

Manned underwater operations

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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 Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.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 standards work and according to established procedures defined in NORSOK A-001.

The NORSOK standards are prepared and published with support by The Norwegian Oil Industry Association (OLF), The Federation of Norwegian Industry, Norwegian Shipowners' Association and The Petroleum Safety Authority Norway.

NORSOK standards are administered and published by Standards Norway.

Annex A and Annex B are informative.

Introduction

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

1 Scope

This NORSOK standard defines basic requirements for personnel, equipment and systems for manned underwater operations within the petroleum industry.

2 Normative and informative references

The following standards include provisions and guidelines which, through reference in this text, constitute provisions and guidelines of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet the requirements of the referenced standards.

2.1 Normative references

ISO 9000 (all parts), Quality management systems –

NORSOK J-003, Marine Operations

NORSOK U-101, Respiratory Equipment - Diving apparatus - Requirements. Testing, marking. Revision 1 edition, 1999.

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- NORSOK U-102, Remotely operated vehicle (ROV) services
- NORSOK S-002, Working Environment
- NS 5814, Krav til risikoanalyser (Requirements for risk analysis) (including Sintef report STF 75 A91021 (ASBN 82-519-0970-8)- Guidance to NS 5814. 1.edition NSF, 1991)
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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

bell run

time between disconnection and reconnection of the diving bell from and to the surface chamber complex when a diving bell is used for transport of divers to and from the work site

3.1.3

can

verbal form used for statements of possibility and capability

3.1.4

competent person

person with authorisation/documentated qualifications for performing a specified function

3.1.5

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

3.1.6**decompression period**

- a) *during saturation diving*: from the start of build-up of the pO₂ in preparation for the final decompression phase, until arrival at atmospheric pressure.
- b) *during surface oriented diving*: From starting final ascent till arrival at surface pressure

3.1.7**diver**

person holding a diving certificate and a valid medical certificate issued by an approved authority

3.1.8**duty diving doctor**

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

3.1.9**diving bell**

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

3.1.10**diving operation**

activity where the diver is directly exposed to increased ambient pressure

3.1.11**diving superintendent**

person who has been appointed in writing by the underwater contractor to be the person in charge of, and responsible for, a manned underwater operation

3.1.12**diving supervisor**

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

3.1.13**diving work-site**

site from which the diving is performed

NOTE Also referred to as diving platform

3.1.14**excursion**

any descent or ascent from pressure at living depth

3.1.15**incident**

generic term covering any undesired event

3.1.16**life support supervisor**

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

3.1.17**life support technician**

person operating a chamber complex with associated equipment

3.1.18**living depth**

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

NOTE Also called "storage depth".

3.1.19

manned underwater operation

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

3.1.20

may

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

3.1.21

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".

3.1.22

operator

oil company, responsible as the obligated party

3.1.23

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

3.1.24

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

3.1.25

stay at working 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

3.1.26

submerged habitat

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

3.1.27

supervisory personnel

personnel on the diving team acting in a supervisory role

NOTE Diving/ADS supervisors, life support supervisors, superintendents, etc.

3.1.28

surface oriented diving

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

3.1.29

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

3.1.30

trainee diving supervisor

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

3.1.31

trainee life support technician

person undergoing a period of planned work experiences for his training to become a life support technician

3.1.32

underwater contractor

diving company or firm undertaking petroleum related manned underwater operations

3.1.33

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 can 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.

3.1.34

wet bell

device with an upper section containing a pocket of breathable gas, and which is used to lower and recover divers to and from work-sites sub sea

3.1.35

working depth

depth of the diver at work

3.2 Abbreviations

ADS	atmospheric diving system
AODC	Association of Offshore Diving Contractors (NOTE Now part of IMCA)
Ar	argon
BA	breathing apparatus
BIBS	built in breathing system
CO ₂	carbon dioxide
DMAC	Diving Medical Advisory Committee
DNV	Det Norske Veritas
DP	dynamic positioning
EDTC	European Diving Technology Committee
HEL	hyperbaric exposure limit
HLB	hyperbaric life boat
HRU	hyperbaric rescue unit (covers hyperbaric rescue vessel and HLB)
HPNS	high pressure nervous syndrome
IMCA	The International Marine Contractors Association (former AODC)
IMO	International Maritime Organisation
kPa	kilopascal
LSP	life support package
LSS	life support supervisor
LST	life support technician
msw	meters of sea water
MRT	modified rhyme test
MUO	manned underwater operations
N ₂	nitrogen
NPD	Norwegian Petroleum Directorate
O ₂	oxygen
OD	Oljedirektoratet (Norwegian Petroleum Directorate)
OLF	Oljeindustriens Landsforening (The Norwegian Oil Industry Association)
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
PSA	Petroleum Safety Authority
QA	quality assurance
ROV	remotely operated vehicle
RTV	Rikstrygdeverket (National Insurance Administration)
SHE	safety, health and environment
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'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/system including, if relevant, the work-site in accordance with ISO 9000 (all parts).

4.2 Documentation

The contractor shall document the diving methods relevant for the scope of work to be conducted under a contract. This documentation shall be based on the contractor's general diving/ADS procedures for MUO and, if relevant, include a description of DP-operations, and be in accordance with [1] and NORSOK J-003.

Management systems and quality assurance shall be implemented in accordance with ISO 9000 (all parts). 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 maintenance, including updating of certificates, covering all diving related equipment, systems and machinery.

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,
- f) detailed job descriptions for all personnel categories involved in the MUO,
- g) SHE activities related to the work-site, if relevant/diving activities.

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 5.3 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. The scenarios shall include provision of medical care for a critically injured/sick diver under pressure.

4.3 Compliance and deviations

An in-date compliance measurement matrix with regards to this NORSOK standard and relevant regulatory requirement shall be available. Compliance shall be documented. 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.

The contractor shall forward all non-compliances to the operator for acceptance. Only non-compliances accepted by operator can be forwarded to the authorities as a deviation request.

Dispensations have to be granted by the parties involved, including representatives from the diving personnel, their safety delegates and the operator. A risk analysis shall be performed.

4.4 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 manned underwater operations 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/ADS, including all relevant components, auxiliary and emergency equipment, are 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.

4.5 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 applicable for the operation to be undertaken	X	X
Relevant informative references listed in 2.2 or equivalent	X	
Updated crew-lists and shift schedules, including sub-contracted personnel	X	X
Documentation to satisfy 6.3	X	
Certificates to satisfy 6.3	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

Description	Contractor	Work-site
Log books to document operational activities		X
Updated compliance measurement	X	X

4.6 Reporting

4.6.1 General

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.

Diver exposure data shall be recorded on an on-line data system that facilitates easy access to individual diver data during the required storage period.

The contractor shall have a system for recording data, which may be used by the operator to generate the required reports and statistics.

4.6.2 Contractor's scheduled reporting responsibilities

4.6.2.1 Daily operation

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

4.6.2.2 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.

4.6.2.3 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.

4.6.2.4 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.

4.6.3 Notification and reporting, accident/near accident/illness

4.6.3.1 General

The contractor shall have an established system for notification, investigation and reporting of accidents, near accidents and illness which satisfies regulatory as well as operator requirements.

4.6.3.2 Notification

In case of an accident or near accident at the work-site, the operator's representative shall be notified immediately, in accordance with the emergency preparedness plan, of the following details:

- location and time;
- name and personal details of any injured persons;
- details of the incident;
- plans for following up the injury;
- name of contact person.

4.6.3.3 Reporting

Every fatal accident, accident, near accident and illness shall be reported as soon as possible to the operator, and as required, to the authorities. Such reporting shall comply with national legislation to preserve anonymity of the individual patient (medical confidentiality).

In addition, during MUO, every incident resulting in first aid, medical or hyperbaric treatment, and near accidents when no person is present in the dive-system shall also be reported.

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

For requirements in operations under the Norwegian Petroleum Legislation, see annex A.

Examples of accidents, near accidents and illness to be reported in a MUO are as follows:

- a) every case of fire in the plant;
- b) unintentional halt in the function of any unit necessary to maintain life and health of personnel working under water;
- c) every form of unconsciousness;
- d) accidental change of ambient pressure;
- e) decompression illness;
- f) gas supply cut-off;
- g) faulty gas mixture;
- h) aborted operation due to illness;
- i) external ear infection.

The report should include information on

- 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:

- a) a description of the injury or illness;
- b) the first symptom;
- c) type of first aid;
- d) who administered first aid;
- e) further treatment;
- f) location of the injury or presenting symptoms;
- g) an assessment of contributing causes to the injury or illness.

4.6.3.4 Equipment failure

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

4.6.3.5 Investigation

Serious accidents and near accidents shall be investigated, 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 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 Safety, health and environment (SHE) requirements

5.1 Health

5.1.1 General

The underwater contractor shall establish, maintain and use procedures which prevent short and long term harmful effects on divers/ADS pilots, see [14]. The underwater contractor shall regularly evaluate and update procedures based on empirical data from available sources.

The underwater 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 diving doctor, shall be appointed as medically responsible for the health service.

5.1.2.2 Duties

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, see [15] and [16],
- 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.

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,
- 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

ADS pilots shall hold a certificate of medical fitness as required by national regulations for offshore workers.

Divers shall hold a certificate of medical fitness for personnel required to work under increased ambient pressure. The medical practitioner performing the examination shall be approved by national authority. The examination shall be performed in accordance with [2] or [3]. See also [17] or [18].

Where an annual medical examination is carried out less than a month before the expiration date of the current medical certificate, the start date of the new certificate may begin from the expiry date of the current certificate.

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 air 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 long and short-term health effects of diving shall be established.

Special attention shall be paid to long term health monitoring of organ systems known to be affected by diving. This shall as a minimum include monitoring of

- a) ear function,
- b) pulmonary function,
- c) nervous system function,
- d) long-bone structure.

Examinations shall be repeated at regular intervals not exceeding three years, using accepted methods.

When diving deeper than 200 msw, the divers shall be followed up in accordance with detailed examination in [19] 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 make 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.

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 contingency medical supplies

The contractor shall supply medical equipment and drugs according to applicable national guidelines or [20]. The responsible diving doctor can 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 a 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 Access to telecommunication

The person 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 may be required.

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. Reference is made to relevant clauses in NORSOK S-002 or equivalent.

5.2.2 Physical work environment

5.2.2.1 General

The physical environment for divers in water, chambers, bells, monobaric craft 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, according to ISO 6385 and [21].

Mapping of ergonomic conditions in chambers, diving bells, 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, habitats and in mono-baric crafts 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 7.8.

In emergency situations, where the divers/occupants cannot be returned to a safe environment, the life support systems shall ensure a thermal status within safe limits for the time required to perform the rescue operation, see 7.8.2 and 9.1.2.

5.2.2.4 Humidity

Life support systems for living chambers and monobaric systems shall have the capacity to control the relative humidity to between 40 % and 60 % relative humidity (RH) at operational depth of the system and with a full complement of divers in the chamber(s).

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 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 reflexes and blinding 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
TUP	150
Diving bell, general	150
Diving bell, at panels	300
Control rooms, general	300
Control rooms, panels/desk	500

For guidance, see EN 12464-1 and ISO/CIE 8995-1.

5.2.2.6 Noise

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 [4] and NORSOK S-002 or equivalent. 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.

5.2.2.7 Radiation

Use of radioactive sources, ionising and non-ionising radiation shall be kept as low as practically possible and in accordance with national legislation and applicable guidelines and standards, see [22], [23] and [24].

5.2.3 Chemical working environment

5.2.3.1 General

When diving in locations where the seabed or seawater may be contaminated, measures shall be taken to ascertain the level of contamination in order to protect the divers from effects of such contamination.

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 may be harmful to the divers during normal operational conditions. Prior to introducing new materials, verification shall be performed in accordance with [25].

To verify that operational practice does not introduce undesired contamination of the atmosphere, the breathing gases in all systems shall be analysed at regular intervals. The level of gases and trace substances shall be kept within acceptable limits. For additional information, see [26].

Impurities in the breathing gas shall be kept as low as possible, and always below the occupational exposure limits (OELs) stipulated in recognised norms, see [5] and NORSOK S-002, and [27] and [28] or equivalent. Generally, norms for contamination in hyperbaric chambers, HELs (in the unit μbar) are stipulated as 1/5 of the recognised 8 h surface norm in air (in ppm).

In the case of substances where [5], NORSOK S-002 and [27], or equivalent, has indicated a STEL, 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 [5] shall be used.

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

For the assessment of the combination effect of several substances, and of skin absorption, see [5].

In the case of the substances CO₂ and CO, exception is made from the general rule of 1/5 of the recognised 8 h surface norm and specific limits have been set in 5.2.3.2 for CO₂ and Table 3 for CO.

5.2.3.2 Carbon dioxide

- a) Exposure > 15 min: maximum 1 kPa (10 mbar)
- b) Exposure < 15 min: maximum 3 kPa (30 mbar)

5.2.3.3 Carbon monoxide

Table 3 - Hyperbaric exposure limits (HELs) for CO

	Duration of exposure	Exposure limits
Breathing gas at work or at rest in bell, chamber, welding habitat etc.	Continuous	1,2 Pa (12 µbar)
	8 h and 12 h	2,0 Pa (20 µbar)
	15 min	5,0 Pa (50 µbar)
Ambient gas when diver is using breathing apparatus		100 Pa (1000 µbar)
Breathing gas in emergency situations	No exposure planned but system to be active for minimum 24 h	5,0 Pa (50 µbar)

5.2.3.4 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.

5.2.3.5 Argon and nitrogen

The presence of Ar and N₂ in the breathing gas produces additive narcotic effects.

Table 4 - Hyperbaric exposure limits (HELs) for argon and nitrogen

	NOT IN SATURATION DECOMPRESSION			DURING SATURATION DECOMPRESSION
	CEILING VALUE	8 HOURS TIME WEIGHTED AVERAGE (TWA)	CONTINUOUS	CONTINUOUS
pN ₂	350 kPa (3,5 bar)		150 kPa (1,5 bar)	80 kPa (0,8 bar) and < 10 %
pAr	150 kPa (1,5 bar)	100 kPa (1,0 bar)	50 kPa (0,5 bar)	1 kPa (10 mbar)
2x pAr + pN ₂	350 kPa (3,5 bar)			

5.3 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, e.g. see [29]

and according to [30] and/or [31]. 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, see NS 5814 or equivalent, e.g. failure mode and effect analysis (FMEA), fault tree analysis, event tree analysis, hazard and operability (HAZOP) studies, hazard identification (HAZID) studies and safe job analysis (SJA).

6 Personnel qualification requirements

6.1 General

Contractor shall provide sufficient personnel to ensure safe and efficient performance of the work.

Personnel engaged in MUOs shall have job descriptions detailing their authorities and responsibilities. They shall be educated in and qualified for, the work they are asked to perform. Qualifications shall be kept up to date and documented. Crews shall be selected to ensure the necessary experience on all levels and within all specialities. All personnel shall be familiar with the installed systems, equipment, tools and diving methods (including gas-mixes) etc. that they are going to use and with the tasks they are going to perform. Required courses and familiarisation programmes shall include emergency procedures, see [34].

Supervisory personnel shall have documented leadership training and be familiar with QA principles. Good leadership and the ability to co-operate and communicate with team members are required. In addition, supervisors and others with responsibility for decisions affecting the working environment, shall have the same or equivalent training as safety delegates and members of the working environment committee.

Personnel going offshore shall have safety training in accordance with the requirements of [33] or equivalent. During all offshore diving operations an authorised nurse shall be present on board.

The qualifications required for personnel listed in this document shall be regarded as minimum requirements. Personnel involved in lifting operations shall have a relevant course in the use of lifting appliances.

An approved diving qualification is not required for personnel providing emergency medical treatment in a chamber.

Operator representative overseeing the diving operations shall have a documented competence on relevant diving methods and their limitations.

6.2 Special requirements for marine personnel on board diving support vessel

Marine personnel on board a diving support vessel shall have sufficient knowledge of diving operations enabling them to understand the relation between their own job performance and the safety of the divers.

This knowledge shall be documented for critical positions such as captain, DP operator, chief engineer, electrician and crane operator.

The duties, responsibilities and authorities of senior personnel shall be described in accordance with ISO 9000 (all parts).

6.3 Requirements for diving personnel

6.3.1 General

Diving supervisors, life support personnel and divers shall, as a minimum be qualified in accordance with EDTC Diving Personnel Competence Standards and shall hold valid certificates recognised by national authority.

Certificates shall be issued based on documented training at qualified schools, where the course syllabus is in accordance with annex B.

The personnel qualification requirements listed below shall be regarded as minimum requirements. If any of the below positions are combined (i.e. if one person covers more than one position), this person shall fulfil the requirements for all positions that he covers.

6.3.2 Diving superintendent

The superintendent shall

- a) comply with the requirements applicable to a diving supervisor with regard to the operation he is responsible for,
- b) have at least 4 years of practical experience as a diving supervisor,
- c) have at least 8 years of practical experience in the diving industry.

Additional requirements are as follows:

- a) minimum two years technical or administrative education, or similar level of career development;
- b) introductory DP-course.

6.3.3 Diving supervisor

6.3.3.1 Diving supervisor, surface oriented diving

Trainee air diving supervisor shall

- a) be a qualified surface oriented diver (does not require valid certificate of medical fitness for divers),
- b) be at least 24 years of age,
- c) have at least two years practical experience as a commercial diver and have carried out at least 100 commercial dives where at least 25 of these dives shall have been carried out from a vessel operating on dynamic positioning,
- d) have undergone a training course at a qualified institution and have completed the final examination for trainee air diving supervisors.

Air diving supervisor shall

- a) comply with the requirements for a trainee diving supervisor,
- b) have at least one work year of practical experience as a trainee air diving supervisor. At least 200 h of this practical experience shall have been served at an air diving control panel,
- c) have carried out at least 200 commercial dives,
- d) have completed a course in advanced first aid and have received management training,
- e) have passed the examination for air diving supervisors.

In addition an introductory DP-course is required, if a DP vessel is directly engaged in the dive operation.

6.3.3.2 Bell diving supervisor

Trainee bell diving supervisor shall

- a) be a qualified bell diver (does not require valid certificate of medical fitness for divers),
- b) be at least 24 years of age,
- c) have at least three years practical experience as a bell diver and have carried out at least 50 commercial dives where at least 25 of these dives shall have been carried out from a vessel operated by dynamic positioning,
- d) have undergone a training course at a qualified institution and have completed the final examination for trainee bell diving supervisors.

Bell diving supervisor shall

- a) comply with the requirements for a trainee bell diving supervisor,
- b) have at least 350 h of practical experience at a bell diving control panel as a trainee bell diving supervisor,
- c) have at least 30 days of practical experience as a trainee LST,
- d) have acted as trainee air diving supervisor during at least 10 surface oriented dives,
- e) have completed a course in advanced first aid in accordance with [6] and have received management training,
- f) have completed the examinations for air diving supervisor and for bell diving supervisor,

- g) have introductory DP-course, if a DP vessel is engaged in the dive operation.

6.3.4 Life support supervisor (LSS)

LSS shall

- a) comply with the requirements applicable to an LST,
- b) have at least 200 days of practical experience as an LST,
- c) have at least 4 years of practical experience from the diving industry,,
- d) have documented knowledge of operation and maintenance of gas supply and monitoring systems and other specialised equipment.

6.3.5 Life support technician (LST)

Trainee LST shall

- a) have undergone a training course at a qualified institution in accordance with minimum requirements, and have completed the final examination,
- b) alternatively be trained as a bell diver.

LST shall

- a) comply with the requirements for a trainee LST,
- b) have at least 200 days of practical experience as a trainee LST,
- c) alternatively, if he is a trained bell diver with a total of 5 years of diving experience and at least 3 years experience as a bell diver, he shall have at least 30 days of practical experience as a trainee LST,
- d) have completed the examination for LSTs,
- e) have completed a course in advanced first aid.

6.3.6 Divers

At any given time, a minimum of 80 % of the divers in saturation shall have undertaken a documented advanced first aid course according to [6]. During operations, minimum two of the divers at each pressure level shall possess this qualification.

6.3.7 Diving technician/maintenance engineer

The diving technician/maintenance engineer shall

- a) have an electrical or mechanical trade education. Both trades shall be covered at a work-site at any given time,
- b) have sufficient documented knowledge of or experience with diving operations/systems enabling them to understand the relation between their own job performance and the safety of the divers.

The diving technician should not have work tasks apart from the diving system witch may involve priority confusion.

6.3.8 Gasman

The gasman shall

- a) have sufficient documented knowledge of, or experience with, diving operations/systems enabling them to understand the relation between their own job performance and the safety of the divers,
- b) be competent and fulfil requirements for bell diver or LST.

The gasman shall not have work tasks apart from the diving system witch may involve priority confusion.

6.3.9 Responsible diving doctor

The responsible diving doctor shall

- a) be approved as responsible diving doctor,
- b) have documented adequate theoretical background in diving medicine,
- c) have documented practical experience in diving medicine corresponding to at least 2 years of work,
- d) have more than 5 years practice after authorisation.

6.3.10 Duty diving doctor

The duty diving doctor shall

- a) have documented adequate theoretical background in diving medicine (minimum 60 h),
- b) be approved as duty diving doctor,
- c) have documented practical experience in diving medicine corresponding to at least 1 years of work,

- d) have more than 3 years practice after authorisation,
- e) be medically fit to work under increased ambient pressure.

6.3.11 Nurse

The nurse shall

- a) have documented training in emergency and hyperbaric medicine, including diagnosis and treatment of injuries and illness related to diving,
- b) be medically fit to work under increased ambient pressure,
- c) have competence in occupational hygiene related to diving,
- d) have minimum 2 years experience in handling medical emergencies, or 1-year experience in handling medical emergencies and 1 year experience in occupational health.

6.3.12 Atmospheric diving system (ADS) supervisor

The ADS supervisor shall

- a) be a certified diving supervisor,
- b) have a minimum of 3 years of experience as a diving supervisor,
- c) have an advanced first aid certificate from an approved source.

An advanced first aid certificate is not required for assistant ADS supervisor.

6.3.13 Atmospheric diving system (ADS) operator/pilot

The ADS operator/pilot shall

- a) have a course in ADS piloting on the relevant equipment,
- b) have courses in use of tools to be utilised.

6.3.14 Atmospheric diving system (ADS) handling equipment operator

The ADS handling equipment operator shall

- a) be fully conversant with all operational, emergency and contingency procedures,
- b) have a formal course in the operation of the actual handling system supervised or generated by the manufacturer of the handling system.

6.3.15 Atmospheric diving system (ADS) technician

The ADS technician shall

- a) have technical trade education in electrical and/or mechanical field,
- b) have formal courses in operation and maintenance of all systems comprising the ADS, and associated systems and tools, supervised or generated by the manufacturer of the systems,
- c) have knowledge of verification and certification of systems and the associated test procedures.

7 Technical requirements

7.1 General

Plant and equipment used in MUO shall be designed, constructed, tested (see [35] and [36]), and maintained in compliance with current regulatory requirements and normative references. It shall be certified by a recognised classifying society according to [7] or [8]. Auxiliary equipment, only covered by DNV's certification rules (i.e. HRUs etc.), shall be verified to meet requirements in [37] and [7]. The design shall ensure efficient integration between the users and all parts of the plant and equipment, according to anthropometric dimensions and other human factor aspects in accordance with ISO 6385.

Further it is a prerequisite that the plant is in compliance with requirements laid down in [1], [4], [9], [10], [38] and [30]. If obvious safety advantages can be achieved through the use of new technology, provisions should be made for this.

Diving systems shall be designed to give early warning of abnormal conditions with significance to safety. When a warning is given it shall be possible to make corrective actions before an emergency situation occur.

All use of electricity in diving operations shall comply with [11] and [24].

Safety related equipment, not covered by the rules of a classification society, shall be certified/controlled and/or verified to a standard compatible with national regulations. The certification/verification process shall be documented.

If planned MUO exceeds limits of existing plant, equipment and procedures, resulting in the use of new technology and/or procedures, the contractor shall prepare a plan for the development, testing and introduction of such new technology/procedures.

Change out of components critical to the pressure integrity of the system shall be performed in accordance with detailed procedures ensuring that the pressure integrity of the system is maintained.

7.2 Dimensions and lay-outs

7.2.1 Chambers

Interior design, decor and colours should be carefully selected to promote safety, efficiency and comfort for the users.

Chamber complex size, architecture, lighting and lay-out shall support and optimise all the functions planned to take place in the chambers for the maximum number of occupants. It shall be possible to bring personnel, equipment and provisions into and out of the chamber complex.

Each section of a chamber complex used in MUO shall have or be connected to a primary and a secondary environmental control facility maintaining correct and uniform atmosphere. This does not apply to smaller locks where personnel are not staying for any length of time, i.e. passing through.

Each pressure compartment where divers may be staying shall be provided with one BIBS for each occupant plus one spare. It shall be possible to lead the exhaled BIBS gases out of the chamber.

It shall be possible to close all pipe penetrations both internally and externally as close as practically to the chamber wall.

7.2.2 Saturation chambers

The saturation chamber complex shall

- a) have toilet facilities, shower and wash basin at each living depth,
- b) be designed for simplicity of cleaning,
- c) allow divers to be evacuated,
- d) allow divers undisturbed rest periods.

Inner height of the chambers shall be no less than 200 cm over the deck plates (measured in the middle of the chamber).

The inner volume shall be at least 4 m³ per diver. The specified volume shall be usable, i.e. apportioned where there is normally sufficient space and height for the occupants. The distribution of the specified minimum volumes between living, sleeping and TUP compartments shall meet the requirements for normal personal comfort.

Chambers used as living and sleeping accommodation shall be equipped with seating and individual bunks for the number of divers who are to make use of this part of the chamber complex. The dimensions of a bunk should be minimum 200 cm x 70 cm.

Permanently installed equipment shall be of non-flammable materials. In general, flammable materials shall be kept at a minimum inside the chamber, i.e. loose items such as newspapers etc.

7.2.3 Surface oriented diving chambers

During surface oriented diving operations a double-lock decompression chamber shall always be available at the work-site.

When surface oriented diving operations with decompression stops are planned, the inside diameter of the chamber shall be at least 180 cm. This also applies where a surface oriented diving spread is standby during saturation diving.

Where no decompression stops are planned, the chamber may have an inside diameter of minimum 160 cm. The length of the chamber shall be minimum 200 cm. It shall be possible for the occupants to lie down in the chamber.

7.2.4 Diving bell

7.2.4.1 Diving bell ergonomics

The diving bell, including all assemblies, components and equipment shall be designed to support the divers in their operational functions inside and outside the bell, e.g. [40]. Principles of ergonomics shall be duly taken into account with regard to the location of equipment in the diving bell.

Diving bells intended for two divers shall have an inside volume of at least 4,5 m³. Diving bells intended for more than two divers shall have an extra inner volume of 1,5 m³ per diver in excess of two. A reduction in the volume requirement may be acceptable in cases where the bell ergonomics have been significantly improved, e.g. by storing divers' umbilicals outside of the bell. The specified volume should be usable, i.e. apportioned around what is normally within the height required for a diver to stand up. The bottom trunk for entry into and exit from the diving bell shall have an inner diameter of minimum 80 cm.

It shall be possible to close all pipe penetrations both internally and externally. Diving bell trunks shall either be equipped with internal and external doors or a double acting door.

The diving bell shall be adequately equipped for the bell-man to bring an unconscious or injured diver into the bell and to a position where first aid can be administered.

7.2.4.2 Diving bell supply

The diving bell shall contain equipment that will ensure that vital functions are maintained in situations when the primary supply is not available. These functions shall be maintained until the situation has been brought under control, e.g. [41] and NS 5814. The functioning time shall be at least 24 h.

Diving bells shall have onboard gas supply for use in emergency situations. The minimum capacity shall be 1250 usable litres of breathing gas for each diver, calculated at ambient pressure (equals 20 min at a breathing rate of 62,5 l/min).

7.2.4.3 Emergency connectors for diving bells, habitats and HRUs

An emergency connector panel shall be provided in accordance with IMO requirements (see [9]) and with OLF requirements as given in Table 5.

Table 5 – Emergency connectors

Item	Diver operable (IMO)	Diver and ROV operable (OLF)
Breathing gas	1/2" NPT Female	1/2" Male Snaptite SVHN-8
Hot water/heating	3/4" NPT Female	3/4" Male Snaptite SVHN-12
Depth	1/4" NPT Female	1/4" Male Snaptite SVHN-4
Communication	8-contact-4-pins-EO connector (Contacts 1 and 2 used, others n.c.)	8-contact-4-pins-EO-connector (Contacts 1 and 2 used, others n.c.)
Emergency power	4-contact-4-pins-EO-connector (Pin1:24V, pin2:0V, pin3:ground, pin4:n.c.)	4-contact-4-pins-EO-connector (Pin1:24V, pin2:0V, pin3:ground, pin4:n.c.)
O ₂ (HRU only)	3/4" NPT Female	3/4" Male Snaptite SVHN-12
Key: EO: "Electro Oceanics"- trade mark - underwater electrical connector n.c. : not connected NPT: National (standard) Pipe Tapered (threads) Snaptite SVHN: trade mark and type designation		

7.2.5 Locking mechanisms

Any pressurised compartment, container or other equipment under pressure, where opening may be dangerous to personnel, shall be physically secured to prevent unintentional pressure drop and/or injury to personnel, i.e. equipped with an interlock. Locking mechanisms shall be designed so that pressure cannot be applied unless the locking device is in the correct position. The internal pressure shall directly control the interlocking mechanism, preventing unintentional opening unless the pressure is at ambient level.

7.2.6 Wet bell and diving basket

Wet bells and diving baskets shall be of adequate size, be equipped for the number of divers intended to man them and for handling of unconscious and/or injured divers, e.g. [43].

Wet bells and diving baskets shall be designed to prevent the diver from falling out and to avoid rotation and tilting. The basket should be equipped with suitable overhead protection and handholds.

Wet bells and diving baskets shall have an on-board gas supply for emergency situations. The minimum gas capacity shall be calculated as for diving bells.

A wet bell shall contain equipment to monitor the following parameters:

- depth;
- pressure of gas supplied from surface;
- pressure of on-board emergency gas supply.

7.2.7 Atmospheric diving system (ADS)

The ADS shall be designed, fabricated and tested in accordance with relevant standards. This shall be documented through certificates from a recognised classification society, see [8]. Corrosion protection shall be provided. Materials, equipment and clothing used inside the ADS shall be flame retardant.

The ADS locking mechanism shall be designed to prevent accidental opening in any situation, including contact with external objects or forces, with maximum possible over-pressure inside the suit. The ADS shall be equipped with a pressure relief system ensuring that the absolute pressure build-up inside the suit cannot become significantly higher than 100 kPa (1 bar). All penetrations of the hull shall be equipped with shut-off valves where it is practically possible.

The emergency facility of the ADS shall be capable of maintaining vital functions for 48 h.

7.2.8 Submerged habitat

The habitat shall provide a dry and safe working area for the divers, be equipped with an adequate number of breathing masks (see 7.2.1) and include a non-contaminated compartment.

Habitats shall be designed to make complete, accidental flooding impossible, leaving sufficient gas volume to allow personnel to dress into survival equipment and to allow personal occupancy in an emergency situation.

It shall be possible to close all pipe penetrations both internally and externally.

Habitats shall be equipped to maintain vital functions for a minimum of 48 h when primary supplies are not available. It shall have an outside panel for emergency connections including gas, heat and communication. Connectors shall be in accordance with 7.2.4.3.

It shall be possible to rescue personnel from a submerged habitat even if the normal access cannot be used. Entrances/exits shall be clearly marked in order to allow easy identification.

7.2.9 Control rooms

Control rooms shall be designed in accordance with accepted ergonomic principles, see NORSOK S-002, ISO 6385, [44] and EN 12464-1 and ISO/CIE 8995-1.

It shall be possible to carry out work and to communicate effectively even if there is no normal breathable atmosphere in the room. Dangerous quantities of gas from chamber or gas plant shall not be released into the control room(s).

7.3 Handling systems (diving bell, wet bell, basket and ADS)

7.3.1 General

The handling system for diving bells shall include means of safe guidance through the surface of the water, such as a moon-pool cursor or a bell cursor tower system.

The design load for the facility shall be calculated on the basis of maximum static and dynamic loads under specified maximum operational limits. The design load shall be at least twice the maximum static load.

The safe workload of the main lifting wire shall be calculated using a minimum safety factor of 4,0 related to the maximum design load. Both static and dynamic loads shall be taken into consideration.

In the case of cross hauling, such equipment shall fulfil the same requirements for strength as the rest of the handling system.

The handling facility shall be secured against uncontrolled pay-out as a result of technical failure, i.e. equipped with automatically applied mechanical breaking devices providing primary and secondary protection. The facility shall also be equipped with limit switches preventing the handling of the bell/wet bell/basket/ADS outside defined limits.

Main bell umbilical- and bell handling systems shall be compatible.

Bell and guide-wire winches used for dry transfer into a habitat shall include a heave compensation/constant tension system.

Where direct visual monitoring of the winch drums from the winch control station is not practical, television monitoring shall be fitted.

Adequate primary and emergency lighting shall be provided in all critical handling areas. Records shall be maintained of umbilical and wire cut-backs, re-termination, end-for-ending and replacements.

The main handling facility shall be operable even if essential components such as a power source or a winch motor are out of action.

In event of main handling facility break down, an alternative handling system shall be ready for immediate use. This system shall have the capacity to recover the bell back to mating position and wet bell, basket and ADS back to deck. The alternative handling system shall comply with the same requirements for load strength as the main handling system.

Guide wire equipment shall ensure a controlled movement of the device in the water and should also provide an arrangement for stopping the device in the event of failure in the primary lifting wire.

7.3.2 Special requirements for ADS handling systems

The ADS shall be locked to a device ensuring safe and quick transit through the surface of the water during both launch and recovery.

This device shall comprise a tether management system designed to enable the ADS to leave and re-enter the device in a safe manner. The tether management system shall have a positive locking system, and shall be operable independent of the ADS pilot.

If operated from a vessel, the handling system shall be equipped with a heave compensation system. Static and dynamic calculations demonstrating the performance of the system shall be available.

7.4 Hyperbaric rescue unit (HRU)

Saturation diving systems shall be equipped to enable adequate evacuation of the divers under pressure. Evacuation shall be possible also in cases of loss of main power on the diving vessel/system. The HRU shall be constructed to withstand loads incurred during launch and shall be equipped for safe and efficient recovery. HRUs shall be equipped with lifting/towing arrangements for rescue, and shall comply with [44] and [45]. Operational procedures for HRUs shall contain information on limitations in connection with launching, towing and recovery operations for different weather conditions, see [9].

Control and monitoring of the HRU's pressure chamber shall be performed from the outside of the chamber, and it shall be possible to lock material in and out of the chamber. While connected to the saturation chamber complex, control and monitoring of HRU's pressure chamber shall be performed from the saturation system control room.

HRUs shall be equipped to maintain an acceptable environment for a minimum of 72 h, both for the chamber occupants and for the support personnel on the outside of the chamber. It shall be possible to maintain vital functions even if the main power unit of the HRU is out of function.

If the HRU is a HLB, it shall be equipped with a propulsion unit capable of functioning for a minimum of 72 h. The effect of the propulsion unit shall be sufficient for proper manoeuvring of the HLB, taken into account its mass and size when fully equipped and manned. Equipment to enable communication with other vessels shall be available, e.g. a two-way marine very high frequency (VHF) radio.

The evacuation unit shall be equipped with an easily accessible panel for connection of supplies, monitoring and control functions between the HRU pressure chamber and an external control and supply source. The panel shall be in accordance with the norm for emergency panels on diving bells, with the addition of a connection for pure oxygen supply, see 7.2.4.3.

In a case where the support personnel must leave the HRU, arrangements shall be made to ensure that the chamber occupants can take control.

The HRU shall be marked according to [45].

7.5 Emergency life support package (LSP)

An emergency LSP, facilitating external supply, monitoring and control of the HRU's pressure chamber shall be available at a convenient location. Proper maintenance of the LSP shall be performed to ensure that it is ready for use at any time during a saturation diving operation. Compatibility between the LSP and the receiving panel on the HRU shall be verified through physical testing of all functions.

Arrangements shall be in place for the mobilisation of the LSP onboard a suitable rescue vessel capable of reaching the HRU within a reasonable time.

Procedures for use of the LSP shall be included in the vessel/systems contingency plan and shall be available both at the LSP and inside the HRU.

Emergency procedures shall be available inside the pressure chamber of the HRU, inside the unit itself and at the LSP, see [9].

7.6 Gas supply systems

The gas supply installation shall ensure correct and adequate gas supply during normal operation and in an emergency situation. The installation shall have

- a) at least two independent sources of supply to the diving bell/habitat,
- b) gas supplies to divers which should be arranged so that interruption of supplies to one diver will not affect other divers' supplies,
- c) two independent sources of gas supply to each section of a chamber complex where divers may be staying (all sections that may be isolated by pressure).

The installation shall be marked according to [12] and [46]. Each colour shall be as defined in the table on page 2 in ISO 32. The marking shall indicate the type of gas and its flow direction.

Where Ar is in use, the gas cylinder shall be coloured grey with dark green shoulder. Where working air (not for breathing purposes) is in use, the gas cylinder shall be coloured bright green.

All gas cylinders shall be clearly marked with type of gas contained in writing.

Gas cylinders, quads or piping containing a pressure in excess of 20 MPa (200 bar) shall be specially marked at the outlet connection point and at control panel connection points.

Two independent gas supplies are required to the panel supplying the main umbilical. One supply shall be dedicated for emergency. It shall be activated if the downstream gas analyser to the diver gives an alarm signal and/or the supply pressure drops below set values. The pre-set pressure on the emergency gas supply shall be lower than the main supply.

The bell-man shall have easy access to operate the gas panel in the diving bell. No more than two operations should be required to activate the spare onboard gas supply.

If leakage into enclosed spaces could produce a hazardous atmosphere, equipment giving necessary warning of such conditions shall be installed.

O₂ and gases representing a fire or explosion hazard shall be stored in a suitable place. The pressure in supply pipelines from the place of storage shall be as low as possible. The routing of such gas lines shall be given special attention, regarding the effects of leakages. Mixtures of gas where O₂ represents more than 25 % shall be treated as pure O₂ with regard to fire and explosion hazard.

Suitable materials and components shall be used for transportation of the appropriate gas mixtures at the relevant pressures. Use of flexible hoses shall be reduced to a minimum.

Inert gases used in support of diving operations shall contain a minimum O₂ content of 2 % unless special arrangements have been made to prevent that pure inert gases can be fed to the breathing gas lines.

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 as a minimum for oxygen content.

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

Where a diver gas reclaim system is used, a CO₂ analyser with audio and visual hi alarm shall be installed into the diver down-stream gas supply.

Water traps for gas reclaim shall be designed for simplicity of cleaning, disinfecting and drying, to prevent microbiological contamination.

Reclaimed chamber gases shall be analysed for O₂ and possible contaminants prior to their re-use.

7.7 Atmospheric diving system (ADS) life support systems

7.7.1 Oxygen system

The O₂ reservoir shall contain enough O₂ to sustain the life of the pilot for at least 54 h. The reservoir shall be arranged so that the accidental emptying of one of the bottles into the suit does not raise the internal percentage of O₂ in the suit to a level that is hazardous to the pilot.

The O₂ pressure shall be reduced at the reservoir, to a pressure that is high enough to ensure efficient mixing, but low enough to ensure against the dangers of high-pressure O₂. No high-pressure O₂ shall enter the pressure hull.

An automatic O₂ injection system shall be installed, which injects O₂ in the right amount relative to the actual O₂ consumption of the pilot.

A manual override shall be installed on the O₂ injection system, enabling the pilot to control the O₂ content of the suit.

7.7.2 Carbon dioxide scrubbing

The CO₂ scrubbers shall be designed so as to ensure effective scrubbing of the gas in the entire suit.

They shall contain enough scrubbing material to keep the CO₂ partial pressure in the suit within acceptable levels for 54 h.

The electric motors and the scrubber fan assembly shall be designed so as to prevent sparks from occurring.

7.7.3 Other gases

The atmosphere during the 54 h survival period shall be documented to be within accepted HELs with regard to other gases according to [5] and [27] or equivalent.

7.8 Systems for thermal balance

7.8.1 General

Facilities for MUO shall be equipped to maintain thermal balance of the divers, so that functional capability is maintained within safe limits. For surface orientated diving and ADS operations where active heating may not be available, it shall be possible to compensate for this and ensure that divers working in water maintain the correct thermal balance.

7.8.2 Normal operation

The environmental control system of chambers, bells and habitats shall have the capacity to control temperature variations during compression and decompression, and to maintain any selected temperature between 22 °C to 33 °C at relevant operational depths. The temperature control for divers in the water and the atmosphere of chambers, bells and habitats shall be sufficiently accurate to ensure thermal balance and comfort for the divers/occupants at all times.

The environmental control system for ADS shall have the capacity to maintain the internal temperature of the ADS at a comfortable level for any physical activity of the pilot(s). The comfort temperature shall be maintained independent of surrounding water temperature.

Actively heated suits shall be used whenever necessary to maintain thermal balance, comfort and efficiency.

Diver primary breathing systems shall be equipped for heating the divers breathing gas when diving deeper than 150 msw. The gas temperature shall be adjustable.

The actively heated suits shall have a thermal control system preventing local burns or local cooling.

7.8.3 Emergency systems

A survival system for diving bells and habitats shall be installed in accordance with [47]. It shall have the capacity to maintain safe thermal condition. The survival system shall ensure the occupants' ability to

participate in the rescue operation. The minimum capacity of these systems shall be in accordance with 9.1.2.

The effectiveness of the ADS survival equipment shall be such that thermal balance, or at least a non-critical thermal situation, is ensured for a minimum of the planned operation time plus 48 h.

7.9 Breathing apparatus (BA)

7.9.1 General

The BA, including bail-out system, stand-by diver system, welders' masks and BIBS, shall fulfil the requirements and recommendations of NORSOK U-101 and e.g. [48].

BA shall have individual documentation providing information on the history and the status of the equipment.

Microbiological sampling/control of BA shall be performed on regular basis.

7.9.2 Stand-by diver system

The stand-by diver's BA shall be designed to allow the diver to dress and enter the water without assistance within 1 min.

The stand-by diver's BA shall have adequate quantity of breathing gas from a dedicated source, see 7.2.4.2. The stand-by diver's BA gas supply shall be independent of the diver's gas supply.

7.9.3 Bail-out system

The bail-out system shall be ergonomically adapted to the primary system, and it shall be possible to activate with no more than two operations. When a diving bell is used, the bail-out system shall be designed to ensure easy entrance.

The bail-out system should in general have sufficient capacity to allow the diver to reach a place of safety. As a minimum the bail-out system shall provide the diver with gas for 10 min based on an average consumption of 62,5 l/min, correlated to the ambient pressure.

7.9.4 Welding mask

The design of the welder's mask shall ensure that atmospheric contaminants within the habitat do not penetrate into the welder's respiratory system, i.e. over-pressure in the mask. The welding mask shall be designed in accordance with ergonomic principles.

7.10 Diver/atmospheric diving system (ADS) umbilical

The umbilical shall

- a) ensure necessary supplies to the diver,
- b) provide necessary transmission of communication,
- c) be of sufficient strength to ensure intact vital functions during emergency recovery.

The divers' umbilical shall in addition be marked as follows:

- 5 m: Red ring around the umbilical
- 10 m: Black ring around the umbilical
- 50 m: Wide black ring around the umbilical (i.e. 15 m are marked with 1 red and 1 black, and
- 45 m are marked with 1 red and 4 black).

Supply and communication lines shall not be subjected to loads which may cause failure during operations.

7.11 Tools

No tools shall be used that can cause harm to the user under predictable conditions, provided that proper procedures are followed for operation and maintenance.

Weight and buoyancy of diver hand-held tools shall be adjusted to ensure efficient handling.

All power tools shall have control systems that automatically isolate or divert the power, when the diver releases the operator handle, and the control room shall have the possibility to de-activate the energy source.

Detailed procedures for the operation of any underwater tools, with emphasis on the safe operation of the equipment, shall be available. It shall be possible to carry out function tests of the underwater tools on deck or in shallow water.

7.12 Diving support vessel

7.12.1 General

The diving support vessel shall be classified by a recognised classification society for vessels (see [7] or [8]), and conform to NORSOK J-003.

7.12.2 Diving from small craft

7.12.2.1 The diving craft

The diving craft shall comply with relevant parts of [49] and [50].

7.12.2.2 The support vessel

The support vessel for small craft diving operations shall be equipped with facilities for providing efficient assistance to the craft as required in see [49]. The support vessel shall have a man riding lifting device to recover injured personnel. If the support vessel is an active part of the diving operation (i.e. used as mooring etc.), it shall conform to NORSOK J-003.

7.13 Monitoring and control panels

Control and monitoring panels shall be designed in accordance with ISO 6385.

Controls and panels shall allow efficient supervision of the operations.

Parameters being monitored shall be displayed with appropriate units and a suitable scale. Standard metric units shall be used.

All instrumentation shall allow easy viewing and shall be clearly identified and labelled in English and other relevant language as required.

7.14 Communication system

Communication shall be provided between divers in water/bell/habitat and chambers and their supervisor. The supervisors shall have the possibility to control all communication to and from the divers under their supervision.

Two independent main systems shall be installed for efficient communication between surface personnel engaged in MUO and the dive operation control room.

Two independent systems for communication between divers and dive control shall also be provided. This facility shall be independent of the main communication systems.

The above requirements for two independent systems do not apply to the communication links in divers' umbilical.

In addition to hardwired communication lines between the surface and personnel positioned in water (e.g. diving bell, submerged habitat, ADS), equipment shall be provided based on wireless communication ("through-water-communication").

The communication system shall provide the possibility for relevant personnel to call the attention of dive control.

The communication system for divers in both water and hyperbaric chambers shall be tested for intelligibility under as realistic operational conditions as possible. A MRT shall be used to verify that the requirements for operational communication systems are in accordance with Table 6.

Means for processing of speech (unscrambling) shall be available when using helium mixtures and used when required. These requirements apply to verbal communication from diver's helmets, bells, chambers, habitats and between divers in water. Communication other than verbal may be acceptable for emergency communication, provided sufficient quality can be achieved.

Table 6 - Intelligibility criteria for voice communication systems (from [51])

Communication requirement	MRT Score
Exceptionally high intelligibility; separate syllables understood.	97 %
Normally acceptable intelligibility; about 98 % of sentences correctly heard; single digits understood.	91 %
Minimally acceptable intelligibility; limited standardized phrases understood; about 90 % sentences correctly heard (not acceptable for operational equipment).	75 %

Switching of communication channels shall be possible so that all persons who need to communicate have the possibility to do this uninterrupted and independent of other communication channels. The panel containing the communication system shall be arranged in a logical and ergonomic manner. A traffic flow matrix of the system shall be documented and available on board.

7.15 Fire protection

Facilities for MUO shall have fire detection and fire fighting equipment covering the entire plant both internally and externally. The equipment shall have adequate capacity to put out fires that may occur. There shall be facilities to control the temperature in the chamber complex during an external fire. The above includes the HRUs and the HRU launch areas.

7.16 Remotely operated vehicle (ROV) system used in conjunction with manned underwater operations (MUO)

ROVs used in connection with MUO shall conform to NORSOK U-102.

7.17 Water supply

The fresh water supply system (potable water) should be designed to tolerate weak acidification of the water.

Potable water should be exposed to UV radiation. This requires extra filters installed prior to the UV-radiation source.

A specific and customised microbiological examination of the fresh water supply to saturation chambers, shall be performed prior to initial pressurisation of the system. Systematic microbiological testing for coliform and other relevant bacteria, shall be performed of the fresh water, e.g. see [52]. Specific and customised microbiological examination of hot water to suits prior to saturation operations shall be performed. Seawater to the divers hot water supply shall be disinfected to minimise skin infections. The filtered seawater should either be heated to 90 °C to 100 °C, or exposed to UV-radiation.

7.18 Maintenance

Facilities and equipment for MUO shall be maintained in accordance with a planned maintenance programme. This programme shall be based on design, construction and operation. Test conditions for components and the facility in general, shall be specified.

The maintenance programme should describe necessary maintenance and planned testing of single components or entire plants, and shall be based on manufacturer's recommendations and the contractor's experience of component wear and tear. The maintenance programme shall seek to avoid unforeseen equipment malfunction through routine checking and replacement of components.

Maintenance records shall be kept in accordance with national legislation or minimum 2 years.

Critical equipment being maintained and/or repaired on board shall be tested and verified to meet requirements (e.g. from classification societies) after maintenance/repair has been carried out and prior to use.

Modifications to the system, part systems or components, shall be executed in accordance with a modification procedure. The procedure shall include acceptance of the modification. All modifications shall be documented and included in the as-built documentation.

7.19 Testing and verification

Components and facilities for MUO shall be tested during fabrication and operation in accordance with the recognised standards to which the facility has been designed.

Functional tests shall be carried out on all components that are used or that may be used during normal operation and in emergency situations.

Vital functions shall be checked immediately prior to the commencement of the operation, as well as during the actual operation.

If visual inspection discloses conditions that may reduce the quality of the facility, further investigation shall be carried out. Measures shall be taken in order to ensure adequate quality of the facility.

In the event of failure during operation, the component and the plant in question shall be functionally tested after repair. Also following modifications, necessary testing shall be performed to verify the proper function of the system.

For intervals and detailed methods of testing, see [35], [36] and [48].

When new equipment is developed for MUO, tests shall provide the basis for the evaluation as to whether the equipment shall be deemed safe for use in operations.

8 Operational requirements

8.1 Planning and execution

8.1.1 General requirements

Operations shall be carried out in accordance with procedures as specified in Clause 4.

During MUOs all relevant data shall be recorded.

8.1.2 Responsibilities

8.1.2.1 Management on installations and vessels

It shall be ensured that other activities will not endanger those who are engaged in the MUO. Furthermore it shall be ensured that information concerning matters that may affect safety is passed on to the operation management and to the shift management.

The vessel master (captain)/installation manager has the overall responsibility for the safety of all personnel on the work-site.

The chief engineer has the overall responsibility for the technical status of all plant and equipment integrated in the vessel/installation.

The electrician at the work-site shall be considered the overall electrical co-ordinator. In this function he is entitled to request documentation that all electrical equipment brought on board, is properly certified and maintained, and that all personnel working on electrical circuits are properly qualified.

8.1.2.2 Operation management

In operations with more than one shift per day, a dedicated superintendent in addition to the supervisors shall manage the operation.

In operations with only one shift, the shift supervisor may assume the duties of the operation management.

The operation management shall be responsible for the implementation of the MUO, and may, in consultation with and with the consent of the shift management, commence an operation. All participants have the right and the duty to suspend operations in the event that the activities are not conducted in a safe manner.

The diving/ADS superintendent has the overall responsibility to ensure that the activities are carried out in accordance with current laws, regulations and applicable procedures. It is the superintendent's responsibility to ensure that all personnel are qualified and familiar with current laws, regulations, procedures and equipment applicable to the operation.

8.1.2.3 Shift management

Shift management is carried out by the diving supervisor. The diving supervisor shall have the responsibility for the safe conduct of diving on his shift.

A MUO may only be commenced if the diving supervisor agrees. The diving supervisor is responsible to ensure that the necessary equipment is available and that laws, regulations and procedures are complied with.

8.1.2.4 Operation management of chamber complex

The LSS shall be responsible for the safe and proper operation of the chamber complex.

8.1.2.5 Working environment committee

The contractor shall have a working environment committee system for the diving activity. The system shall comply with acts and regulations.

The working environment committee members shall receive the necessary training to perform their duties in a satisfactory manner. Time shall be allocated so that the members can perform their duties satisfactorily, preferably within their working period.

The working environment committee shall focus on items relating to safety and working environment. Reported accidents and near misses shall be evaluated. The working environment committee shall have an advisory function and shall recommend necessary preventive measures.

If the working environment committee members are unable to reach an agreement, the various views shall be recorded and resulting decisions taken at management level. The members shall sign the minutes of meetings, and a copy shall be supplied to the operator's representative.

8.1.2.6 Personnel subject to hyperbaric conditions or work under water

The divers and pilots of ADS shall keep a personal logbook and hold this in safekeeping. The line management shall verify the logbook.

The diver's log book shall contain the following:

- a) name and signature of the diver;
- b) name and address of the underwater contractor;
- c) date to which entry relates;
- d) location of the diving operation, including the name of any vessel or installation from which diving is taking place;
- e) the maximum depth reached on each occasion;
- f) the time the diver left the surface, the bottom time, and the time the diver reached the surface on each occasion;
- g) where the dive includes time spent in a compression chamber, details of any time spent outside the chamber at a different pressure;
- h) breathing apparatus and breathing mixture used by the diver;
- i) any decompression schedules followed by the diver on each occasion;
- j) any work done by the diver on each occasion, and the plant (including any tools) used in that work;

- k) any episode of barotrauma, discomfort or injury suffered by the diver, including details of any decompression illness and the treatment given;
- l) any emergency or incident of special note which occurred during the diving operation;
- m) other factors relevant to the diver's health or safety;
- n) name and signature of the authorised representative of the underwater contractor (this will normally be the diving supervisor) who confirms the details recorded. Names and addresses should be printed and in block capitals.

Work under water and stay under pressure shall only be carried out if the diver feels fit to do so.

8.1.2.7 Technical work

All technical personnel involved in maintenance of the diving plant and equipment shall be familiar with the applicable procedures. The operation and shift management shall at all times be familiar with the status of the plant and equipment in use. Technical personnel shall adhere to the procedures for approval of alterations of the plant and equipment.

8.1.3 Mobilisation/demobilisation

8.1.3.1 General

Mobilisation/demobilisation shall be carried out in accordance with a defined plan. When the contractor considers mobilisation/demobilisation to be completed, notification shall be submitted to the operator for acceptance.

8.1.3.2 Mobilisation of personnel

The contractor's system for mobilisation of personnel shall ensure that all personnel employed by the contractor meet their job requirements, and are familiar with and trained in carrying out their regular assigned duties and any special procedures related to safe execution of the work.

The mobilisation plan shall allow sufficient time for necessary familiarisation of all personnel.

8.1.3.3 Familiarisation

Familiarisation shall include all diving/ADS personnel, and shall be conducted in accordance with a specified programme defining time schedules and content.

The programme shall be adapted to the level of previous knowledge of the work-site and work tasks of the individual participants. Familiarisation shall be documented and verified.

8.1.3.4 Supervisory personnel

All offshore supervisory personnel shall be allowed adequate time for familiarising with contract specifications, job procedures and current regulations. They shall also be familiarised with, and in agreement with, the documented risk analyses performed and the resulting risk reducing measures.

8.1.3.5 New personnel

New personnel being mobilised during the operation shall receive a familiarisation of the same standard as those taking part in the initial familiarisation programme.

8.2 Diving procedures

8.2.1 General

Validated procedures that will prevent decompression sickness and any other harmful effects shall be used. Procedures shall be prepared to avoid extraordinary strain and discomfort for the personnel. Treatment- and emergency-tables shall be established.

Procedures shall be based on recognised standards. Contractor shall substantiate the efficiency and reliability of diving tables by maintaining track records for the procedures, and by systematically analysing these records as part of their system for experience feedback. The contractor shall prepare statistical material in order to evaluate the quality of the procedures.

Decompression procedures shall allow for therapeutic treatment to be carried out without increased risks for involved personnel.

8.2.2 Surface oriented diving

Diving procedures in accordance with [53] should be used.

The diving schedule shall be arranged so that the divers have one day in every four, free from dives deeper than 9 msw, or the equivalent air depth.

Bottom time limitations as per health and safety executive recommendations shall be used. These limitations can be found in [53] under "OD-O2 point 23", page 63.

For oxygen limitations, see 5.2.2.4.

Diving that requires decompression stops shall not be planned when diving from small crafts. Further operational recommendations are given in [49].

8.2.3 Saturation diving

8.2.3.1 General

The framework conditions in 8.2.3.2 to 8.2.3.5 are extracted from [43].

8.2.3.2 Compression

Compression to 180 msw shall be at a rate of maximum 1 msw/min. There shall be a stop at 10 msw (2 bar) for a minimum of 20 min for checks. In the depth range from 0 msw to 89 msw, the diver shall have a rest period (non-diving) of at least 1 h after end of compression.

In the depth range 90 msw to 180 msw, this period shall be a minimum of 2 h. The stand-off periods shall not take place more than 1 msw shallower than the planned living depth. The ambient pressure and established diurnal rhythm shall be taken into account in the evaluation of when personnel are ready to start work.

8.2.3.3 Decompression

Decompression shall be performed in accordance with validated procedures aiming to avoid decompression sickness and other negative short or long-term health effects on the divers, see Table 7. Decompression shall not start with a pressure reducing (upward) excursion. The pO_2 shall be in the range of 40 kPa to 50 kPa (400 mbar to 500 mbar).

During decompression there shall be a 6 h stop every 24 h. During final decompression this stop should be between 24:00 hours and 06:00 hours. The last stop shall not be shallower than 3 msw. Light physical activity should be encouraged.

The shallowest saturation living depth is 14 msw.

Table 7 - Saturation decompression

Depth msw	Minutes/msw	msw/day
180 to 60	40	27
60 to 30	50	21,6
30 to 15	60	18
15 to 0	80	13,5

8.2.3.4 Excursions

Procedures for excursions shall be prepared. If excursions are extended compared to Table 8, longer stays at living depth prior to start of decompression should be considered. Decompression shall not start with an upward excursion. There shall be a minimum 8 h hold at living depth prior to decompression after an excursion.

Table 8 – Excursions

Living depth msw	Excursion msw	
	Upward	Downwards
14	0	3
15	1	3
16	2	3
17	3	3
18 to 22	4	4
23 to 29	5	5
30	6	6
31 to 39	7	7
40 to 59	8	8
60 to 79	9	9
80 to 99	10	10
100 to 119	11	11
120 to 139	12	12
140 to 180	13	13

As a minimum, the procedures shall define

- a) living depth,
- b) working depth,
- c) limitations of excursion after change of living and/or working depth,
- d) maximum rates for compression and decompression during excursion,
- e) maximum pressure increase and decrease during the excursion.

It is of special importance to restrict the use and distance of upward excursions.

The maximum ascent rate during excursion is 10 msw/min.

8.2.3.5 Living depth

Dive planning shall be based on minimum change of living depth and excursion exposures.

The living depth shall be as close to the working depth as possible, based on a total evaluation of all safety aspects.

Living depth changes are permitted, but it is not allowed to compress, decompress, and then recompress.

8.2.4 Deep saturation diving

For diving at depths deeper than 180 msw, special attention shall be given to selection of divers, compression and decompression procedures. Validated procedures that will prevent decompression sickness and any other harmful effects shall be used.

Tests for HPNS symptoms shall be performed, e.g. in accordance with [55].

References [56] and [57] give guidance (not satisfactorily validated) on diving procedures for diving deeper than 180 msw.

8.3 Monitoring

8.3.1 General

All diving systems shall have equipment allowing monitoring of important parameters and conditions. There shall be primary and secondary systems for monitoring of parameters, to verify that a correct atmosphere is maintained.

Monitoring equipment shall be arranged to give time for corrective measures before any loss of safety. The design of the monitoring equipment shall allow the setting of limit values with alarm signals when measured values exceeds defined limits.

8.3.2 Monitoring of parameters

An on-line data system shall be used for recording of diver, ADS, bell, habitat and chamber parameters. Sensors for depth monitoring shall be located on the bell and on the diver.

The following parameters shall be measured, displayed and logged on a continuous basis:

- a) time;
- b) divers/ADS depth;
- c) pO_2 and pCO_2 in the diver's/ADS breathing gas;
- d) hot water temperature and flow to the bell;
- e) bell internal and external pressure;
- f) bell internal pO_2 , pCO_2 and temperature ;
- g) chamber internal pressure, humidity, pO_2 , pCO_2 and temperature;
- h) ADS O_2 supply bottle pressure;
- i) ADS suit temperature, pressure and humidity;
- j) habitat internal and external pressure;
- k) habitat internal pO_2 , pCO_2 and temperature.

For diving deeper than 200 msw hot water temperature at the bell and at the diver's suit, and hot water flow to the diver at the bell shall be measured, displayed and logged.

The following substances shall be monitored and logged on a routine basis:

- a) potentially toxic gases in the hyperbaric environment;
- b) in habitat when welding: CO, Ar, NO_x, O₃, fumes, dust (not required on-line);
- c) bacterial growth/content in all critical places.

8.3.3 Visual monitoring

All chamber compartments, bells and habitats shall be equipped with video monitoring system, enabling the surface support crew to visually monitor the occupants and operations.

The ADS shall be equipped with a video camera enabling the ADS supervisor to visually monitor the area in front of the suit. The suit shall be equipped with ample lighting for illuminating the work area and for relocating purposes. A battery-operated strobe light shall be fitted to the suit. The pilot shall easily view all monitoring equipment in the suit.

Before deploying a bell near structures, inside another vessel's anchor pattern, etc., the work-site shall be visually checked by an ROV.

When a diver is in the water, an ROV or diver carried camera shall be used to visually monitor the diver and the operation. Video recordings shall be kept for at least 24 h.

8.3.4 Recordings during operations

Recordings of communication with diver in water/bell/basket/wet bell/ habitat shall be made during every MUO. Recordings from the last 48 h shall be available and shall include the check of equipment and personnel prior to the commencement of the operation.

In case of accidents or serious near incidents, recordings of communication and video tapes shall be kept and made available for later investigation.

8.4 Provisions regarding time

8.4.1 Stay at working depth

During saturation diving stay at working depth shall not exceed 14 days. For diving deeper than 250 msw this stay shall not exceed 10 days.

The planning shall take into consideration the strain that the divers will be exposed to during the operation when the time period for stay at working depth is determined. The strain on the divers shall be continuously considered during the operation with regard to whether a shorter period should be applied. It is a prerequisite that the total length of stay under pressure is the subject of discussions with the representatives of the personnel including safety delegates.

8.4.2 Time between saturation periods

The time between saturation periods shall at least be equal to the duration of the preceding saturation period. In the case of diving deeper than 250 msw the time between saturation periods shall be at least twice the duration of the last saturation period.

8.4.3 Bell run

Maximum time for a bell run is 8 h for ordinary saturation diving, and 6 h for diving deeper than 200 msw. Workloads shall be assessed during planning of the diving operations, and if applicable a shorter bell run may be chosen. If the divers request that the dive should be suspended before the maximum permissible time is up, this shall be decisive. Timing of bell run duration starts when the clamp is first taken off, and stops when the clamp is reconnected, ready for equalization and final transfer of divers to the chamber complex.

Unnecessary periods of stay in the bell, outside of the defined bell run, shall be avoided.

8.4.4 Time in water

During bell diving shallower than 200 msw continuous time in water during a 12 h period shall not exceed 4 h.

While using three man bell-runs, the total time in water during a 12 h period can be extended to 6 h (see definition of time in water, bell diving) on the following conditions:

- a) divers shall return to the bell and take off his mask for a minimum 30 min break after approximately 2 h to 4 h to ensure fluid balance;
- b) the break in the bell to be logged;
- c) each diver shall be given a dry day as bell-man every third day.

For bell diving deeper than 200 msw continuous time in water during a 12 h period shall not exceed 3 h.

Reports from the divers with regard to work conditions, need for rest period and/or suspension of the dive should, however, normally determine the length of stay in the water, up to the maximum time stipulated.

8.4.5 Time limit for diving/atmospheric diving system (ADS) supervisor

The diving/ADS supervisor shall have a rest period from the direct communication control after a period of 4 h. The rest period shall be at least 0,5 h. The total time for this function shall be limited to 8 h in the course of a 12 h period. The workload should determine the length of the rest period. Inside a 24 h period supervisory personnel should normally have a 12 h period of continuous rest.

The direct communication control can be assigned to a trainee diving supervisor, provided the diving supervisor supervises the trainee.

8.4.6 Operational time for atmospheric diving system (ADS)

An ADS manned by one person shall have a maximum operation time in water of 6 h. If manned by more than one person, the maximum operation time in water is 8 h.

In the case of larger, autonomous submersible craft operating independently of support vessel on the surface, the time limits stipulated above will normally not be applicable.

8.4.7 Time in submerged habitat

The bell run including the time in the habitat shall not exceed 8 h. When a breathing mask is used continuously, the personnel shall have a rest period after 4 h in a safe atmosphere without using a breathing mask. This break shall be at least 0,5 h.

8.4.8 Daily rest period

A continuous work free period of at least 12 h shall be included in any 24 h period for personnel working under water or under increased ambient pressure. Work and rest periods shall be specified in a shift programme and shall be planned at regular hours.

In the case of unforeseen delays in diving operations, the need for minor changes in the original shift plan may be considered. If changes are to be made, the parties involved including representative of the personnel and safety delegate shall approve them.

Surface personnel carrying out support functions for the manned underwater operation, and whose work has an influence on safety during the operation, shall have at least 8 h continuous rest period during the course of a 24 h period.

8.4.9 Observation time following completed diving operation

After a completed saturation period, divers shall have a 24 h rest period with immediate access to therapeutic re-compression. During this period, the diver should not perform hard physical work.

In the case of surface oriented diving divers shall have immediate access to therapeutic re-compression for a minimum of 12 h following a completed dive.

Limitation regarding flying after diving shall be regulated in diving tables in accordance with [54] and [53].

8.5 Operational measures

8.5.1 Manning of control room

During operations at least two qualified persons shall be present in a control room attending to safety related functions. For short periods (e.g. in connection with meal breaks) at least one competent person in addition to one qualified person shall be present in the control room, see annex B.

8.5.2 Depth limitation

Surface oriented diving shall not be carried out at depths exceeding 50 msw.

When diving deeper than 50 msw a diving bell shall be used.

8.5.3 Surface oriented pressure chamber

For all surface oriented diving operations a compression chamber shall be ready for use. It shall be possible for the diver to reach maximum depth in the chamber within time limits as specified in diving tables.

8.5.4 Tendering the diver's umbilical

Diver's umbilical shall at all times be under supervision of a tender. The height from the water surface to the tender's work position shall not exceed 5 m.

8.5.5 Standby diver/contingency diver

At depths shallower than 20 msw the standby diver may be located at the surface, provided the location is less than 5 m above the water level.

At depths deeper than 20 msw the standby diver shall be located below surface in suitable position in water/bell/wet-bell/basket.

During bell diving, the stand-by diver is not required to carry bail-out system during emergency interventions.

During every diving operation a contingency diver shall be appointed and located at surface. Necessary equipment shall be ready for use. For diving from small crafts, the contingency diver can be located on board the mother vessel.

8.5.6 Length of diver's umbilical

The length of the diver's umbilical shall not exceed the length considered necessary at any given time, and shall not exceed 45 m from point of tending in the bell/wet bell.

When determining maximum umbilical length, the following hazard points shall be taken into consideration:

- a) the distance from the diver to the nearest hazard point (e.g. thrusters, sea water intake etc.) shall be minimum 5 m;
- b) duration of bail-out equipment;
- c) breathing resistance;
- d) thermal conditions;
- e) umbilical storage, deployment, handling and recovery;
- f) wet tendering;
- g) ROV survey with mapping of debris/ obstructions;

- h) positioning and stability of the work-site;

The stand-by diver's umbilical shall be at least 3 m longer than the diver's umbilical.

8.5.7 Diving operation from a dynamically positioned vessel

Specific safety measures shall be taken in the planning and implementation of MUO carried out from dynamically positioned vessels, see [1], NORSOK J-003, [13] and NORSOK S-002 or equivalent.

The operation manual for DP vessel shall give guidance and procedures concerning the transfer of information, along with a description of the communication systems and alarm systems available, and shall define the meaning of commonly used terms, particularly where they refer to emergency situations.

The operational manual for the DP vessel shall include an up-to-date description of the diving system(s) and guidance on the conduct of diving operations as they may be affected by the DP vessel itself. Procedures shall comprise

- a) actions to be taken in case of changes in alert level status,
- b) operations of divers in enclosed spaces and free flooding,
- c) precautions to guard against thruster wash or suction effect,
- d) surface support and down-line handling,
- e) preparations and use of emergency plans,
- f) moving vessel.

Communications between the dive control position and the DP console shall be regular and frequent. They shall inform each other about any change in operational circumstances.

When surface oriented diving is performed from a DP vessel, careful consideration shall be applied in the planning and execution to minimise the effect from thrusters. Specific consideration shall be given to the diver's umbilical lengths and deployment method.

A DP audio-visual slave alarm shall be installed in the diving control rooms.

8.5.8 Operation with atmospheric diving system (ADS)

ADS shall be equipped according to the planned operation time. Necessary measures in order to bring the personnel to safety in emergency situations shall be taken.

8.5.9 Welding process

During the welding process the divers shall use effective respiratory protective equipment. The respiratory protective equipment shall not be removed before it has been verified that the habitat atmosphere is within the limits as specified in 5.2.3.

8.5.10 Radioactive sources

National authority (according to [22]) shall accept procedures for use of radioactive sources. Activation of radioactive sources when a diver is inside the habitat shall not be possible.

9 Emergency preparedness requirements

9.1 Emergency preparedness plan

An emergency preparedness plan shall describe measures to limit the effects of hazards and accidents and cover predefined hazardous situations.

Risk analyses shall constitute the basis for the emergency preparedness plan. Experience feed back shall be considered.

The measures to be implemented in the event of specific accidents or hazard situations shall be described based on these processes. Use of equipment, personnel and other resources shall be included.

The emergency preparedness plan shall include an organisation plan showing the lines of communication, responsibility and reporting, as well as a description of equipment and procedures. Authority and responsibilities shall be clearly defined.

The emergency preparedness plan for the specific project or operation shall be interfaced with the operator's emergency preparedness plan for the area, and with the overall contingency plan applicable to the operator's activities.

9.2 Emergency preparedness training

At the planning stage of a MUO the requirements for emergency preparedness training shall be assessed.

Prior to the start of the operation, all personnel shall undergo training to ensure that they are conversant with, and drilled in, their tasks in connection with potential emergencies, see [34].

A programme for routine, repetitive training and drills in this respect, to ensure a high level of emergency preparedness, shall be established. This programme and its implementation shall be documented.

Personnel with medical duties in an emergency situation shall be trained according to [6].

9.3 Emergency preparedness equipment

Diving bell, submerged habitat and ADS shall be equipped to ensure that personnel can maintain vital functions in emergency situations. Emergency equipment shall have sufficient capacity to ensure that personnel are brought to safety.

The minimum capacity for emergency situations shall be as follows:

- | | |
|-------------------------|--------|
| a) Divers in the water: | 10 min |
| b) Diving bells: | 24 h |
| c) Chamber and HRUs: | 72 h |
| d) Habitats: | 48 h |
| e) ADS | 48 h |

When conducting a MUO, means to effectively locate, assist and recover the bell/habitat/ADS shall always be available. Such means shall be an additional diving bell for depths exceeding 200 msw, or, for shallower depths, an ROV capable of assisting units in distress, or additional ADS.

Diving bell, submerged habitat and ADS shall be equipped with a transponder, permanently fixed and operating at a frequency of 37,5 kHz. Vessels and mobile facilities that may be called upon to assist in diving emergencies shall have equipment to locate a diving bell/habitat/ADS in distress.

For ADS operations, the recovery system's ability to recover the ADS in a 'worst case' situation shall be demonstrated and documented. Personnel shall be available, in immediate readiness, to operate the back-up system.

9.4 Contractor's contingency centre

While in operation, the contractor shall maintain, in immediate readiness, a contingency room with adequate communication facilities, documentation and other necessary facilities for the contingency team.

9.5 Hyperbaric evacuation

9.5.1 General

In the event of an emergency it shall be possible to evacuate divers under pressure to a safe place.

The emergency preparedness plan shall include a description of the procedure for hyperbaric evacuation, and how to bring the divers back to atmospheric pressure.

The plan for hyperbaric evacuation shall be based on risk analyses covering the launch, stabilisation, recovery and normalisation phases of an evacuation.

9.5.2 Saturation divers

Saturation divers shall, if necessary, as quickly as possible, be evacuated to an HRU and transported to a dedicated place for decompression.

The following three phases shall be described in the contingency plan:

Phase 1: Transfer of divers to- and launch of the HRU

Phase 2: The HRU in the water, including a description of how the life support functions are planned to be maintained, where and how the HRU is to be moved and, if applicable, taken out of the water

Phase 3: HRU under control, transfer to reception centre and decompression of divers

If there is more than 1,8 MPa (18 bar) difference in pressure between divers who are to be evacuated, it shall be possible to maintain a difference in pressure during evacuation.

The time from when the last diver enters the HRU until it is 100 m away from the diving launch site, shall not exceed 15 min. The total period between notification of evacuation, with divers in the chamber complex, and until the time when the HRU is 100 m away from the diving platform, should not exceed 30 min. This includes the time required to bring the system to a pressure enabling transfer of divers into the HRU using emergency procedures as in [58] or equivalent. This recommendation shall be seen with reference to the time required to bring the divers to the same pressure using emergency procedures as in [58] or equivalent.

The selection of HRU reception centre shall be based on an evaluation of the time it will take, under the prevailing weather conditions, to transport the HRU to the centre from the operational location, and the centre's proven capability to receive the HRU. Compatibility shall be confirmed through a test between the reception centre and the different types of HRUs. This shall be documented.

Annex A (Informative)

Accident/near accident reporting in activity under Norwegian petroleum law

A.1 Requirements under the Norwegian petroleum law in general

General requirements for the petroleum activities including

- a) the notification of accidents having resulted in loss of life or serious personal injury and particularly serious accidents of this kind;
- b) reporting of accident resulting in personal injury.

are regulated by «Regulations relating to material and information in the petroleum activities», §11 and §13. The National Insurance Administration (RTV) form 11.01E shall be used for this type of reports.

A.2 Additional requirements for manned underwater operations

In conjunction with manned underwater operations in the petroleum activity there are additional requirements to reporting of incidents. A specialised form (see A.3.3.3) shall be used for this kind of reporting.

The following shall be reported by contractor to PSA on this form:

- a) every incident requiring first aid;
- b) every incident requiring medical- or hyperbaric -treatment;
- c) near accident, including situations when no person is present in the system used for the manned underwater operations.

The information reported is used by PSA for input to the PSA diving data base (DSYS). A copy of this report shall be given to the operator's representative.

A.3 Reporting

A.3.1 First-aid/medical treatment/personal injury

In case of accident resulting in personal injury in conjunction with manned underwater operations both RTV and the enclosed form should be sent to PSA.

A.3.2 Near accident

If no personal injury, first-aid, or medical treatment is involved, the enclosed form only should be used.

A.3.3 Guidance to enclosed form

NOTE If it is required to tick off more than one item in the same column, the most significant item should be marked with a circle.

A.3.3.1 Information related to the incident

Operator:	Name of operator
Field/ area:	Name of oil-field and location where incident took place
Contractor:	Name of manned underwater contractor
Work-site:	Name of vessel/platform/ barge from where the MUO took place
Date:	Date of incident
Reported by:	Name of person reporting incident
Date reported:	Date of issuing report of incident
Incident category:	Tick off in correct box
Depth:	The depth in chamber/ water when incident took place
Breathing gas:	Air/Nitrox/Heliox/Trimix/etc.
Dive type:	Tick off in correct box or state method in use
Purpose of dive:	Tick off in correct box or state purpose
Injured body part:	Tick off in correct box or state other body parts
Type of injury:	Tick off in correct box or state other types of injury

Treatment and follow up: State briefly the first symptom, type of first aid, who administered the first aid, further treatment and follow up.

A.3.3.2 Analysis for cause

Phase of the diving operation:	Tick off correct phase in the operation when incident took place
Activity:	Activity of involved personnel when incident took place
Place of occurrence:	Tick off for correct place where incident took place. "In arena" means areas on the work-site outside the diving facility, but in close conjunction with the diving operation, e.g. chamber control room, dive control, DP-control, gas-bag room, gas-storage room, compressor room, external life support room and rooms where equipment in conjunction with MUO is tested and/or stored. All other areas on the work site
System fault:	Tick of correct system directly involved in the cause of incident
Equipment:	Tick of correct cause of incident with regards to equipment
Personnel:	Tick of correct cause of incident with regards to personnel
Other contributing factors:	Tick off other contributing factors or state type

A.3.3.3 Comments/follow up/signature

Corrective actions on long and short term:	List both implemented and planned corrective actions
Comments from safety delegate:	Safety delegate states his comments to the incident as relevant
Signature:	Signature of person reporting incident

Accidents/near accidents during manned underwater operations under the Norwegian petroleum law

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OPERATOR:	FIELD/AREA:	CONTRACTOR(S):	
WORK-SITE:	DATE OF INCIDENT:	REPORTED BY/DATE REPORTED:	
Incident category: Near accident Accident with personal injury		Depth:	Breathing gas:
INFORMATION RELATED TO THE INCIDENT			
PURPOSE OF DIVE Inspection Construction Repair Welding Maintenance Other (describe):	TYPE OF DIVE Saturation dive Bounce diving Surface oriented diving Monobaric diving Other (describe):	PHASE OF THE DIVING OPERATION Pre dive Compression Bottom phase Decompression Post dive	ACTIVITY Preparations During transport At work Post work At rest
PLACE OF OCCURRENCE In chamber In diving bell/ basket In water In habitat In rescue unit In other hyperbar unit In monobar unit In arena Outside arena	INJURED PART OF BODY Head/ Neck Eye Ear Sinuses Shoulder/Arm Hand/Finger Chest/Stomach Back Hip/ Knee/Thigh/Leg Ankle/Foot/Toe Skin Other (describe):	TYPE OF INJURY Decompression sickness Barotraume during compression Barotraume during decompression Outer ear infection Other infection Wounds Fracture Heat injury Cold injury Unconsciousness Death Other (describe):	
TREATMENT (describe):			
ANALYSIS FOR CAUSE			
SYSTEM FAULT			
Chamber complex system Environmental control plant DP system Others (describe):	Bell system Hot water system Vessel/ Installation outside diving plant (describe):	Control rooms Tools Personal diving equipment	Handling system Gas supply
EQUIPMENT Construction/ Design/ Ergonomics Mechanical failure Poor maintenance	PERSONNEL Poor organisation Lack of or poor procedures Lack of training/ skills Unawareness Incorrect use of equipment Illness/ Personal injury	OTHER CONTRIBUTING CAUSES Pollution/ contamination Weather conditions Fire Other subsea operations (describe): Others (describe):	

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CORRECTIVE ACTIONS	
SHORT TERM (describe):	LONG TERM (describe):

COMMENTS FROM SAFETY DELEGATE:	
SIGNATURE SAFETY DELEGATE:	

SIGNATURE:	
------------	--

Annex B (Informative)

Training requirements for personnel engaged in manned underwater operations

B.1 General

All trainees undergoing diver training shall hold a valid certificate of medical fitness for diving issued by a medical practitioner approved for the examination of divers. Further, the recommended standard for participants of a bell diving course is that they are qualified as surface oriented divers with at least 12 months experience from commercial diving, including at least 50 h bottom time (out of these at least 10 h at depths exceeding 20 m, including 6 h at depths greater than 30 m).

B.2 Surface oriented diver - Training requirements

B.2.1 Aim

The aim of the training shall be to enable the divers to carry out their work safely to a depth of (a) 30 m using self-contained diving equipment, and (b) 50 m with surface oriented diving equipment. Furthermore the aim is to provide the diver with the understanding and knowledge of basic skills required in order to complete various underwater tasks safely and efficiently.

B.2.2 Course syllabus

The following training is required for the issuing of certificates:

B.2.2.1 Hours theory

a) Diving physics	12
b) Use of equipment	20
c) Seamanship	8
d) Diver communication systems	4
e) Underwater tasks	10
f) Underwater hazards	2
g) Diving plant and equipment	7
h) Compression chamber operations	included in b)
i) Decompression	12
j) Legislation, statutory instruments	4
k) First aid and diving medicine	16

Number of hours for theoretical training is intended as a guideline. The number of hours for h) is comprised in the number given for b).

B.2.2.2 Diving physics

B.2.2.2.1 Theory

- a) The relationship between pressure and volume (Boyle's Law)
- b) The relationship between volume and temperature (Charles' Law)
- c) Partial pressure of gases (Dalton's Law)
- d) Solubility of gases (Henry's Law)
- e) Buoyancy (Archimedes' Principle)

B.2.2.2.2 Practice

The theory shall be applied in diving operations.

B.2.3 Use of equipment

B.2.3.1 Theory

- a) Diving equipment

- b) Chamber theory
- c) Hot water plant
- d) Wet bell plant

B.2.3.2 Practice

- a) Diving in open sea
- b) Diving with self-contained breathing equipment
- c) Diving with surface oriented diving equipment (this practice should be carried out in connection with dive in open sea to a depth of at least 20 m)
- d) Practice of emergency procedures
- e) Pre- and post-dive procedures
- f) Maintenance and repairs
- g) Diving suits
- h) Closed and semi-closed circuit breathing apparatus
- i) Wet bell
- j) Practice time in water.

The following minimum time periods shall be achieved during controlled practice in water. Time in water should include decompression stops. Time in compression chamber shall not be included.

0 m to 19 msw:	1600 min (including at least 400 min at depth range 10 m to 19 m)
20 m to 39 msw:	250 min (divided into at least 8 dives with a minimum bottom time of 10 min, including at least 100 min at depth range 30 m to 39 m)
40 m to 50 msw:	150 min (including at least three dives in open sea with a total bottom time no less than 75 min).

A significant proportion of the practical diving exercises should be completed using surface oriented equipment, and during at least one dive to a depth exceeding 35 m, an exercise with a hydraulically/pneumatically/electrically powered tool should be carried out. The exercise should have a duration of at least 20 min.

B.2.4 Seamanship

B.2.4.1 Theory

- a) Tides
- b) Charts and navigation
- c) Safety equipment

B.2.4.2 Practice

- a) Small boat handling
- b) Safety equipment practice
- c) Act as crew-member

B.2.5 Communication systems

B.2.5.1 Theory

- a) Hand and line signals
- b) Underwater oral communication

B.2.5.2 Practice

- a) Practice hand and line signals
- b) Practice use of underwater communication

B.2.6 Underwater tasks

B.2.6.1 Theory

- a) Explosives theory
- b) Rigging and light construction and repair work
- c) Pneumatically/hydraulically powered tools
- d) Other relevant underwater tools

B.2.6.2 Practice

- a) The practice of underwater tasks is intended to provide the trainees with a general appreciation of the techniques, problems and safety aspects related to work under water. For certain operations such as cutting, welding, use of explosives and non-destructive testing (NDT) further practice will be required before the diver may be considered to be qualified.
- b) For all work involving use of special equipment, the trainee shall be familiar with statutory testing and examination requirements, and their frequency, including
 - a) underwater search, inspection and survey,
 - b) rigging,
 - c) tools,
 - d) water jetting, airlifts and lifting bags,
 - e) bolt guns,
 - f) cutting equipment,
 - g) welding equipment,
 - h) explosives,
 - i) construction techniques.

B.2.7 Underwater hazards**B.2.7.1 Theory**

- a) Underwater structures
- b) Dynamically positioned vessels
- c) Stages, baskets and wet bells

B.2.8 Diving plant and equipment**B.2.8.1 Theory**

- a) Air compressors and cylinders
- b) Winches, air motors etc.
- c) Fire fighting equipment

B.2.8.2 Practice**B.2.9 Chamber operation****B.2.9.1 Theory****B.2.9.2 Practice**

- a) Practical chamber operation
- b) Chamber diving

B.2.10 Decompression**B.2.10.1 Theory**

- a) Decompression tables
- b) Decompression stops in water
- c) Surface decompression

B.2.10.2 Practice

Practical decompression training

B.2.11 Legislation, statutory instruments

The diver is required to be familiar with and understand relevant legislation, regulations, guidelines, safety notices, etc. He shall further be able to assess problems and situations in connection with relevant diving operations subjected to the above mentioned legislation etc.

B.2.12 First aid and diving medicine**B.2.12.1 Structure and function of the human body**

- a) Musculo/skeletal systems
- b) Nervous system
- c) Heart, blood vessels, blood circulation
- d) Lungs
- e) Ears, sinuses and vestibular organs

B.2.12.2 First aid causes, prevention, symptoms and management under normal and hyperbaric conditions

- a) Bleeding
- b) Fractures, sprains and muscle trauma
- c) Shock
- d) Burns
- e) Electrocution
- f) Asphyxia
- g) Pulmonary oedema
- h) Respiratory arrest
- i) Cardiac arrest
- j) Hypothermia
- k) Hyperthermia
- l) Underwater blast injury
- m) Importance of personal hygiene in the management of injuries. Measures at the casualty site and during transportation of injured person. First aid equipment and its use during a manned underwater operation.

B.2.12.3 Diving related injuries and side effects

Cause, effect, symptoms and treatment of

- a) Decompression sickness
- b) Pressure related injuries
- c) Pressure equalisation - ear and sinuses
- d) Drowning
- e) Vomiting under water
- f) Gas embolism and pulmonary barotrauma
- g) Carbon dioxide poisoning
- h) Carbon monoxide poisoning
- i) Oxygen toxicity
- j) Anoxia and hypoxia
- k) Nitrogen narcosis

B.3 Bell diver - Training requirements

B.3.1 Aim

The aim of the training shall be to enable experienced surface oriented divers to carry out work safely as bell divers and standby divers in a diving bell.

B.3.2 Course syllabus

B.3.2.1 General

Training as specified in B.3.2.2 to B.3.2.7 is mandatory prior to the issuing of certificates:

B.3.2.2 Hours theory

- | | |
|---------------------------------------|----|
| a) Diving physics | 20 |
| b) Chamber operation | 10 |
| c) Bell diving operations | 12 |
| d) Legislation, statutory instruments | 6 |
| e) Physiology and first aid | 36 |

Number of hours for theoretical training is intended as a guideline.

B.3.2.3 Diving physics**B.3.2.3.1 Properties of liquids and gases**

- a) The relationship between pressure and volume (Boyle's law)
- b) The relationship between volume and temperature (Charles' law)
- c) Partial pressure of gases (Dalton's law)
- d) Solubility of gases (Henry's law)
- e) Buoyancy (Archimedes' principle)

B.3.2.3.2 Practical application of diving physics in diving operations**B.3.2.4 Chamber operations**

- a) BIBS - functioning and operation
- b) Gas distribution system
- c) Gas monitoring and recording
- d) Carbon dioxide absorption system
- e) Impurities in gas distribution systems
- f) Gas purity
- g) Cleaning of gas distribution systems
- h) Monitoring and recording of parameters during chamber operation
- i) Fire fighting equipment
- j) Checks and maintenance
- k) Sanitary arrangements
- l) Medical and equipment locks
- m) Communications
- n) Emergency procedures
- o) Compression and decompression
- p) Dive log
- q) Surface team
- r) Diving operation

B.3.2.5 Bell diving operations**B.3.2.5.1 Practical experience - minimum requirements**

The practical experience shall comprise work both as diver and as standby diver in a diving bell.

- a) An instructor shall be present in the bell until satisfied that the trainee has the necessary knowledge of the functions of diver and of standby diver. The following number of dives shall be completed at the depth range of 5 m to 10 m:
 - 1) 24 bell lockouts as diver;
 - 2) 24 bell lockouts acting as bell-man (standby diver);
 - 3) 5 simulated rescues of unconscious diver;
 - 4) 12 complete bell-runs including transfer under pressure.
- b) As a minimum, the first three bell lockouts should be completed with the instructor in the bell, if desirable without transfer under pressure. All subsequent bell runs should be made according to the procedures for transfer under pressure. The trainee diver may only make one lockout from the bell at any one depth during each bell run. However, the diver and the bell-man (standby diver) may change around so that each carries out one lockout at a particular depth. Further lockouts may be made during the same bell-run provided the depth of the bell is changed and operation of the bottom door is included.
- c) Each trainee shall
 - 1) perform at least 4 chamber pressurisations including check of transfer chamber,
 - 2) perform at least 4 pre-dive bell checks,
 - 3) train on simultaneous simulated gas loss and communication failure, while in water,
 - 4) perform at least three bell bounce dives to depths of 55 m, 75 m and 100 m respectively,

5) perform simulated rescue of an unconscious diver during one of these dives.

d) Saturation

From a living depth greater than 50 m the trainee shall complete two bell runs in open water to a depth greater than 50 m. The lockout time for each bell run should be at least 15 min for each diver. The saturation period should have duration of minimum 60 h.

B.3.2.5.2 Monitoring and recording

Theory and practice

B.3.2.5.3 Bell gas distribution system

Theory and practice

B.3.2.5.4 Carbon dioxide absorption system

Theory and practice

B.3.2.5.5 Heating systems

Theory and practice

B.3.2.5.6 Communications

Theory and practice

B.3.2.5.7 Emergency recovery system for diving bell

Theory and practice

B.3.2.5.8 Handling system for diving bell

Theory and practice

B.3.2.5.9 Checks, pre- and post-dive procedures

Theory and practice

B.3.2.5.10 Emergency measures

Theory and practice

B.3.2.5.11 Breathing gas recovery systems

Theory and practice

B.3.2.5.12 Survival equipment

Theory and practice

B.3.2.5.13 Dynamically positioned vessels

Theory and practice

B.3.2.5.14 Surface team

Theory and practice

B.3.2.6 Legislation, statutory instruments

The diver is required to be familiar with and understand relevant legislation, regulations, guidelines, safety notices, etc. He shall further be able to assess problems and situations in connection with relevant diving operations subjected to the above mentioned legislation.

B.3.2.7 Physiology and first aid**B.3.2.7.1 Structure and function of the human body**

This shall include

- a) musculo/skeletal systems,
- b) nervous system,
- c) heart, blood vessels, blood circulation,
- d) lungs,
- e) ears, sinuses and vestibular organs.

B.3.2.7.2 O₂-toxicity

This shall include

- a) the cause, effects, symptoms and management of O₂-toxicity,
- b) calculation of O₂ partial pressure and the significance of this pressure to the safety of the divers.

B.3.2.7.3 First aid

The candidate shall possess knowledge of causes, prevention, symptoms and how to manage, under normal and hyperbaric conditions (including inside a diving bell), first aid in connection with following conditions:

- a) bleeding;
- b) fractures, sprains and muscle trauma;
- c) shock;
- d) burns;
- e) injuries caused by electricity;
- f) asphyxia;
- g) pulmonary oedema;
- h) respiratory arrest;
- i) cardiac arrest;
- j) hypothermia;
- k) hyperthermia;
- l) underwater blast injury.

Importance of personal hygiene in the management of injuries. Patient examination. Checking pulse, respiratory rate and temperature. Measures to be taken during transfer of injured person from diving bell to chamber. Measures to be taken in the bell or chamber and during transportation of injured person. First aid equipment and its use during a manned underwater operation.

B.3.2.7.4 Diving related injuries

The following injuries, including their side effects, cause, effect, symptoms and management shall be known:

- a) pressure related injuries,
- b) ear related injuries and illnesses,
- c) drowning (both primary and secondary),
- d) vomiting under water,
- e) carbon dioxide poisoning,
- f) carbon monoxide poisoning,
- g) HPNS,
- h) nitrogen narcosis,
- i) anoxia and hypoxia.

B.3.2.7.5 Decompression related illness

Causes, effects, symptoms, diagnosis and management of illnesses requiring recompression, e.g. decompression sickness, gas embolism, pulmonary barotrauma and related conditions.

B.4 Trainee air diving supervisor - Training requirements**B.4.1 Aim**

The aim of the training shall be to enable the trainee to carry out work safely as trainee air diving supervisor during manned underwater operations.

B.4.2 Course syllabus

The following training should be required for the issuing of certificates:

B.4.2.1 Hours theory

a) Diving physics	8
b) First aid and diving medicine	10
c) Diving plant and equipment	4
d) Support equipment, tools and remotely controlled submersible craft	4
e) Legislation and safety notices	6
f) Advisory bodies and classification societies	3
g) Procedures, emergency procedures, tables	6
h) Labour legislation	4
i) Management systems, quality assurance	6
j) Dynamic positioning	3

Number of hours for theoretical training is intended as a guideline.

B.4.2.2 Diving physics**B.4.2.2.1 Revision**

- a) Boyle's law
- b) Charles' law
- c) Dalton's law
- d) Henry's law
- e) Archimedes' principle

B.4.2.2.2 Heat conduction, heat loss**B.4.3 Physiology and first aid****B.4.3.1 Repetition**

- a) Diving medicine
- b) Treatment tables
- c) First aid

B.4.3.2**B.4.4 Diving plant and equipment**

- a) Symbols and schematics
- b) Wet bell and diving basket
- c) Decompression chamber
- d) Analysis equipment
- e) Pipes, valves and fittings

B.4.5 Support equipment, tools and remotely controlled submersible craft

- a) Compressors and filters

- b) Hot water machines
- c) Electrical equipment
- d) Lifting and handling gear
- e) Hydraulic equipment
- f) Inspection equipment
- g) High pressure water jet
- h) Liaison with remotely controlled vehicle

B.4.6 Statutory instruments and safety notices

- a) Relevant labour legislation
- b) Relevant diving regulations
- c) Relevant safety notices
- d) Breathing gas purity requirements
- e) Casualty register, casualties during air diving

B.4.7 Advisory bodies and classification societies

Recommendations by

- a) DMAC
- b) AODC/IMCA
- c) DNV

B.4.8 Procedures, emergency procedures

B.4.8.1 Procedures for air diving

- a) Operational procedures
- b) Length of umbilical when diving from dynamically positioned vessels
- c) Log keeping

B.4.8.2 Emergency procedures for air diving

- a) Emergency situation in sea
- b) Emergency situation in chamber
- c) Emergency situation on diving work-sites

B.4.8.3 Decompression tables

B.4.9 Internal control, quality assurance

- a) Regulations relating to management systems for compliance with statutory requirements in relation to safety, working environment and protection of the external environment in the petroleum activities.
- b) Principles for management systems and quality assurance.

B.4.10 Dynamic positioning

- a) Relevant standards
- b) IMCA's recommendations

B.5 Trainee bell diving supervisor - Training requirements

B.5.1 Aim

The aim of the training shall be to enable the trainee to function as trainee bell diving supervisor during manned underwater operations.

B.5.2 Course syllabus

The following training should be required for the issuing of certificates:

B.5.2.1 Hours theory

a) Diving physics, gas mixture and gas consumption	10
b) First aid and diving medicine	13
c) Diving plant and equipment	7
d) Support equipment, tools and remotely controlled vehicles	5
e) Legislation and safety reports	2
f) Advisory bodies and classification societies	4
g) Procedures, emergency procedures, tables	7
h) Management systems, quality assurance	6
i) Dynamic positioning	2

Number of hours for theoretical training is intended as a guideline.

B.5.2.2 Diving physics, gas mixture, gas consumption

B.5.2.2.1 Revision

Gas laws

B.5.2.2.2 Gas mixture and compression

B.5.2.2.3 Consumption of gas and chemicals

B.5.3 First aid and diving medicine

- a) Diving medical conditions
- b) Hypothermia and hyperthermia
- c) Medical equipment and first aid equipment
- d) Examination of patient
- e) Treatment tables
- f) Bacteriology

B.5.4 Diving plant and equipment

- a) Chamber and regeneration plant
- b) Recovery plant
- c) Panels, regulators, pipes and fittings
- d) Analysis equipment, gas purity, cleaning for O₂ use

B.5.5 Support equipment, tools and remotely controlled submersible craft

- a) Electronic equipment, electricity in water
- b) Hyperbaric welding
- c) Radioactivity - hazards and hazard limit values
- d) Liaison with remotely controlled submersible craft

B.5.6 Statutory instruments and safety notices

- a) Relevant labour legislation
- b) Relevant diving regulations
- c) Relevant safety notices
- d) Breathing gas purity requirements
- e) Casualty register, casualties during bell diving

B.5.7 Advisory bodies and classification societies

Recommendations by

- a) DMAC
- b) AODC/IMCA
- c) DNV

B.5.8 Procedures, emergency procedures, tables

Procedures for bell diving with emphasis on

- a) operation planning,
- b) equipment requirements,
- c) log keeping.

B.5.9 Management systems, quality control

- a) Quality assurance systems
- b) Management systems
- c) Planned maintenance

B.5.10 Dynamic positioning

- a) Relevant standards
- b) IMCA's recommendations

B.6 Trainee life support technician (LST) - Training requirements**B.6.1 Aim**

The aim of the training shall be to enable the trainee to function as trainee LST during manned underwater operations.

B.6.2 Course syllabus

The following training should be required for the issuing of certificates:

B.6.2.1 Hours theory

a) Diving physics	13
b) Diving medicine	20
c) First aid	19
d) Decompression and treatment tables	6
e) Diving plant and equipment	10
f) Emergency procedures	4
g) Legislation and safety notices	4
h) Practical training	40

Number of hours for theoretical training is intended as a guideline.

B.6.2.2 Diving physics**B.6.2.2.1 Properties of gases**

- a) The relationship between pressure and volume (Boyle's law)
- b) The relationship between volume and temperature (Charles' law)
- c) Partial pressure of gases (Dalton's law)
- d) Solubility of gases (Henry's law)

B.6.2.2.2 Gases used in diving**B.6.2.2.3 Gas mixture, compression****B.6.2.2.4 Physiology****B.6.2.2.5 Structure and function of the human body**

Knowledge of the structure and function of

- a) musculo/skeletal systems,
- b) nervous system,
- c) heart, blood vessels, blood circulation,
- d) lungs,
- e) ears, sinuses and vestibular organs.

B.6.2.2.6 Diving related injuries and side effects

Knowledge of the cause, effects, symptoms and treatment of

- a) gas embolism and barotrauma,
- b) decompression sickness,
- c) nitrogen narcosis,
- d) HPNS,
- e) O₂-toxicity,

- f) anoxia and hypoxia,
- g) carbon dioxide poisoning,
- h) carbon monoxide poisoning,
- i) hyperthermia and hypothermia.

B.6.2.2.7 Hygiene, bacteria growth, control, treatment

B.6.2.2.8 Medical life-saving equipment for diving operations

B.6.3 First aid

B.6.3.1 Theory

Knowledge of cause, prevention, symptoms and treatment under normal and hyperbaric conditions of circulation failure:

- a) bleeding,
- b) fractures, sprains and muscle trauma,
- c) burns,
- d) shock.

B.6.3.2 First aid equipment for diving operations

B.6.4 Tables for compression, decompression and treatment

- a) Compression profile
- b) Decompression tables
- c) Treatment tables

B.6.5 Diving plant and equipment

B.6.5.1 Chamber complex

- a) System design
- b) Locks and locking mechanism
- c) Regeneration plant
- d) Sanitary plant

B.6.5.2 Gas distribution system

- a) Gas containers
- b) Pipelines and hoses
- c) Valves, pressure reduction valves and fittings
- d) Pressure gauges
- e) Compressors and booster pumps
- f) BIBS
- g) Thread forms
- h) Cleaning

B.6.5.3 Equipment for monitoring and recording

- a) Equipment for analysis of O₂ and CO₂
- b) Equipment for monitoring and recording of depth, temperature and humidity
- c) Equipment for monitoring and communication

B.6.5.4 Fire fighting equipment

B.6.6 Emergency procedures

- a) Measures for fire prevention
- b) Chamber evacuation, isolation of chamber
- c) Measures in the event of pressure drop
- d) Contamination - precautions and corrective action

B.6.7 Legislation

Relevant legislation, regulations, rules, guidelines, safety notices

B.6.8 Practical training

- a) Analysis of stored gas and chamber atmosphere
- b) Calibration of analysis equipment
- c) Gas supply to control panels and chambers
- d) Monitoring and recording of depth, temperature and humidity
- e) Calibration of monitoring and recording equipment
- f) Operation of communication equipment
- g) Compression and decompression of chamber complex
- h) Operation of sanitary arrangements and locks
- i) Transfer of personnel under pressure
- j) Practice of emergency procedures
- k) Use of treatment tables
- l) Cleaning

B.7 Leadership training**B.7.1 Leadership and communication****B.7.1.1 Role of leader**

- a) Definition of leadership
- b) What is expected of a leader
- c) Definition of the leader function
- d) Ways of co-operation
- e) Attitudes
- f) Leadership over time

B.7.1.2 Communication

- a) One-way/two-way communication
- b) Types of communication, language and body language
- c) Making people conscious of the matter in hand/the evolving process
- d) Information
- e) Instruction techniques

B.7.1.3 Conflicts

- a) Symptoms
- b) Causes
- c) Solutions
- d) Preventive measures

B.7.2 Planning and organising work

- a) Resource assessment
- b) Organising and assigning work tasks
- c) Definition of work
- d) Ways of co-operation
- e) Team building
- f) Transfer of experience

B.7.3 Organisation and administration

- a) Mutual expectations
- b) Duties and responsibilities, framework/requirements
- c) Organisational structure
- d) Communication lines
- e) Administration

B.7.4 Leadership in emergency and stress situations

- a) Symptom recognition
- b) Behaviour and reactions
- c) Expectations to leaders in time of crisis
- d) Leadership styles, ad hoc leadership

- e) Awareness, preventive measures, training/crisis preparation
- f) Course of action
- g) Debriefing
- h) Transfer of experience

Guideline for theoretical training in leadership training is 16 h.

