

Manned underwater operations

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Revision information

Major changes from revision 3 to 4 are listed below.

Removed:

- Standards for use of ADS (atmospheric diving system) is removed, information may be found in edition 3.

Edited:

- 2.1 Normative references list has been evaluated and revised.
- 2.2 Informative reference list has been replaced with Bibliography (after last Annex).
- Edition 3 subclause 4.6.3.1 has been modified. This is covered in edition 4 subclause 4.8.3.1, 4.8.3.4, Annex A and in Styringsforskriften/management regulations.
- 5.1.5.3 has been changed from "access to telecommunication" to "Telemedicine".
- 5.2.3 Chemical working environment and subclauses have been modified.
- 6.3 Requirements for diving personnel – some subclause content has been modified.
- 7.2.3 Chambers for surface oriented diving have been modified.
- 7.2.4.3 Emergency connectors for diving bells, habitats and SPHLs – table and figure have been modified.
- 7.4 and clause 9 are upgraded to match new IMCA documents D051, 052 and 053, and OGP-478.
- 7.7.2 Normal operation have been modified.
- 7.11.3.4 The support vessel has been modified (edition 3 subclause 7.12.2.2).
- 7.17 Maintenance have been modified reference to NORSOK Z-008.
- 8.1.2.6 Content of logbooks amended to included requirements for signed medical and stamped photo.
- 8.2.1 General – text edited.
- 8.2.2 Surface oriented diving – text modified.
- 8.2.4 Deeper saturation diving – text modified. All references to additional depth requirements are changed to 180 msw ref. aktivitetsforskriften para 94.
- 8.5.1 Manning of control room – text modified.
- 8.5.2 Depth limits for diving from small diving craft - edited
- 8.5.5 Stand-by diver and contingency diver – text modified.
- 9.2 Emergency preparedness training – text modified
- Annex B – new build up and content.

Edited and moved:

- Risk management is moved from subclause 5.3 to new 4.2.

New and added text:

- 1 Scope – added text deeper than 180 msw.
- 4.5 Management of Change – new.
- 5.1.4 Short and long term health monitoring – added text.
- 5.2.3 Chemical environment – added new subclauses.
- 6.3 Diving personnel: Use of simulator as part of training.
- 6.3.2 Requirements for offshore manager included
- 6.3.7 Divers, requirements for health and approved certificate included, as well as advanced first aid training for surface oriented diving teams.
- 6.3.8 Diving technician/maintenance engineer – new text added.
- 6.3.12 Hyperbaric trained Nurse – new text added.
- 7.1.2 Implementing new technology – new.
- 7.3 Handling Systems (diving bell, wet bell and basket) – added text with reference to NORSOK R-002.
- 7.6 Gas supply systems, color coding for gas.
- 7.8.1 General – text added regarding disinfection and microbiological sampling/control of BA.
- 7.11 Diving support vessel (DSV) – several new subclauses.
- 8.3.1 General – text added regarding PLC controlled dive systems.

Foreword

The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations. Furthermore, NORSOK standards are, as far as possible, intended to replace oil company specifications and serve as references in the authorities' regulations.

The NORSOK standards are normally based on recognised international standards, adding the provisions deemed necessary to fill the broad needs of the Norwegian petroleum industry. Where relevant, NORSOK standards will be used to provide the Norwegian industry input to the international standardisation process. Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.

The NORSOK standards are developed according to the consensus principle generally applicable for most standardisation work and according to established procedures defined in NORSOK A-001.

The NORSOK standards are prepared and published with support by the Norwegian Oil and Gas Association, The Federation of Norwegian Industries, Norwegian Shipowners' Association and The Petroleum Safety Authority Norway.

NORSOK standards are administered and published by Standards Norway.

Annex A and B are informative.

Introduction

This NORSOK standard is the result of an industry-wide effort to establish a standard for manned underwater operations (MUOs).

1 Scope

This NORSOK standard defines basic requirements for personnel, equipment and systems for MUOs within the petroleum industry. Main focus for this NORSOK standard is diving down to 180 msw. For diving deeper than 180 msw, special consideration, evaluations and mitigating actions, some of which are specified in this standard, are required.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this text and are indispensable for the application of this NORSOK standard. Latest issue of the referenced documents (including any amendments) applies unless otherwise agreed. Other recognised standards may be used provided it can be shown that they meet the requirements of the referenced standards.

CEN/TR 15321	Guidelines on the selection, use, care and maintenance of protective clothing
EN 482	Workplace exposure – General requirements for the performance of procedures for the measurement of chemical agents
EN 689	Workplace atmospheres – Guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy
EN 1089-3	Transportable gas cylinders – Gas cylinder identification (excluding LPG) – Part 3: Colour coding
EN 13921	Personal protective equipment – Ergonomic principles
EN 14042	Workplace atmospheres – Guide for the application and use of procedures for the assessment of exposure to chemical and biological agents
HSE-MA1	The medical examination and assessment of divers (MA1)
IMCA D 045	Code of practice for the safe use of electricity underwater
IMO 808E	Code of safety for diving systems (resolution A.536(13) as amended by resolution A.831(19)) and any further amendments. As printed in ISBN 978-92-801-14324 (Sales number IMO 808E, London: IMO, 1997) or later edition
ISO 9001	Quality management systems – Requirements
ISO 19901-7	Petroleum and natural gas industries – Specific requirements for offshore structures – Part 7: Stationkeeping systems for floating offshore structures and mobile offshore units
NBH IS-1879	Guidelines to Regulations regarding health requirements for persons working on installations in petroleum activities offshore
NORSOK R-002	Lifting equipment
NORSOK R-003	Safe use of lifting equipment
NORSOK U-101	Diving respiratory equipment
NORSOK U-102	Remotely operated vehicle (ROV) services
NORSOK U-103	Petroleum related manned underwater operations inshore
NORSOK Z-008	Risk based maintenance and consequence classification
NORSOK Z-013	Risk and emergency preparedness assessment

3 Terms, definitions and abbreviations

For the purposes of this NORSOK standard, the following terms, definitions and abbreviations apply.

3.1 Terms and definitions

3.1.1

accident

unwanted event which causes personal injury, environmental/material damage or loss of production

3.1.2

assistant life support technician

ALST

person with the proper theoretical qualifications who is undergoing a period of planned work experiences for his training to become a LST

3.1.3**bail-out**

emergency breathing gas supply that contains sufficient breathing gas for the diver to be able to reach a place of safety where more breathing gas is available, such as the surface or a diving bell

3.1.4**bell run**

begins when the clamp between the bell and the chamber is first loosened and ends when the clamp is reconnected, ready for pressure equalization and final transfer of the divers back to the chamber complex

3.1.5**can**

verbal form used for statements of possibility and capability, whether material, physical or casual

3.1.6**competent person**

person with authorisation/documentated qualifications for performing a specified function

3.1.7**compression period**

compression commences at the start of pressurisation and is completed upon arrival at the working depth, or for saturation diving, the planned living depth including stand-off periods and HPNS screening time

3.1.8**contingency diver**

nominated diver as part of the contingency preparedness, which has diving equipment ready for use on surface but is not necessarily dressed

3.1.9**decompression period**

- a) *during saturation diving*: from the start of build-up of the pO_2 in preparation for the final decompression phase, until arrival at atmospheric pressure
- b) *during surface oriented diving*: from starting final ascent from working depth until arrival at surface pressure

3.1.10**diver**

person holding a diving certificate and a valid medical certificate issued by an approved authority or by institutions/organizations accredited by an approved authority

3.1.11**diving basket**

device used to lower and recover divers to and from work-sites subsea, which do not protect against contact with surrounding water

3.1.12**duty diving doctor**

medical doctor, approved as duty diving doctor, who is on call during diving operations

3.1.13**diving bell**

submersible compression chamber designed for transport of personnel between the surface and the work site at atmospheric pressure or under increased pressure

3.1.14**diving contractor**

diving company or firm undertaking petroleum related MUOs

3.1.15**diving operation**

activity where the diver is directly exposed to increased ambient pressure

3.1.16**diving superintendent**

person who is qualified and has been appointed in writing by the diving contractor to be the person in charge of, and responsible for, a MUO

3.1.17**diving supervisor**

person who has been appointed in writing by the diving contractor to be in charge of a MUO or parts of such operation

3.1.18**diving work-site**

site from which the diving is performed

NOTE Also referred to as diving platform

3.1.19**excursion**

any descent or ascent from pressure at living depth during saturation diving

3.1.20**incident**

generic term covering any undesired event

3.1.21**life support supervisor****LSS**

person who has been appointed in writing by the diving contractor to act as "person in charge" of the operation of a chamber complex with associated equipment

3.1.22**life support technician****LST**

qualified person operating a chamber complex with associated equipment

3.1.23**living depth**

pressure/depth at which the saturation divers stay in the chamber complex following the compression period and intermediate compressions/decompressions, in between excursions, and prior to final decompression period

NOTE Also called "storage depth"

3.1.24**manned underwater operation****MUO**

activity when humans stay below surface and/or are exposed to increased ambient pressure

3.1.25**may**

verbal form used to indicate a course of action permissible within the limits of this NORSOK standard

3.1.26**meter of sea water****msw**

pressure unit equal to 10 kPa (making 10 msw exactly 1 bar or 100 kPa), implies a relative density of 1,01972

3.1.27**near-accident**

event that, under slightly different circumstances, could have caused personal injury, fire, environmental/material damage or loss of production

NOTE Also called "near miss"

3.1.28**offshore manager**

the diving contractor's representative at the worksite

3.1.29**operator**

oil company, responsible as the obligated party

3.1.30**responsible competent diving doctor****RCDD**

nominated medical doctor, with adequate competence and practice in diving medicine, who is medically responsible for the health service covering diving operations

3.1.31**safety critical element**

a safety critical system is a system whose failure or malfunction can result in death or serious injury to people, or loss or severe damage to equipment or environmental harm

3.1.32**SCUBA (Self Contained Underwater Breathing Apparatus) diving**

is a form of underwater diving in which a diver uses SCUBA to breathe underwater

3.1.33**shall**

verbal form used to indicate requirements strictly to be followed in order to conform to this NORSOK standard and from which no deviation is permitted, unless accepted by all involved parties

3.1.34**small / light diving craft****LDC**

small boat equipped as a complete dive station and operating from a mother vessel

3.1.35**should**

verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required

3.1.36**stand-by diver**

diver who is prepared, dressed and equipped to give immediate assistance to the diver

NOTE: For saturation diving the bell-man is the stand-by diver.

3.1.37**stay at living depth**

period of time between completed compression, or first compression if work is to take place at several levels of pressure, and commencement of the final decompression excluding stabilising period and O₂ build up which is part of the decompression

3.1.38**submerged habitat**

submerged chamber or device positioned below surface and designed so as to allow personnel to work there under dry conditions

3.1.39**supervisory personnel**

personnel on the diving team acting in a supervisory role

NOTE Diving supervisors, LSSs, superintendents, etc.

3.1.40**surface oriented diving**

diving where the diver enters and leaves the water at normal ambient pressure

NOTE The term "surface supplied diving" is also used in the industry.

3.1.41**time in water, bell diving**

period of time from when a diver leaves the bell on a lock-out until he returns to the bell after completed lock-out, including any rest periods required during the lock-out, but not including mandatory rest period

3.1.42**trainee diving supervisor**

diver undergoing a period of planned work experiences for his training to become a diving supervisor

3.1.43**transfer under pressure diving****TUP**

is an alternative diving method transferring divers in a closed bell from their working depth to a surface decompression chamber whilst maintaining bottom pressure, and their subsequent decompression to surface ambient.

NOTE By removing in-water decompression-stops, surface intervals and re-compression, TUP is generally considered as a healthier, safer and more efficient alternative to other traditional surface oriented air/nitrox diving techniques (in-water decompression-stops and traditional surface decompression). The term TUP has different meaning in different contexts. Sometimes it is used for any process where divers are kept at a pressure above the surrounding, while they move or are moved. In other cases the term is used to designate the facility that is used for the transfer, e.g. the bell or a special surface chamber used by the underwater workers passing from the diving bell to another chamber.

3.1.44**verification**

confirmation, through provision of objective evidence, that specified requirements have been fulfilled

NOTE 1 The term "verified" is used to designate the corresponding status.

NOTE 2 Confirmation may comprise activities such as

- performing alternative calculations,
- comparing a new design specification with a similar proven design specification,
- undertaking tests and demonstrations,
- reviewing documents prior to issue.

3.1.45**wet bell**

open unit with an upper section containing a pocket of breathable gas, used to lower and recover divers to and from work-sites subsea, and equipped with an umbilical for normal supply of breathing gas as well as an on board contingency breathing gas supply, and a breathing gas panel for diver's umbilicals.

3.1.46**working depth**

actual water depth at the diver's worksite

3.2 Abbreviations

ALST	assistant life support technician
Ar	argon
BA	breathing apparatus
BIBS	built in breathing system
CO	carbon monoxide
CO ₂	carbon dioxide
DMAC	Diving Medical Advisory Committee
DNV	Det norske Veritas
DP	dynamic positioning
DSV	diving support vessel
EDTC	European Diving Technology Committee
FMEA	failure mode and effects analysis
FMECA	failure mode, effects and criticality analysis
FRC	fast rescue craft
HAZID	hazard identification
HAZOP	hazard and operability study
HEL	hyperbaric exposure limit
HPNS	high pressure nervous syndrome
HRF	hyperbaric reception facility
HSE	Health and Safety Authority (UK)
IMCA	The International Marine Contractors Association
IMO	International Maritime Organisation
IOGP	The International Association of Oil and Gas Producers
kPa	kilopascal
LARS	launch and recovery system
LDC	light diving craft
LSP	life support package
LSS	life support supervisor
LST	life support technician
msw	meters of sea water
MUO	manned underwater operation
N ₂	nitrogen
NO _x	mono-nitrogen oxides (NO, NO ₂)
NBH	Norwegian board of health
NAV	the Norwegian Labour and Welfare Administration
NOROG	the Norwegian Oil and Gas Association
NPD	Norwegian Petroleum Directorate
O ₂	oxygen
O ₃	ozone
OEL	occupational exposure limit
pAr	partial pressure of Ar
pN ₂	partial pressure of N ₂
pCO ₂	partial pressure of CO ₂
pO ₂	partial pressure of O ₂
ppm	parts per million
PLC	programmable logic controller
PSA	Petroleum Safety Authority (Petroleumstilsynet)
QA	quality assurance
RCDD	responsible competent diving doctor
ROV	remotely operated vehicle
SCUBA	Self-contained underwater breathing apparatus
SHE	safety, health and environment
SJA	safe job analysis
SPHL	self-propelled hyperbaric life boat
STEL	short term exposure limit
TUP	transfer under pressure
UV	ultraviolet

4 Administrative requirements

4.1 General

If there are safety aspects not covered in this NORSOK standard, an independent responsibility to maintain the safety level indicated by this standard is imposed on anyone engaged in MUO.

The contractor shall set internal requirements that put these NORSOK requirements into concrete terms, and that contribute to achieving the objectives for SHE. If the internal requirements are expressed as functional requirements, achievement criteria shall be set.

The contractor's organisation shall include administrative functions responsible for areas that ensure a safe and efficient operation. As a minimum, these functions are

- a) diving discipline,
- b) SHE,
- c) emergency preparedness,
- d) QA,
- e) personnel,
- f) management of diving equipment and systems,
- g) competent controls engineering group responsible for safekeeping of software.

4.2 Safety

The contractor shall during all activities and on all levels in the organisation strive to enhance safety.

Responsibility for safety is in the line organisation, and each individual shares this responsibility. However, top management holds a particular responsibility for creating an atmosphere and a psychosocial working environment within the organisation that enhances safety, places safety issues on the daily agenda and rewards the safe conduct of work.

All critical equipment, and operational and emergency procedures, shall be subject to thorough risk analyses to disclose consequences of single failures and series of failures, and to evaluate the possibilities for such failures. Operational and technical expertise and experience shall be brought into these assessments. The results shall be compared to the acceptance criteria, and on this basis, risk-reducing measures shall be taken. These analyses and resulting measures shall be documented.

Risks analyses shall be performed using recognised methods, e.g. FMEA, fault tree analysis, event tree analysis, HAZOP, HAZID and SJA, in accordance with NORSOK Z-013.

Technical risk analyses (FMECA, FMEA, HAZID, HAZOP, SJA) should provide a single, consistent top-down approach for all diving related risks, ensuring there are no gaps in the suite of risk documentation and that human interaction and operator error risks are accounted for. Risk analyses, including FMECA's should be routinely updated based on changing conditions, equipment, assumptions, knowledge etc. Feedback from updated risk analysis (FMECA's) should be used to improve the emergency preparedness. Likewise, if operational experience uncover gaps in the emergency preparedness this should be fed back to the FMECA process to ensure that the next FMECA revision consider these findings and evaluate risks and mitigations.

4.3 Documentation

The contractor shall document the diving methods, diving equipment operation and dive system maintenance relevant for the scope of work to be conducted under a contract. This documentation shall be based on the contractor's general diving procedures and, if relevant, include a description of DP-operations in accordance with ISO 19901-7.

Management systems and QA shall be implemented in accordance with ISO 9001. Technical and operational documentation shall be in accordance with national legislation and this NORSOK standard.

The contractor shall have a documented system for systematic, preventive and criticality based maintenance, including updating of certificates, covering all diving related equipment, systems and machinery, in accordance with NORSOK Z-008.

As a minimum, the contractor shall define, document and make available procedures covering

- a) normal and emergency operation of the equipment,
- b) function and verification testing, including acceptance parameters,
- c) limits for monitoring parameters, including early warning,
- d) check lists for routine operation, for technical equipment and operational aspects,
- e) manning requirements for competence in accordance with normal and emergency operation checklists and procedures,
- f) detailed job descriptions for all personnel categories involved in the MUO,
- g) SHE activities related to the work-site (if relevant)/diving activities,
- h) individual equipment criticality rating system including overall system accept criteria for use, ref. 7.18.

These procedures shall include minimum requirements in order to commence an operation, criteria for suspension and emergency procedures.

Findings/reports from relevant risk analyses, including resulting risk reducing measures shall be available to operational personnel, see 4.2 and clause 9.

Personnel certification status and qualifications shall be presented in the form of a personnel qualification matrix.

Check lists are part of the operational documentation, and shall be an aid to ensure that the preconditions for initiation, implementation and termination of a safe operation are met. Check lists should have a simple and straightforward lay-out and should cover both normal operations and emergency situations.

Emergency procedures shall be specific to the equipment and work-site. Detailed emergency procedures covering all emergency scenarios shall be available e.g. FMECA. The scenarios shall include provision of medical care for a critically injured/sick diver under pressure.

4.4 Compliance and deviations

The contractor shall prepare in-date compliance measurement matrices with regards to this NORSOK standard and relevant regulatory requirements. The matrices shall be available to the operator. Compliance shall be documented and the contractor shall evaluate all items of non-compliance. Qualified alternative solutions may be suggested, and shall be documented. The compliance matrix shall state the administrative function responsible for handling a non-compliance.

Exemptions from this NORSOK standard shall be evaluated and accepted by the parties involved, including representatives from the diving personnel, their safety delegates and the operator. A risk analysis shall be performed.

Non-compliances to regulatory requirements shall be evaluated by the operator before an application for exemption may be forwarded to the applicable authority.

4.5 Management of change

The procedure for management of change shall include a risk assessment of the proposed change (change to procedures, or modifications to equipment and plant), peer acceptance of the modification (including class approval as required), documented implementation, testing and verification (7.18) after implementation and final close-out. All modifications shall be documented and included in the affected system as-built documentation (4.3). Affected compliance measurements, (4.4), and certificate status, (4.6), shall continuously reflect the current as-built status of the system.

4.6 Certification/verification

Documentation shall be provided to demonstrate that equipment for MUO has been manufactured, function tested and, where relevant, type approved in accordance with the requirements of this NORSOK standard.

The contractor shall document that procedures and equipment critical to SHE, and used in connection with MUOs at any given time, comply with functional and technical requirements in this NORSOK standard.

Prior to commencement of any MUO, the contractor shall ensure that the above documentation, in addition to certificates for the diving system, including all relevant components, auxiliary and emergency equipment,

is issued and valid. Certificates issued shall be specific and identify the equipment they cover. Limiting factors for the above shall be included in the operating instructions. The contractor shall have a system for ensuring that the documentation is kept valid for the duration of the operation.

4.7 Document availability

As a minimum, the contractor shall ensure availability of updated editions of the documentation referred to in Table 1.

Table 1 – Documentation required

Description	Contractor	Work-site
Contractor's project QA manual/plan	X	X
Contractor's SHE plan for the operation/work-site	X	X
Contractor's operational manuals, pertaining to the relevant contract	X	X
Contractor's contingency plan for the relevant contract, interfaced with operator's plan for the relevant concession areas	X	X
Contractor's personnel documentation matrix (including sub-contractors)	X	X
Experience reports from previous, relevant operations.	X	X
All relevant regulations	X	X
All normative references in this NORSOK standard applicable for the operation to be undertaken	X	X
Relevant bibliography references listed in Bibliography in this NORSOK standard or equivalent	X	
Updated crew-lists and shift schedules, including sub-contracted personnel	X	X
Documentation to satisfy 6.3 in this NORSOK standard	X	
Certificates to satisfy 6.3 in this NORSOK standard	X	X
Suppliers instructions for maintenance and operation of all equipment	X	X
Procedures for all activities pertaining to the relevant contract	X	X
All relevant safety notices	X	X
Copies of contracts relating to the operation	X	X
Applicable classification rules	X	X
Copies of any dispensations granted from operator and/or authority requirements, together with documentation for which the dispensation is granted	X	X
Relevant risk analysis	X	X
Logbooks to document operational activities		X
Updated compliance measurement	X	X

4.8 Reporting

4.8.1 General

The diving contractor shall have a system for recording, storage and retention of diver exposure data (8.3). The contractor's reporting of manned underwater activities shall be structured to provide the operator with data to meet regulatory and operator's requirements for reporting.

4.8.2 Contractor's scheduled reporting responsibilities

4.8.2.1 Daily operation

A daily progress report shall include MUO data. Copies of all logs and reports shall be made available to the operator's representative upon request.

4.8.2.2 Experience feedback reporting

Experience gained during operation shall be systematically reported back to the discipline department, where it shall be analysed and evaluated by competent personnel. If required, corrective actions shall be implemented as a result of this process.

4.8.2.3 Monthly activity report

The contractor shall, if relevant, at the end of each calendar month submit to the operator a summary of the previous month's activities, specifying abnormalities, technical and operational problems of relevance to the safety or health of the personnel, and detailing corrective actions taken.

An evaluation of the medical aspects of the operation shall be included. The working environment committee shall have reviewed this evaluation report.

4.8.2.4 Annual/final experience report

Within three weeks after completed demobilisation, or other defined work period (e.g. season), the contractor shall submit to the operator a complete evaluation report, prepared in co-operation with the safety delegates and the responsible diving doctor. All aspects relevant to the applicable regulations, safety, occupational health and technical/operational issues shall be included.

4.8.3 Notification and reporting, accident/near-accident/illness

4.8.3.1 General

The contractor shall have an established system for alert/notification, reporting and investigation of accidents, near-accidents and illness, which satisfies regulatory as well as operator requirements. Equipment failures detected during routine, pre-dive checks (documented in checklists/logs) should be registered as equipment failures (see 4.8.3.6), and are not considered to be near-accidents.

4.8.3.2 Special requirements for MUO under the Norwegian Petroleum Act

During MUO under the Norwegian Petroleum Legislation, special requirements shall be observed. All notification and reporting to Norwegian authorities shall be done by the operator (with the exception of the NAV form). For further guidance on these requirements, see Annex A.

4.8.3.3 Alert/notification

The operator's on board/onsite representative shall be notified immediately of all accidents/illnesses involving first aid or medical treatment and all near-accidents at the work-site (see Annex A), in accordance with the emergency preparedness plan. As a minimum, following details shall be included:

- a) location and time;
- b) details of the incident;
- c) plans for following up the injury/illness;
- d) name of contact person.

For MUO the following additional information shall be included with the alert/notification when relevant:

- e) planned depth;
- f) depth at which the first symptoms occurred;
- g) gas mixture;
- h) purpose of the ongoing operation;
- i) location of personnel;
- j) operational method;
- k) name of persons in the operation management;
- l) wind and wave conditions, visibility, etc.

4.8.3.4 Reporting

Every fatal accident, accidents/illnesses that require first aid and/or medical/hyperbaric treatment and near-accidents (see General 4.8.3.1) shall, without delay, be reported to the operator representative, and subsequently, as required, to the authorities. For MUO, the specialized form in A.3 shall be used. All reporting shall comply with national legislation to preserve anonymity of the individual patient (medical confidentiality).

For MUO the following additional details shall be reported, where relevant:

- a) planned depth;
- b) depth at which the first symptoms occurred;
- c) gas mixture;
- d) purpose of the ongoing operation;
- e) location of personnel;
- f) operational method;
- g) name of persons in the operation management;
- h) wind and wave conditions, visibility, etc.

With respect to injury or illness, the following should be included in the report:

- i) a description of the injury or illness;
- j) the first symptom;
- k) type of first aid;
- l) who administered first aid;
- m) further treatment;
- n) location of the injury or presenting symptoms;
- o) an assessment of contributing causes to the injury or illness.

4.8.3.5 Use of medication

All use of medication shall be logged and reported to the health service.

4.8.3.6 Equipment failure

The contractor shall have an established system for registration/notification and correction of equipment failures.

4.8.3.7 Investigation

Serious accidents and near-accidents shall be investigated in accordance with an established procedure, and the conclusions drawn from this investigation shall be reported to the operator, together with planned measures to prevent reoccurrence. The method used for investigation shall ensure that operational, human, technical and organisational aspects are considered when defining the causes of the occurrence.

The investigation shall take place as soon as possible after the event. The scene of the accident/near-accident shall not be disturbed until all investigations are completed.

The investigation shall be carried out in addition to any investigation implemented by a public authority, or a public appointed accident commission.

5 Health and environment requirements

5.1 Health

5.1.1 General

The diving contractor shall establish, maintain and use procedures which prevent short and long term harmful effects on divers. The diving contractor shall regularly evaluate and update procedures based on empirical data from available sources.

The diving contractor shall establish an occupational health service covering MUO.

5.1.2 Health service

5.1.2.1 Organisation

The health service shall be organized so that it remains professionally and medically independent, and the lines of reporting shall be clear and unambiguous. The health service shall have access to all information necessary to enable it to carry out required tasks.

A responsible competent diving doctor shall be appointed as medically responsible for the health service.

5.1.2.2 Duties

5.1.2.2.1 The health service

The health service is responsible for

- a) the supervision of all health-related aspects in all phases of MUO,
- b) evaluating and accepting diving procedures,
- c) reviewing diving related injuries and illnesses,
- d) promoting safety through involvement in planning of MUO,
- e) advising line management and personnel engaged in MUO on conditions of significance to health,

- f) preparing medical contingency plans,
- g) organising a duty diving doctor service to ensure diving medical treatment in cases of illness or injury,
- h) supervision of all aspects of hygiene during MUO,
- i) establishing a system for provision of adequate nutrition, including adequate fluids,
- j) establishing a system for first aid training of offshore personnel involved in MUO,
- k) short and long term follow up of diver's health.

5.1.2.2.2 The medical contingency plan

The medical contingency plan shall address

- a) handling of all acute medical problems in MUO,
- b) procedures for hyperbaric evacuation,
- c) how to return personnel to surface pressure and give required medical treatment during decompression period,
- d) how qualified medical treatment can be given to personnel under pressure,
- e) how drills are to be carried out in order to handle an accident or a hazardous situation.

5.1.3 Evaluation of medical fitness

Divers shall hold a valid certificate of medical fitness for personnel required to work under increased ambient pressure in accordance with national guidelines (ref. NBH IS-1879, HSE-MA1 or equivalent). The medical practitioner performing the examination shall be approved by national authority. The examination shall be performed in accordance with NBH IS-1879 or HSE-MA1. See also EDTC-FTD ^[1] or Wendling et al. (2004) ^[2] for information. Proof of valid diver medical fitness certificate shall be logged, stamped and signed in the diver's logbook by the issuing medical doctor.

The health service shall establish individual medical files for all divers, containing information on

- a) health status,
- b) previous work experience, including diving exposure data,
- c) illnesses and injuries with relevance to diving.

5.1.4 Short and long term health monitoring

Pre- and post-dive medical checks, in accordance with procedures approved by the responsible diving doctor, shall be conducted routinely for all divers. For saturation divers these checks shall be performed upon entering and surfacing from saturation dives, and for surface oriented divers prior to and after completion of work periods.

Reports from these checks shall be part of the individual follow-up of the divers. A system for monitoring also long term health effects of diving shall be established. The health surveillance system shall provide a strategy for the early detection of adverse health changes related to exposure to hazardous substances or procedures in connection with diving. The general criteria for conducting health surveillance are:

- a) There is an identifiable disease or other identifiable adverse health outcome.
- b) The disease or health effect can be related to exposure.
- c) There is a likelihood that the disease or health effect can occur.
- d) There are valid techniques for detecting indications of the disease or health effects.

The health surveillance system shall be based on a health risk assessments and statutory requirements. The following exposures for divers may dictate health surveillance of organs at risk:

- e) exposure to noise or other inner ear hazards;
- f) exposure to pulmonary hazards;
- g) use of hand-arm vibration tools;
- h) exposure to central nervous system hazards.

Health surveillance techniques should be sensitive, specific, easy to perform and interpret, safe, non-invasive, and acceptable. Examples are hearing test (audiometry), lung function test (spirometry), and questionnaires.

Examinations shall be repeated at regular intervals not exceeding three years. When diving deeper than 180 msw, the divers shall be followed up in accordance with detailed examination as specified in NUI-1994-20 ^[3] or equivalent.

When following up the individual diver's health, diving exposure data is an important parameter. The contractor shall therefore maintain a system to collect and store such data in a manner enhancing a prompt retrieval of each individual diver's exposure data. The contractor shall further contractually require that the individual diver makes available to the health service (in the form of a self-declaration) all diving exposure data, including data from diving taking place outside the confines of employment/appointment with the contractor.

Individual medical data shall be protected, as a minimum, in accordance with national requirements.

5.1.5 Medical contingency

5.1.5.1 General

The contractor shall establish a system for handling medical contingencies in connection with MUO. A duty diving doctor system shall be established for this purpose.

5.1.5.2 Mandatory medical supplies

The contractor shall supply medical equipment and drugs according to applicable national guidelines or e.g. NOROG-073 ^[4]. The responsible diving doctor may deviate from this list if an equal or higher level of medical support/contingency can be assured by other means. Such changes shall be documented.

The contractor shall have a system ensuring that there always is an adequate supply of the following materials:

- a) first aid equipment, with user's manual, if necessary;
- b) medical supplies and medical equipment intended for use during MUO, with user's handbooks;
- c) medical supplies and other material for medical contingency.

The stores shall be checked regularly by competent personnel.

5.1.5.3 Telemedicine

Persons performing advanced first aid shall have priority and unimpeded access to suitable telecommunication with the responsible diving doctor, the duty diving doctor or any other competent personnel as might be required. The saturation system should be equipped with facilities and penetrators to support telemedicine, and monitoring equipment including 12 channel ECG (Electrocardiography).

5.2 Working environment

5.2.1 General

The contractor shall ensure a working environment that, in all respects, enhances the safety and well-being of all personnel. A working environment programme shall describe activities to improve the working environment. This programme shall be reviewed yearly based on findings from, amongst others, working environment mapping and shall involve active participation from the workers. Such participation shall be documented. For information, see relevant clauses in NORSOK S-002 ^[5] or equivalent. Relevant personal protective equipment (PPE) shall be provided for all personnel, including divers in water, chambers, bells, LDC and/or habitats. Relevance is dependent on: scope of work, environmental conditions and risk assessments. PPE used shall be documented to be in accordance with relevant parts of EN 13921 and CEN/TR 15321.

5.2.2 Physical work environment

5.2.2.1 General

The physical environment for divers in water, chambers, bells, LDC and/or habitats, shall be subject to particular and close monitoring, with control of all parameters relevant to the safety and health of the diver.

Methods to achieve optimum conditions shall be implemented by the contractor by actively seeking and evaluating new knowledge.

5.2.2.2 Ergonomics

The design and lay-out of plant and equipment shall aim to reduce negative effects from environmental factors on the users' safety, efficiency or comfort. This may be obtained by the incorporation of ergonomic principles, such as system models, into the design process. For information, see ISO 6385 ^[6].

Mapping of ergonomic conditions in chambers, diving bells, welding habitats, control rooms, and the divers' working conditions, shall be performed initially and repeated following modifications. Mapping shall be initiated and followed up by contractors' health service with input from the users, and performed by competent personnel. Recommended corrective actions shall be evaluated and followed up.

5.2.2.3 Temperature

Thermal control systems for divers in water, in hyperbaric chambers, bells and habitats shall have the capacity and the accuracy to ensure thermal balance and comfort for the divers/occupants during all phases of a normal dive, see 7.7.

In emergency situations, where the divers/occupants cannot be returned to a safe environment, the environmental control systems shall ensure a thermal status within safe limits for the time required to perform the rescue operation, see 7.8.3 and 9.3.

5.2.2.4 Humidity

Environmental control systems for living chambers shall have the capacity to control the relative humidity to between 40 % and 60 % relative humidity at operational depth of the system and with a full complement of divers in the chambers.

5.2.2.5 Lighting

Lighting shall be adequate (see Table 2) for the tasks to be performed, including, but not limited to the chambers, bells (internal and external), habitats, handling systems and at the divers' work site.

It shall be possible to adjust and shade the light to a comfortable level where relevant. Light sources should be positioned so that reflections and glare are avoided.

Table 2 – Recommendations for lighting relevant in areas for safety and well being

Place	Lux
Living chamber, general	100
Living chamber, reading light	300
Transfer chamber	150
Diving bell, general	150
Diving bell, at panels	300
Control rooms, general	300
Control rooms, panels/desk	500

For information, see EN 12464-1 ^[7] and ISO 8995 ^[8].

5.2.2.6 Noise and vibration

The noise exposure shall be as low as practically possible. Personnel exposed to harmful levels of noise (exceeding 83 dB (A)) shall use protective equipment. The use of noise protection equipment shall not reduce the quality of oral communication.

In living chambers and in control rooms during normal operations, noise levels should be in accordance with relevant parts of NORSOK S-002 ^[5]. The levels corrected for depth and gas composition shall not exceed the following values:

Sleeping chambers	60 dB (A)
Living chambers	65 dB (A)
Control room	65 dB (A)
Diving bell	65 dB (A)
Habitats	65 dB (A) (see NOTE)
Diver in water	70 dB (A) (see NOTE)

NOTE This does not include self-induced noise.

Exposure to vibrations should be kept as low as possible, for information see relevant parts of NORSOK S-002 ^[5].

5.2.2.7 Radiation

Use of radioactive sources, ionising and non-ionising radiation shall be kept as low as practicably possible and in accordance with national legislation and applicable guidelines and standards.

5.2.3 Chemical working environment

5.2.3.1 General

The content of breathing gases (O₂ and inert gases) and trace substances (contaminants) shall be kept within acceptable limits.

Sources for contamination and potential hazardous substance shall as far as practically possible be identified, documented and controlled through established programs. Definition of such programs shall involve the health service (5.1.2).

The program shall include risk assessment, in line with relevant recommendations and requirements in EN 14042, EN 482 and EN 689 with references. Because of the special conditions connected to staying and breathing gas under pressure, all general (normobaric) requirements for indoor, ambient and workplace air shall be adhered to. Normobaric OEL values shall be replaced by HELs, see below.

The program should be linked to the short and long term health monitoring (5.1.4) so that any possible health effect can be identified as early as possible and pertinent preventive actions instigated.

The program shall include a system for data systemization and storage, to facilitate experience feedback. This shall also be part of the annual/final experience report (see 4.8.2.4), and made available to the workers and/or their representatives and publically so that other diving contractors can gain from "the lessons learned". Since the total experience from diving in this respect in foreseeable future will be limited, any possible experience and research results that can be useful shall be sought, including in general, environmental, indoor and work atmospheres especially the knowledge from space cabins, submarine and aviation.

In addition to health risk, the flammability risk and explosion hazard shall also be controlled (see 7.6).

About marking of gas cylinders see 7.6.

5.2.3.2 Sources

As a minimum the following sources for contamination of the breathing atmospheres shall be evaluated in a documented and systematic order, including enduring accumulation of data/information:

- a) endogenous production (CO₂, CO, isoprene etc.);
- b) food, drinks, medicines, hygiene, microbiology;
- c) fume, dust, micro particles;
- d) welding, grinding and cutting (material certificates with specification of content shall be available);
- e) other work processes;
- f) produced/natural gas (hydrocarbons, H₂S, Hg etc.);
- g) produced water (benzene etc.);

- h) other contamination of seabed or seawater;
- i) unusual events, emergencies, contingencies.

The contractor shall document a system to ensure that all materials utilised in chambers, bells and breathing circuits etc., do not contain or produce gases or vapours that can be harmful to the divers during normal operational conditions. Prior to introducing new materials, verification shall be performed in accordance with e.g. NUI-1994-05^[9].

5.2.3.3 Monitoring

Any potential hazardous substance should be identified and controlled, following the principles given in EN 14042, EN 482 and EN 689 with references.

As many substances as practical possible shall be analysed on-site, and others in on shore laboratory. The frequency of sampling shall follow the principles given in EN 689. For additional guidance, see NUI-1995-27^[10].

Breathing gases shall be accompanied by an analysis certificate. Certificates should not be accepted as correct until a competent member of the dive team has analysed it for O₂ and CO content, as a minimum. Results for contaminants shall be < 0,1 HEL at actual pressure.

Any new calibration gas should be checked against another calibration gas with similar content, before taken in use, see ISO 6143^[11], ISO 13752^[12], ISO 16664 Annex A^[13], ISO/IEC 17025^[14] and ISO Guide 35^[15].

Gas breathed by diver(s) during normal operation, shall as a minimum continuously be analysed online for O₂ and CO₂ content (8.3.2).

An O₂ analyser with audio and visual hi/low alarm shall be fitted to the diver's downstream gas supply.

When a diver gas reclaim system is used, a CO₂ analyser with audio and visual hi alarm shall be installed into the diver downstream gas supply.

Reclaimed chamber gases shall be analysed for O₂ and CO₂ content and other possible contaminants (including, but not limited to N₂, CO, VOC) prior to their re-use. Results shall be < 0,1 HEL at actual pressure.

If there is danger of contamination of the bell from natural/produced gas, there shall be online indication with alarm of hydrocarbons, Hg and H₂S. For saturation/living compartments there shall be on-site periodic monitoring of at least CO and N₂.

As it is not possible to electronically/chemically monitor for all possible contaminants, the benefits of human sensation by olfactometry (odour, smell) shall be facilitated, by having at least two trained persons from the surface crew, checking the gas of each living compartment at least once a day, according to guidance in EN 13725^[16], ISO 13301^[17].

Contaminated seabed/seawater shall be analysed to document the level of contamination as a basis for minimising the exposure to the contaminants. If the analysis is done at the surface, a sampling technique that allows the gas-tight seabed sampling to be brought to surface maintaining the content of possible contaminants, shall be applied.

Required analysis in habitat when welding: CO, Ar, NO_x (not required if welding atmosphere is documented free of N₂), O₃, fumes and dust (with metal identification).

Required analysis in habitat when grinding: fumes and dust (with metal identification).

As an extra indicator for post-exposure evaluation, biological monitoring shall be used when justified. Exhaled breath, urine, blood, spit, and hair-sampling shall be considered (ref ACGIH^[18]).

5.2.3.4 Gas purification

All living compartments, welding habitat and breathing gas reclaim system shall in addition to O₂, temperature and humidity control, be equipped with gas purification that as a minimum removes CO₂ (e.g. sodalime), CO (e.g. catalyst), VOC (activated charcoal) and odorous compounds (e.g. Sofnofil). For guidance on configuration and practical implementation see SINTEF STF78 F021047^[19].

5.2.3.5 Personal protection

BIBS is the primary personal protection equipment for situations where gas contamination above HELs is suspected in ambient gas. Use of BIBS for this purpose shall not be planned for; it shall be used for contingencies only.

If there is risk for contaminated seabed or seawater, measures shall be taken to ascertain that contamination do not come in contact with the divers' skin, breathing gas or is in any way carried in to the diving system.

5.2.3.6 Hyperbaric exposure limits

5.2.3.6.1 General

Impurities in the breathing gas shall be kept as low as possible, and always below the OELs stipulated in recognised norms, and national regulations. For information, see also relevant parts of NORSOK S-002 ^[5], ACGIH ^[18], NASA-JSC-20584 ^[20] or equivalent.

Normobaric OELs shall be replaced by HELs that take into consideration the special conditions including high pressure, elevated pO₂, long (semi-continuous) exposures and the effects of multiple contaminations (additive/synergistic effects). Generally, norms for contamination in hyperbaric living chambers, HELs (in the unit µbar) are calculated as 1/5 of a recognised 8 h surface norm (e.g. the national OEL) in air (in ppm). When substances are detected where no recognised OEL exist, or where there is reason to believe that the general rule of 1/5 is inadequate, a stipulation shall be justified, documented and be made publicly available. An example for benzene is described in Djurhuus et al. (2011) ^[21].

In the case of substances where a STEL has been indicated, this is applied as maximum concentration over a 15 min period. In the case of substances without STEL or ceiling value, the excess factors of national norms shall be used.

The 8 h upper limit for unspecified welding smoke/dust particles from hyperbaric welding shall be 5 mg/m³.

For the assessment of combination effect of several substances, and of skin absorption, acknowledged methods shall be used.

In the case of the substances CO₂, CO, Ar, N₂ and benzene, exception is made from the general rule of 1/5 of the recognised 8 h surface norm and specific HELs have been set below.

5.2.3.6.2 Oxygen

The pO₂ levels shall be kept at a level as close as possible to 21 kPa (210 mbar), balanced against the diver's need for a higher than normal pO₂. The pO₂ shall not be lower than 20 kPa or higher than 150 kPa.

For medical treatment, a higher pO₂ may be used.

For other exposures of short duration (e.g. bailout) the maximum pO₂ limits may be relaxed according to the following equation, Morrison and Reimers (1982) ^[22].

$$T = 108 \ln 109 \cdot \langle pO_2 \cdot [(DO_2 + D_I) / DO_2]^{0.21} \cdot [Y/2]^{0.35} - 122 \rangle^{-1}$$

where

T = maximal exposure time in minutes

pO₂ = allowable partial pressure of O₂ in kPa

DO₂ = partial density of O₂ in gas mixture

D_I = partial density of inert gas in gas mixture

Y = diver workload measured in oxygen-uptake (l/min STPD)

Based on the formula above and assumptions on maximal endurance times at each workload, Table 3 indicates maximal duration for higher pO₂ at different depths for heliox breathing gas.