1), attention to particularly sensitive workers (Art. 183), information and training obligations (Art. 184), health surveillance, and the maintenance

of health risk records (Arts. 185 and 186).

Therefore, if the risk associated with hyperbaric environments cannot be justified, the employer has, pursuant to Article 17 of Legislative Decree 81/2008, a non-delegable obligation—subject to penalties—to assess the risk associated with hyperbaric atmospheres and to prepare the document referred to in Article 28, which must identify the appropriate preventive and protective measures to be adopted to minimize the risk.

E.2. Are adverse health effects resulting from exposure to hyperbaric atmospheres recognized as an occupational disease?

INSURANCE CONCEPT OF OCCUPATIONAL DISEASE: a disease caused by or related to work that differs from a work-related injury in that the harmful cause acts gradually over time rather than in a chronologically concentrated manner. With regard to the causal relationship (in light of the considerations of the Constitutional Court and the Court of Cassation), it has been reaffirmed that this relationship must be direct and effective, without prejudice, however, to the possibility of the concurrence of non-occupational causal factors; such concurrence may, under certain conditions, act as a factor that amplifies occupational risk by increasing its harmful effect. Obviously, the concept of occupational risk is to be understood not only as “the harmful nature of the work processes involved in the company’s production cycle” but also in the broader sense attributable to all the conditions under which the work is performed—in other words, “the organization of work.”

The Tables of Occupational Diseases are statutory tables for insurance purposes, which include lists of diseases for which there is a legal presumption of work-related origin—that is, a presumption of a causal link between the disease and the work performed. They represent a legal instrument developed and periodically updated based on scientific evidence and epidemiological data.

The New Tables of Occupational Diseases—one for Industry and one for Agriculture (Ministerial Decree of April 9, 2008)—are structured into three columns: the first column lists diseases grouped by causative agent (physical agents, chemical agents, etc.), nosologically defined and identified according to the International Classification of Diseases, 10th Revision (ICD-10); the second column, for each disease, lists the types of work that expose workers to the causative agent; the third column specifies the maximum period of eligibility for compensation following the worker’s cessation of the risky work. For the legal presumption of the origin of the reported disease to apply, three requirements must therefore be met: 1) the disease presented by the worker must be among those listed in the first column; 2) there must have been systematic and habitual assignment to one of the occupations listed in the second column; 3) the maximum period of eligibility for compensation must not have been exceeded.

The presumption of causation is a “relative” presumption, meaning that the insurance provider may provide evidence to the contrary, which may take various forms: by demonstrating that the worker was assigned sporadically or occasionally to the task or process listed in the tables; that the worker was exposed to the pathogen associated with the listed process to an extent insufficient to cause the disease; or that the disease is attributable to another cause unrelated to work.

In order not to limit insurance coverage exclusively to the occupational diseases listed in the relevant Tables, the Constitutional Court, in Judgment No. 179 of February 18, 1988, introduced the so-called “mixed system” into Italian law, which preserves the Tables and their specific characteristics while simultaneously extending coverage to all diseases for which the worker can prove a work-related origin. Therefore, even diseases not listed in the Tables—or those contracted in the course of, or due to, work activities other than those specified therein, or those that manifest after the maximum period of eligibility for compensation—may be covered by INAIL, provided that their occupational origin is demonstrated: in such cases, the burden of proof lies with the worker, who, in addition to demonstrating that they have the disease and were exposed to the risk, must prove the existence of a

causal link. In fact, the insurance agency takes an active role in reconstructing the evidence supporting the causal link—both from the perspective of risk assessment and forensic medicine—in the case of diseases not listed in the Tables. The New Tables of Occupational Diseases in Industry and Agriculture, approved by Ministerial Decree of October 10, 2023.

Item 76 of the table for industry (Table E.1.) lists “DISEASES CAUSED BY UNDERWATER WORK AND WORK IN HYPERBARIC CHAMBERS,” specifically osteoarthropathies, while the second column of the table indicates that underwater work and work in hyperbaric chambers are considered listed occupations.

Regarding the maximum period of eligibility for compensation following the cessation of work, a period of 10 years has been established; therefore, if the disease is reported more than 10 years after ceasing the hazardous work, the worker must provide medical documentation certifying that the onset of the disease occurred within the prescribed time limit. If the disease manifested itself beyond the time limits specified in the table, it will be treated as a non-scheduled disease.

Table E.1. Excerpt from the Table of Occupational Diseases in Industry approved by Ministerial Decree of October 10, 2023

DISEASES (ICD-10)	WORK ACTIVITIES	Maximum Period of Eligibility for Compensation from the the cessation of the work
76) DISEASES CAUSED BY UNDERWATER WORK AND WORK IN HYPERBARIC CHAMBERS		
a) OSTEOARTHROPATHIES (CAISSON SICKNESS, DIVER’S DISEASE) (M90.3)	Underwater work and work in hyperbaric chambers	10 years

INAIL’s insurance coverage for workers suffering from occupational diseases is provided through the delivery of medical and financial benefits. Once an occupational disease is recognized, the resulting sequelae are assessed and the biological damage is evaluated based on the disability rating tables. A lump-sum payment is provided for impairments assessed between 6% and 15%, while a monthly annuity is provided for impairments exceeding 15%. The compensation is determined, after applying the disability rating table, using the biological damage compensation table. The lump-sum compensation is independent of income; it varies according to the insured person’s age, increases with the severity of the disability, and is the same for both genders, in accordance with the recent adjustment made by Presidential Decision No. 2 of January 9, 2019. The new amounts listed in the lump-sum compensation table, expressed in euros, are derived from the weighting of the previous tables, which were differentiated by gender and provided for higher amounts for females than for males. The annuity compensation consists of a portion calculated according to the criteria for compensation for biological damage, plus an additional portion calculated in proportion to the insured person’s income.

E.3. How should hyperbaric risks be managed as part of risk assessments on construction sites (POS and PSC) and interfering risks (DUVRI)?

In the event of overlapping work activities among multiple employers, the contracting employer promotes cooperation and coordination of the various work activities in order to implement adequate

measures to prevent the occurrence of hazardous situations for all workers, providing detailed information on the specific risks present in the environment where contract workers will operate and, on the preventive, and emergency measures that have been and will be adopted. Overlap between work activities refers to both spatial and temporal overlap and concerns the environmental conditions in which contracted workers are required to work.

As with all risk factors, two cases must be distinguished:

1. For work related to contracting, construction, or temporary staffing agreements, pursuant to Article 26 of Legislative Decree 81/2008, the risk of exposure to hyperbaric atmospheres must be managed through the preparation of the Single Document for the Assessment of Interference Risks (DUVRI).
2. In the event of overlapping work activities at a construction site, pursuant to Title IV of Legislative Decree 81/2008, the risk of exposure to hyperbaric atmospheres must be assessed in the Safety and Coordination Plan (PSC), prepared by the Safety Coordinator, and in the Operational Safety Plan (POS), prepared by the employer of the contracting firm.

In both cases, the client's safety employer must provide the contractor's safety employer with all information necessary for assessment and prevention, while ensuring that workplaces meet health and safety standards.

In the first case, the client must provide detailed information regarding any hyperbaric risks in the work environments where the contract will be carried out, as well as the preventive and emergency measures adopted in relation to their activities. Employers, including subcontractors, must cooperate in the implementation of prevention and protection measures, carrying out all preventive measures within their purview. This assessment and decision-making process must be formally documented in the DUVRI, prepared by the client's employer and signed by all employers involved in the contract. For activities falling under Title IV "Construction Sites," as defined in Annex X of Legislative Decree 81/2008, the Design Coordinator (CSP) must also take into account the risk of hyperbaric environments when drafting the Safety and Coordination Plan (PSC). The Construction Site Coordinator (CSE) must implement the measures set forth in the PSC throughout the construction project's timeline, including those related to hyperbaric environments. The employers of the contracting firms must include specific measures for organizing on-site work within their own Site Operation Plans (POS).

GLOSSARY

1. **Deep Water:** bathymetric depths exceeding 50 meters;
2. **Shallow Water:** bathymetric depths ranging from 0 to 50 meters;
3. **Hyperbaric Chamber:** a pressurized chamber suitable for housing people breathing oxygen with $FiO_2 = 1$ (100% O_2) at a pressure higher than atmospheric pressure. In Italy, hyperbaric chambers are multi-compartment (main chamber and secondary or equilibrium chamber) and multi-person (capable of accommodating 2 or more people);
4. **Recompression chamber:** a hyperbaric chamber located at the work site as a DPC, based on the risk assessment conducted by the employer under specific conditions (chamber transfer and/or hyperbaric centers located more than 2 hours away from the work site);
5. **Design Coordinator (CSP) and Construction Coordinator (CSE):** individuals appointed by the client to perform the duties required by Articles 91–92 of Legislative Decree 81/08;
6. **Safety Curve:** a guideline for dive times that, depending on depth, allow for a direct ascent to the surface—that is, without decompression stops—always in compliance with the ascent rate prescribed by the applicable tables;

7. **Employer (DL):** pursuant to Article 2(b) of Legislative Decree 81/08, as amended, is the party with whom the worker has an employment relationship or, in any case, the party who, depending on the type and structure of the organization within which the worker performs his or her duties, is responsible for the organization itself or the production unit, as he or she exercises decision-making and spending authority;
8. **Risk Assessment Document (DVR):** a document formalizing the results of the risk assessment for the health and safety of workers within an organization, indicating the prevention and protection measures to be adopted for the performance of work activities, drafted and maintained in accordance with the provisions of Article 29 of Legislative Decree 81/08, as amended;
9. **Single Document for the Assessment of Interfering Risks (DUVRI):** a document that analyzes and describes the proper management of safety during contracted activities, indicating the measures adopted to eliminate or, where this is not possible, minimize risks arising from interference. The DUVRI must include a preliminary assessment of standard risks related to the type of service that could potentially arise from the performance of the contract. The party at whose premises the contract is to be performed must, prior to the start of work, supplement the aforementioned document by addressing the specific risks of interference present at the sites where the contract will be carried out; this supplement, signed by the contractor to indicate acceptance, forms part of the contractual documents;
10. **PPE:** any equipment intended to be worn and held by a worker to protect them against one or more risks that could endanger their safety or health while working, as well as any accessory or component intended for that purpose;
11. **CPE:** a set of systems and devices designed to act directly on the source of hazards. Their purpose is, therefore, to protect all workers exposed to the same risk;
12. **Breathing Gas or Mixture:** a mixture of compressed gas(es), whether natural or synthetic, for the OTS to breathe in a hyperbaric environment;
13. **Occupational Physician (OP):** a medical specialist designated by a company or organization to manage occupational health matters; pursuant to Article 2, letter h) of Legislative Decree 81/08, as amended, is a physician who holds one of the qualifications and meets the educational and professional requirements set forth in Article 38, who collaborates, as provided for in Article 29, paragraph 1, with the employer for the purposes of risk assessment and is appointed by the employer to conduct health surveillance and perform all other duties referred to in Legislative Decree 81/08, as amended;
14. **Hyperbaric Physician (HP):** a medical specialist in diving with expertise in managing aspects of professional diving medicine;
15. **Hyperbaric Chamber Operator:** a technician trained in the routine maintenance of hyperbaric systems;
16. **Operator Technical Diver (OTS):** Specialized in underwater (scuba diver and/or commercial diver);
17. **Underwater Operation:** any activity involving the use of OTS;
18. **Operational Safety Plan (OSP):** a document to be prepared before the start of operational activities at a temporary or mobile worksite, in accordance with Legislative Decree 81/2008, as amended;
19. **Safety and Coordination Plan (PSC):** a document required and regulated by Legislative Decree 81/2008 that, within the worksite, describes and details all the operational phases necessary to complete construction, appropriately identifying those phases most exposed to risk and requiring preventive measures to be implemented to safeguard the health and safety of workers;
20. **Supervisor:** a person who, by virtue of their professional expertise and within the limits of hierarchical and functional authority appropriate to the nature of the assignment entrusted to them, supervises work activities and ensures the implementation of received directives, verifying their proper execution by workers and exercising functional authority to take initiative (pursuant

to Article 2, letter e) of Legislative Decree 81/08, as amended) The supervisor must be appointed in writing and oversees work activities, verifies their proper execution by workers, and ensures the implementation of safety directives;

21. **Decompression Table:** a numerical matrix that specifies the times and depths for decompression following hyperbaric exposure, based on the duration of exposure and the mixtures of gases inhaled;
22. **Company Decompression Table:** a decompression table officially adopted by a company;
23. **Decompression stop:** This is the period of time a diver must spend at a constant depth at the end of a dive to safely reduce the concentration of inert gases in the body to prevent problems such as decompression sickness.
24. **pO₂:** partial pressure of oxygen.
25. **pCO₂:** partial pressure of carbon dioxide.

CREDITS

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TABLE 1:

Possible specific criteria to follow for health surveillance, including initial and periodic fitness assessments for exposed workers.

Where medical fitness and fitness for the specific job have not been determined by the Maritime Health Service, based on current regulations, at the time of the worker's medical examination, a list of possible tests (Table 1) is suggested, which the Occupational Physician may use for the purpose of assessing fitness.

These guidelines must be taken into account in the risk assessment document to evaluate the impact on the specific work site and/or the company.

SYSTEMS	TESTS	First examination	Annual	every 3 years up to age 45	every 2 years after age 45	Every 5 years up to age 50	Every 3 years after age 50	Every 6 years
Cardiovascular	Baseline and stress ECG		x					
	Transthoracic echocardiogram	x		x	x			
	Color Doppler ultrasound of the TSA						x	
Respiratory	Spirometry		x					
	Chest X-ray					x	x	
	HRCT of the lungs without contrast	x						
ENT	Hearing Impedance Testing		x					
Vision	Orthoptic chart and fundus		x					
	Ishihara test	x						

Osteoarticular	MRI of Major Joints (**)	x						x
	DEXA Densitometry (**)	x						x
Neurological	neurological examination*	x	x					
	EEG	x						
Skin - Integumentary System	Assessment of absence of skin lesions**		x					
Oral and Masticatory System	Oral examination		x					
Abdomen	Physical examination (liver, spleen, gastroesophageal reflux) BMI		x					
Blood Chemistry Tests								
Complete blood count			x					
Serum Protein Electrophoresis		x		x	x			
PCR			x					
Blood glucose			x					
Serum creatinine			x					
Total cholesterol		x		x	x			

HDL cholesterol		x		x	x			
Triglycerides		x		x	x			
Uric acid		x		x	x			
Gamma-GT		x		x	x			
ALT		x		x	x			
AST		x		x	x			
Total/Direct Bilirubin		x		x	x			
PT - INR			x					
Fibrinogen			x					
Complete Urinalysis			x					
TSH reflex		x						
* Non-specialist examination **Only for Technical Divers with exposure to hyperbaric environments for thirty days per year (e.g., deep-water diving)								

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