Workplace Safety and Health Guidelines

Inland/Inshore Commercial Diving

WSHCOUNCIL

Tripartite Alliance for
Workplace Safety and Health

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Contents

1. Introduction

This guide provides recommendations and guidelines for commercial diving operations, not exceeding 50 metres in water depth within Singapore's inshore and inland boundaries.

1.1 Objective

The objective of this guide is to provide guidance and best practices for:

- Service providers such as commercial diving contractors and dive team;
- Service buyers such as shipyards, vessel owners, oil/gas and petrochemical plant operators; and
- Public agencies such as the Public Utilities Board, Singapore Food Agency on Fish Farm Aquaculture, National Environment Agency, National Parks Board, and Defence Science and Technology Agency.

The guide is not intended to be prescriptive but comprises proper planning and assessment of diving operation and use of compressed air breathing supply apparatus with the specific requirements. The guide also covers risk assessment of common hazards and their recommended risk controls. Emergency response plans are included as a guide to address various emergency situations such as recovery of an unconscious or injured diver and loss of respiratory air.

1.2 Scope

The guide covers two diving methods, namely Surface-Supplied Diving Equipment (SSDE)/ Surface-Supplied Breathing Apparatus (SSBA) and Commercial Self-Contained Underwater Breathing Apparatus (CSCUBA). Recreational Self-Contained Underwater Breathing Apparatus (SCUBA) shall <u>not</u> be used for commercial diving operations.

The scope does not cover recreational diving/technical diving, scientific diving, archaeological diving projects as well as diving activities using oxygen-enriched gas mixtures (NITROX).

> **Note**
> This set of guidelines replaces the *Technical Advisory for Inland/Inshore Commercial Diving Safety and Health* published by the Workplace Safety and Health Council in 2009.

2. Types of Diving Methods

This section outlines an overview of two common types of commercial diving methods (SSDE/SSBA, CSCUBA) and their applications. More details are covered in Section 4.

In all diving operations, a comprehensive risk assessment needs to be done prior to the selection of the appropriate diving method for the assigned task(s). Other factors to take into consideration may include but not limited to the experience and competencies of the dive team, environmental conditions and water depth.

Table 1 provides a good guide on the use of the appropriate diving methods based on water depth. (Source: SS511:2018 Code of Practice for Diving At Work)

Water Depth	Appropriate Diving Method
Not exceeding 30m	SSDE/SSBA or CSCUBA
Not exceeding 50m	SSDE/SSBA

Table 1: Use of appropriate diving methods based on water depth.

2.1 Application of SSDE/SSBA

The diver using SSDE/SSBA receives a supply of breathing air from the surface via an umbilical attached to the diver's harness which is connected to the helmet. The method provides a two-way verbal communication between the diver and diving supervisor. The diving supervisor will record the conversation throughout the dive.

The use of SSDE/SSBA is applicable at jetty/dock side, anchored or secured small vessel/craft, jack up rig, power plant, water plant, lakes and reservoirs. When carrying out the dive planning and risk assessment, SSDE/SSBA should be the preferred choice for all commercial diving work, unless the risk assessment clearly identifies CSCUBA for the work to be conducted with the hazards and risks mitigated to an acceptable level, within the constraints on the use of CSCUBA outlined in Section 2.2.

2.1.1 Benefits of SSDE/SSBA

Some of the benefits of using SSDE/SSBA include:

- The diver receives sufficient air supply sources, mainly from the main supply (primary) and an independent or shared secondary air supply at the surface. The bail-out cylinder provides emergency air in the event of the failure of/disruption to the surface air supply (primary and secondary).

- The umbilical serves two purposes: (i) enables the diver to orientate himself in poor visibility and to surface safely by following the umbilical back to the surface, and (ii) enables the diving supervisor to monitor the diver's depth by use of the pneumofathometer/depth gauge on the surface control panel.

- The diving supervisor who has direct communications with the diver is able to monitor the diver work progress if the surface monitor and hat camera are available. In the event of a communication failure at any time, the dive is to be terminated until communications are reinstated.

In line with the benefits of using SSDE/SSBA, a diver is required to observe the precautionary measures during diving operation which may include but not limited to the following:

- **Possible entanglement:** The slack on the umbilical may get caught by protruding debris on the seabed or twisted with other hoses or ropes during diving operation work carried out between the hull of the ship and the anchor chain as well as other existing underwater structure.

- **Disruption to air supply:** The life of a diver can be endangered due to limited air supply. This can be caused by air leaks or lowered air pressure as a result of a ruptured umbilical, hat flooding or a faulty air regulator which may also compromise the quality of the breathing air.

- **CO_2 toxicity:** Divers performing tasks with a long duration may build up a higher than normal CO_2 level due to the rapid respiration process as a result of nature of assignment and environment, e.g. tidal and high-water currents and pressure changes. This can lead to possible gas toxicity if flushing of the helmet is not done regularly.

Figure 1: SSDE/SSBA diver.

2.2 Application of CSCUBA

CSCUBA operation is carried in diving operations not exceeding a depth of 30 metres of sea water (msw). The diver receives main air supply and emergency air supply (bail-out) from the cylinders within the harness and communicates with the diving supervisor via a two-way diver communication system with video camera, where applicable, or as required by the client/ service buyer.

The CSCUBA diving operation is planned such that that the diving operation does not increase the risk level associated with the dive. As such, each dive is calculated properly with all risk control measures in place, mainly applicable for single dives or dives with a short duration.

Based on the risk assessment, the justification and the rationale to use CSCUBA instead of SSDE/ SSBA for the assigned task need to be documented.

Figure 2: **CSCUBA diver.**

2.2.1 Restriction to the Use of CSCUBA

For dive depths of more than 30 metres where the CSCUBA method may not be suitable for use, there are other hazardous conditions such as dive sites with poor visibility and/or the presence of substantial potential differential pressure. Refer to SS511:2018, Para 13.2.2 for more information.

2.3 Differences between SSDE/SSBA, CSCUBA and Recreational SCUBA

Item	SSDE/SSBA	CSCUBA	Recreational SCUBA
Air Supply (Main)	Surface supplied	Air Cylinders — Main and Bail-out	Air Cylinder — Normally only one
Backup Air Supply from surface	Yes	Nil	Nil
Emergency Air Supply — carried by diver	Yes	Yes	Nil
Type of mask/air regulator	Full face mask or helmet/ integrated demand regulator	Full face mask/ integrated demand regulator	Half mask/separate integrated demand regulator held by a 'mouthpiece'
Voice communications	Yes	Yes	Nil
Full Body Harness	Yes	Yes	Sometimes
Lifeline using rope	Yes	Yes	Sometimes

Table 2: **Comparison between the different types of diving methods.**

(Source: Commercial Diving Association Singapore, CDAS newsletter 2016, Issue #2)

3. Roles and Responsibilities of All Stakeholders

This section outlines the roles and responsibilities of all stakeholders, mainly service buyers (clients) and service providers (diving contractors, diving supervisors, divers) in ensuring a safe and healthy work environment during the diving operation. Refer to SS511:2018, Para 4 for more details.

Section 3.4.6 (Table 3) covers a summary of the dive team's common functions while section 3.4.7 on Dive Team Size which is dependent on the number of diver(s) required for the diving operation.

3.1 Site Owner

Prior to any diving project, site owners are required to inform the diving contractor in writing of any underwater or above water obstructions such as plants, pipelines, equipment or subsea structures which may pose a hazard to the dive team. Site owners should conduct preliminary assessment on the presence of other hazards which may include but not limited to locks, weirs, water intakes, propellers, discharge/drain points, energy sources, differential pressures, debris or scaffolding. Risk assessment of the identified hazards with risk control measures are to be shared with the diving contractor via a toolbox talk or project brief at the outset of the project.

3.2 Client

The client is usually the operator or site owner of an organisation or facility, e.g. vessel, dock, proposed or existing installation, pipeline or other structure. Clients may also include authorities who own platforms projecting into the water, e.g. quays, wharves, jetties, piers, harbours and anchorages. A diving contract is used as an agreement between the client and the diving contractor. In some cases, the client may hire a main/principal contractor or service buyer to act on their behalf to oversee the work of the diving contractor in alignment to the contract.

An on-site representative with the necessary experience and competency for the task may be appointed by the client or main/principal contractor or diving contractor. The client, main/principal contractor and diving contractor are required to have a safety management system addressing all diving activities and related hazards with risk controls.

For instance, prior to the start of the dive project, the client needs to:

- Ensure there is sufficient lead time and facilities provided for the diving contractor to carry out all necessary site-specific safety and familiarisation training.
- Ensure a safe diving operation, as well as ensuring the worksite is not affected by other incompatible activities, e.g. supply boat unloading, bunkering, scaffolding in the vicinity.

- All Safe Work Practices involving the dive team and/or support personnel, e.g. master or boat coxswain in installation activities should be incorporated in dive operation.

- Conduct a risk assessment to determine the requirement for other support personnel which may include, but not limited to client on-site representative, vessel crew, project personnel, e.g. engineer and surveyor.

3.3 Diving Contractor

The diving contractor is usually an employer of a dive team who works closely with the site owner or client/service buyer. Prior to the commencement of the diving project, the diving contractor is required to obtain prior consent from the site owner/client or authorities for the dive operation to be conducted at a suitable and safe location.

The diving contractor appoints diving supervisor/s in writing, in line with the diving requirements to be adopted for the assigned task/s.

The following are some of the key responsibilities of a diving contractor but not limited to:

Operational

- Select appropriate diving methodologies and issue of diving procedures.

- Carry out risk assessment for the assigned tasks and diving activities prior to the start of dive operation to ensure the dive work operation is safe and suitable.

- Review the risk control measures to ensure their effectiveness for a safe diving operation.

- Ensure all diving equipment provided is fit for purpose and is maintained with up-to-date register, maintenance records and certificates, e.g. test and examination.

- Ensure audio recording is available throughout the dive using a recording device, e.g. a hard disk drive or digital video disc maintained in a 'black box' for at least 48 hours.

- Conduct briefings to familiarise the dive team on the on-site dive operation and the requirements.

- Provide the diving supervisor with a diver's log and diving operation logbooks for all diving activities and required information to be recorded accurately and to be duly completed.

- Ensure on call availability of appointed hyperbaric and diving specialist/physician (diving doctor) and the medical facilities for emergency transfer of injured diver/s.

Procedural

- Ensure a dive project plan is available at the work site.

- Ensure the availability of first aid and medical equipment is put in place such as Cardiopulmonary Resuscitation (CPR), Automated External Defibrillator (AED) and on-site Oxygen Provider/Resuscitation Set (with 100% medical oxygen administration) equipped with sufficient duration to last from the worksite to the hyperbaric chamber in line with rescue procedures in the Emergency Response Plan.

- Establish effective communication protocol among the dive team, owner or person(s) in control of the place, emergency services, e.g. Maritime and Port Authority of Singapore (MPA), Singapore Police Force (SPF), Singapore Civil Defence Force (SCDF) and recompression facility, and the personnel, e.g. vessel master, deck crew, crane operator.

- Ensure safe work procedures, e.g. safety instructions and rules and proper training are provided to dive team on the use of the plant and equipment.

- Inform all dive team members of the emergency arrangements such as location of the emergency facility, availability of a decompression chamber and the required travelling time from the dive site to the decompression chamber.

- Ensure all divers who are employed full time or on a contract basis to undergo annual/ periodic medical examination by appointed hyperbaric and diving specialist/physician (diving doctor) registered in Singapore.

Documentation and records

- Ensure the dive team is trained and competent with training records, e.g. type of diving attended, diving first aid, certification as oxygen provider, occupational first aid such as CPR, AED which is subjected to two-year refresher training.

- Ensure the emergency response plan is documented and implemented with emergency preparedness, site specific contingency plans, recovery procedures of injured diver/s to the dive platform and emergency decompression.

- Maintain the dive records for a minimum of 12 months, which include the dive log sheet, planned maintenance of diving plant and equipment, incident and investigation reports, and management of change updates.

- Ensure that a diving operation manual (Refer to SS511:2018 Annex C) is available at the work site.

- A copy of the valid insurance policy with coverage for dive team including freelance divers should be available on-site.

3.4 Dive Team

The dive team comprises the diving supervisor, diver, standby diver, dive tender and standby diver's attendant employed by the diving contractor with at least 18 years of age (Refer to SS511:2018, Para 4 on Roles and Responsibilities). Together they work closely with the owner or person-in-control of the place on-site and are responsible for the safety of the diving operation.

3.4.1 Diving Supervisor

The diving supervisor who is appointed in writing by the diving contractor/company to supervise the diving operation, ensures the safety and health of the dive team. For instance, the diving supervisor gives instruction for diver/s to enter the water after checking safe work procedures are in place, e.g. dive plan, emergency response plan, risk assessments, permit to work, lock-out tag-out systems, diving equipment checks are completed, a suitable and sufficient dive team is available, and toolbox talks and dive briefings are completed.

In the event of any imminent danger, the diving supervisor needs to assess the situation and has full authority to terminate the dive for safety reasons. Other stakeholders, e.g. owner, client or the master of the vessel and authorities may also instruct the diving supervisor to terminate the diving operation for safety reasons. However the stakeholders cannot instruct the diving supervisor to start the diving operation. Only the diving supervisor has the authority to start the diving operation when he is ready with all checks in place.

The key responsibilities of a diving supervisor may include but not limited to (Refer to SS511:2018, Para 4.3):

Operational

- Recognise the symptoms of decompression illness, e.g. bends, barotrauma, arterial gas embolism.
- Supervise treatment under the consultation with an appointed hyperbaric and diving specialist/ physician.
- Ensure familiarity with the procedure for evacuation of the injured diver/s to the nearest facility, e.g. re-compression chamber for treatment.
- Ensure pre-dive checks of diver's equipment are carried out prior to each use.
- Ensure appropriate and adequate breathing air is used for the diving operation including for emergency.
- Ensure the dive team understand the dive project plan requirements, has access to the diving procedures, and know what their roles and responsibilities are.
- Ensure that all hazards have been evaluated and are understood by all relevant parties and where required, training should be provided.

- Carry out an on-site job safety analysis and ensure the risk assessment is completed prior to the start of the dive operation.

- Ensure the dive team including diving supervisor is medically fit[1] to perform the assigned task.

- Ensure the dive project plan is completed and the dive team is briefed on the work activity, requirements and emergency response plan.

- Ensure decompression procedure is done properly in the water or within a decompression chamber in accordance with decompression tables widely used by the diving industry.

- Supervise the diving operations at all times while the diver is in the water or under treatment in a decompression chamber.

- Ensure that diving operations are stopped safely and suspended when any approved dive project plan is compromised/changed, or any situation where the dive team's safety is compromised.

Procedural

- Ensure diving supervisor is not allowed to dive unless prior documentation of the handover of the diving operation to alternate diving supervisor (appointed in writing by the diving contractor) is done.

- Ensure the operation and supervisory functions align with the requirements of the Workplace Safety and Health Act, diver contractor's diving procedures and other relevant code of practice, e.g. SS511:2018.

- Ensure the operation and maintenance of the plant and equipment comply with the manufacturer's recommendations and/or legislative requirements. In the event the servicing period for the item is more frequent/stringent than legislatively required, the manufacturer's recommendations should prevail.

- Maintain the diving supervisor logbook with detailed records of all the diving operations.

- Ensure daily records in the diver's operation log for each diving operation by diver/s are correctly entered and signed off.

[1] A diving medical certificate has a validity period of 12 months from date of issue. The diving medical certificate must be issued by a diving doctor registered with the Singapore Medical Council, Ministry of Health. Refer to SS511:2018, Para 15.1.2 on the medical requirements of the diving doctor. Dive team personnel who are not diving such as the diving supervisor or dive equipment technician should hold a valid medical certificate that has a validity period of 24 months from date of issue.

Documentation and records

- Ensure all checks on dive records and equipment checklists are properly done and recorded.

- Maintain communications with the diver/s at all times and record all communications throughout the entire duration of the dive, starting from the time the diver leaves the surface till the time the diver arrives on the surface, subjected to a minimum duration of 48 hours.

- Maintain training records with certification by an accredited organisation to supervise commercial diving operations safely on site.

3.4.2 Diver

The diver is responsible for the following duties which may include but not limited to:

- Have attended and completed relevant diving courses by an accredited organisation with the competencies and experience, e.g. updated diver's logbook records of using the required diving equipment safely.

- Possession of a valid dive medical certificate issued by a qualified and registered medical physician.

- Perform a pre-dive check on the personal diving equipment to ensure it is working properly to meet the dive requirements and the assigned tasks.

- Understand the dive project plan and be able to comply with the operation and emergency procedures.

- Update the diving supervisor on any equipment faults, potential hazards, near misses or accidents on site.

- Maintain personal diving equipment after use.

- Complete the records in the personal diving logbook with endorsement from diving supervisor after each dive.

- Inform the diving supervisor if there is any medical or other reason which diver is deemed not suitable to dive.

- Report any medical problems or symptoms that occur during or after the dive.

3.4.3 Standby Diver

Standby diver/s should be present on the surface whenever there are divers underwater. For every two[2] divers in the water, there should be **one** standby diver and one standby diver's attendant on the surface.

Prior to the dive, both the diver and standby diver are required to check and test their helmets/ masks and all diving equipment to be in working condition. The standby diver should be fully dressed and be ready for instructions to put on the checked and tested helmet/mask and diving equipment, as well as be ready to dive when required by the diving supervisor. The standby divers should be provided with an umbilical that is at least 5 metres (16.5 feet) longer than the diver's umbilical to facilitate emergency use.

As both the standby diver and diver work closely in any diving operation, the roles and responsibilities of the diver in Para 3.4.2 are applicable to the standby diver too.

Generally, the diving operation is planned such that the standby diver does not perform any duties other than the duties of the standby diver. However, in the event of an emergency, if the standby diver is unable to decompress in the water, he must be placed in a recompression chamber on the surface to complete his decompression. In line with SS511:2018, Para 11.7.2 for planned decompression diving, a deck decompression chamber needs to be on site.

3.4.4 Diver's Tender

The diver's tender is a surface member of the dive team and should assist the diver/standby diver in preparation and during the diving operation as follows:

- Briefed by the diving supervisor on the diving task to be carried out by the diver.
- Understand the actions required in the event of an emergency.
- Understand the requirements of underwater/subsea work.
- Understand diving signals and communications, and verbal and line signals.
- Understand decompression procedures.
- Have a good knowledge of how diving plant and equipment work.

In normal circumstances the diver's tender/attendant will be a qualified or trainee diver. In the event that the diver's tender/attendant has no formal training in the duties and responsibilities required, such training should be provided.

3.4.5 Standby Diver's Attendant

Similar for the diver's tender, a standby diver's attendant is a surface member of the dive team and should assist the standby diver in preparation during the diving operation as well as emergency or site-specific contingency.

[2] Where two divers are in the water at the same time, they shall not act as standby diver for each other under any circumstances. A standby diver should always be present on the surface.

3.4.6 Common Functions of Dive Team

The following table summarises common functions which should be observed.

S/N	Functions	Diving Supervisor	Diver	Standby Diver	Diver's Tender	Standby Diver's Attendant
1	Conduct pre-dive and post-dive checks on diver's personal diving equipment.	x	x	x	x	x
2	Report faulty equipment or unsafe situation to diving supervisor/ diving contractor.	x	x	x	x	x
3	Understand the dive project plan, task to be assigned and is within one's competence.	x	x	x	x	x
4	Participate in WSH briefings and activities • Risk Assessment • Toolbox talks • Pre-dive	x	x	x	x	x
5	Equipped with valid dive medical certificate(s) to ensure fitness to dive at the time the operation starts.	See note[3]	x	x		

[3] If otherwise required, under normal circumstance, diving supervisor does not dive as the role is to monitor the diving operation at the control panel. In such case, a valid dive medical certificate is not required.

S/N	Functions	Diving Supervisor	Diver	Standby Diver	Diver's Tender	Standby Diver's Attendant
6	Attend to diver who is underwater or subjected to pressure using proper decompression procedures in line with ascent rates and in-water decompression stops in accordance with dive/ decompression tables.	x			x	x
7	Proper management of umbilical/lifeline to eliminate slack or tension, rupture by protrusion, debris or any seabed obstruction structures.				x	x
8	Maintain lifeline signals and communication with diver, keeping diving supervisor informed.				x	x

S/N	Functions	Diving Supervisor	Diver	Standby Diver	Diver's Tender	Standby Diver's Attendant
9	Attend to diver at the start of dive • Check top-side air supply for normal operation e.g. purity, pressure and quantity to last for the duration of dive. • Dress diver and ensure diver is fully equipped with personal diving equipment.				x	x
10	Stay on the surface and monitor the diving operation and diver's sequence of activities — from start when diving helmet is put on till end of diving when diving helmet is removed.			x	x	x

S/N	Functions	Diving Supervisor	Diver	Standby Diver	Diver's Tender	Standby Diver's Attendant
11	Stay vigilant for any signs of emergency and when required, call for assistance from diving supervisor and standby diver.				x	x

Table 3: Summary of common functions of dive team.

3.4.7 Dive Team Size

The dive team size should commensurate with the planned diving operation and the assigned task(s).

One working diver

Water depth of less than 1.5 metres

In shallow water depth of less than 1.5 metres, the minimum size of dive team is at least **four** personnel, mainly diving supervisor, diver, dive tender and standby diver. For an additional diver in the water, there is a need for another diver's tender to attend to the diver's umbilical/lifeline. This is applicable in relatively shallow waters in a benign location, e.g. aquarium or swimming pool. In the event where there is an additional working diver, there is a need for another diver's tender/attendant to attend to the diver's umbilical/lifeline.

Water depth of 1.5 metres to 50 metres

Generally, in most diving operations, where the depth of water is greater than 1.5 metres and up to 50 metres with one working diver in the water, the dive team must be made up of at least **five** personnel, consisting of the diving supervisor, diver, dive tender, standby diver and standby diver's attendant. There may also be a need for dive equipment technician to operate machinery or support the diving operation.

Note

Within Singapore waters the majority of diving operations are conducted at a maximum depth of 30 metres of sea water.

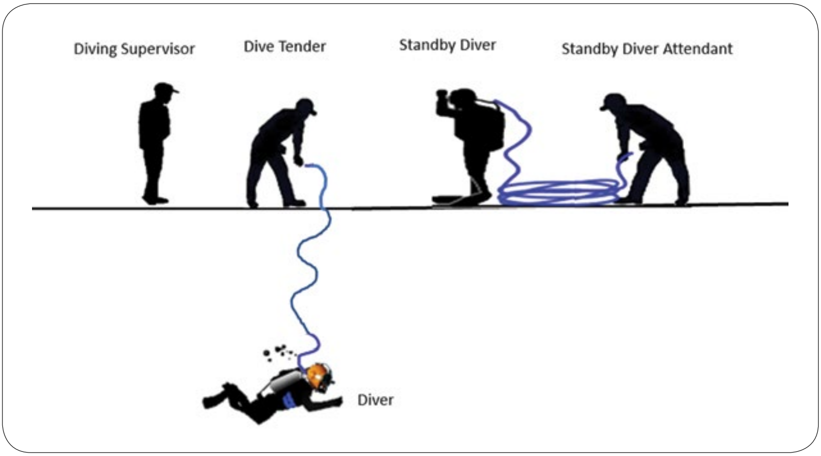

Figure 3: Five-men team with one diver.

Two or more working divers

In the case of **two** or more working divers in the water at the same time, ensure a diver's tender is available to tend to each diver, and a standby diver should be equipped and dressed in a ready mode to be activated at any time. As a requirement, ensure one standby diver and his standby diver's attendant on the surface for every two divers in the water, giving a total of at least a **seven-men** dive team.

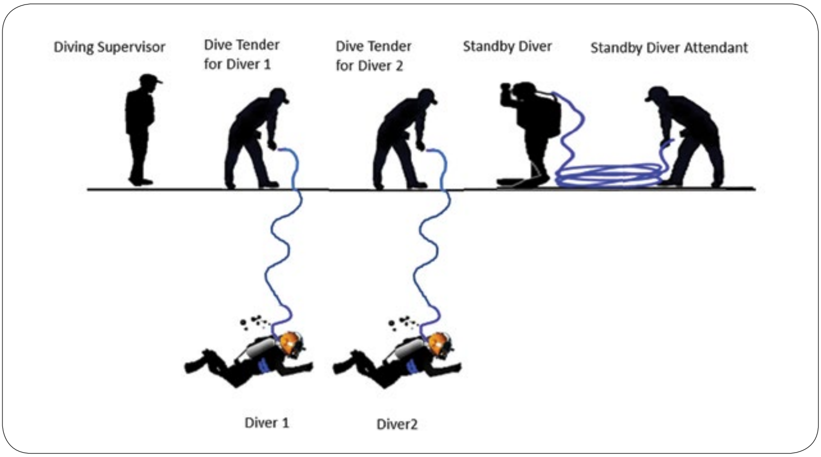

Figure 4: Seven-men team with two divers.

4. Equipment and Maintenance

This section introduces the various equipment used in commercial diving necessary to facilitate a safe diving operation.

The equipment used may be divided into three basic categories:

- Personal Diving Equipment
- Commercial Diving Equipment — CSCUBA and SSDE/SSBA
- Plant and Equipment

Refer to the specific category or equipment for more information on selecting the right equipment and the considerations essential for workplace safety and health.

4.1 Personal Diving Equipment

A commercial diver is equipped with the basic personal diving equipment comprising suits, fins/boots and gloves which serve as a personal protective equipment (PPE) against thermal stress and injury, e.g. cuts and abrasion from physical contact or other harmful exposures when working around marine encrusted surfaces.

In order to be effective, PPE thermal barrier, suits, gloves and fins/boots need to be tight-fitting, including the zipper. In addition to the diving suits, dry suits are used in near-cold water as well as contaminated water environment.

Refer to Annex B — Personal Diving Equipment Components.

4.2 Commercial Diving Equipment

4.2.1 Commercial Self-Contained Breathing Apparatus (CSCUBA)

The use of CSCUBA is applicable for diving operations with a water depth not exceeding 30 metres of sea water. The diver receives main air supply from the high pressure (HP) cylinder while emergency supply is provided by bail-out cylinder.

For a safe dive operation, diving supervisor needs to ensure the diver's air cylinders are fully charged, the main supply air supply cylinder and emergency air supply cylinder endurance calculations are established, and the diver is equipped with the appropriate diving equipment. There should be no disruption to the assigned task due to limited air supply which will affect diver's concentration.

A CSCUBA diver shall be equipped with diving equipment provided by diving contractor company. Refer to SS511:2018, Para 13.1.6 for details.

Some of the key highlights in WSH include:

Face Mask Checking for Good Seal

It is essential that the face mask protects the diver's face and allows him/her to carry out the assigned task. It is important to check if there is any crack on the glass of the face mask which can result in possible water seepage. The mask should also sit comfortably on the diver's face with good sealing with air space required for clear vision.

Lifeline for Communication

As the lifeline does not come with surface air supply, communication amongst the dive team is important due to limited air supply. The dive team need to be trained on the use of the lifeline for both communication modes, namely, rope signal as well as hard-wire communication. The lifeline must be secured/attached to the diver's full body harness using a screw gate/ lockable karabiner. Refer to SS511:2018, Para 4 on dive tender's roles and responsibilities in lifeline management.

Submersible Pressure Gauge — Accuracy

A Submersible Pressure Gauge (SPG) needs to show accurate reading of the air supply in the tank. Hence SPG should be regularly calibrated and tested to fulfil its function for safe diving. Divers use such information to determine the appropriate time to surface safely so as to mitigate the risk of sustaining injury.

Buoyancy Compensator Device — Tight Fitting

Buoyancy Compensator Device (BCD) allows diver to stay afloat in diving and should provide a good fit as an oversized or loose BCD may subject the diver to choking hazard due to the sliding of the chest straps against the base of his/her neck. BCD should not be used in lifting heavy loads or assist in reaching the surface which can lead to uncontrolled ascent thus endangering the diver's life.

4.2.2 Surface Supplied Diving Equipment (SSDE)/Surface Supplied Breathing Apparatus (SSBA)

SSDE/SSBA is carried out for diving operation in water depth not exceeding 50 metres of sea water. Breathing air is supplied from the surface via an umbilical attached to the diver's harness which is connected to the helmet.

The diver receives air supply from low pressure (LP) and high pressure (HP) sources as well as bail-out cylinder in the event of emergency. The equipment also provides two-way verbal communication between diver and diving supervisor where the conversation is recorded throughout the dive.

Similar for the CSCUBA diver, all surface supplied diving equipment needs to be maintained to be fit-for-purpose so as to ensure that there is no failure or malfunction of equipment during the diving operation. For instance, prior to each dive, dive tenders and diver are required to check that all the regulators and the fittings are working, and any leak should be reported to the diving supervisor immediately.

Besides dive control station items, e.g. dive control panel/air supply panel, diver's communication equipment and recording equipment, diving contractor/company ensures a SSDE/SSBA diver is equipped with the following minimum items:

- Diving helmet
- Diver's umbilical with lifeline/communication line
- Diver's full body harness
- Emergency air supply cylinder

Note
Umbilical to equip with the minimum breaking strain of at least 6 kN as umbilical may serve as a lifeline to lift diver safely, in line with SS511:2018, Para 9.7.7.2.

Some of the key highlights in WSH include:

Dive Control Panel

LP and HP setting

Diver obtains the breathing air from the surface cylinders/surface LP Compressor. There must be a primary independent air supply for each diver, with a secondary air supply as emergency air supply (LP and HP) supplied via the pressure regulators in the dive control panel. Correct setting of the supply pressures is important so that the right pressure and volume of air is supplied to the diver. The fittings and connections need to be checked to ensure no leaks.

Critical Components

The dive control panel also houses other critical components which include gauges, e.g. depth gauge, LP and HP gauges which need to be tested and calibrated regularly to ensure accurate readings.

Diving supervisor uses the depth gauge readings to:

- Monitor the deepest depth during the dive and along with the time spent at the depth.
- Determine if the diver requires to carry out decompression.
- Ensure a safe ascent diver's profile without subjecting the diver to the risk of suffering decompression illness.

Figure 5: Dive control panel with monitor and communication recording system.

Diver’s Umbilical with Lifeline/Communication Line

Unlike the CSCUBA diver, the umbilical used by a SSDE/SSBA diver comes with a hose that maintains continuous surface air supply and diving supervisor is able to monitor the well-being and safety of the diver whereby:

i. A lifeline coupled can be used as a rope signal for communication with attendant.

ii. The umbilical which consists of a communication cable serves as a hard-wired communication between diver and the diving supervisor.

Maintain continuous air flow

The umbilical should consist of a single length without any joint to provide a continuous flow of air supply at the required pressure. Any leak will lead to reduced air supply flow, thus endangering the diver’s life.

Length variation of umbilicals

The umbilical needs to be well secured to the harness of the diver using karabiners of industrial grade. The length of umbilical used by the standby diver is at least five metres longer than the one used by working diver to facilitate rescue in the event of emergency. The diving contractor determines the exact length deemed suitable for the project.

Figure 6: **Diver’s umbilicals.**

Figure 7: **Diver’s communications equipment.**

Diver’s Communications Equipment

Good communication is essential during any diving operation, e.g. with the use of hard-wire and in emergency such as rope signals using line pulls. This is a two-way communication between the diver underwater and the diving supervisor at the surface. Any lapse in communication between the diving supervisor, diver and attendant may result in the occurrence of a diving incident. For instance, a diving supervisor monitors the diver’s breathing rate and air consumption to determine possible signs and symptoms of diving illness or cardiac arrest.

There is a need to visually check the communication equipment for any defects such as loose contacts, broken wires as well as umbilical/communication line for any cuts or damage to the insulation material. Any cut or defect detected on the umbilical/communication line should be rejected and labelled as ‘Not For Use’.

Recording Equipment

“Black box” recording of conversation between diver/s and diving supervisor is crucial especially in incident investigation to determine the actions and activities that occurred prior to and during a diving incident.

It is essential to ensure quality in the recording of the voice communication such as clear conversation and video recordings. If the camera is available on the helmet, e.g. monitor diving operation, this should help to follow through the diving operation and to derive useful information for operational and investigation purposes, when required. The recordings of conversation also include the diver’s breathing pattern to assess the level of difficulty of the activity performed by diver. This can help to determine if additional assistance of a standby diver needs to be activated. There should be a backup of the recording device for storage of the media such as a hard drive or memory card for playback where necessary too.

The set-up of recording equipment and diver’s equipment are placed in proximity to the diver’s control panel so that the diving supervisor has full control of the diving operation and recording functions. As these are electronic equipment, there is a need to ensure there is proper storage to prevent humidity as well as protection to prevent water seepage into the equipment.

Figure 8: **Recording equipment.**

All alternating current (AC) powered equipment should be used with a ground fault interrupter in line with manufacturer's recommendations or instruction manual/guide.

4.3 Plant and Equipment

The plant and equipment used in diving operation includes the following items:

- Air cylinders (HP and bail-out)
- Regulators (1st stage and 2nd stage)
- Air compressors (LP, HP)
- CSCUBA Replacement Package (SRP)
- Deck Decompression Chamber (DDC) — when required

Some of the key highlights in WSH include:

4.3.1 Air Cylinders

All cylinders (HP and bail-out) supplied on-site should be identified for use with serial number, hydro test date, correct colour code and 'diving quality air' label in line with BS EN 12021 and certificate of analysis requirement. For instance, HP cylinders for use on surface should be accompanied by in-date, five yearly hydrostatic test and inspection certificate. Refer to Annex C — Recommended Equipment Periodic Test and Examination Schedule, in line with SS 639:2018 (Part 1) — Annex A requirement.

High Pressure (HP) Cylinders

The quads comprising HP cylinders (range from 6 to 64) in a frame should be stored in sheltered place and dry area to prevent corrosion of the metal surface body of the cylinders, pipes and fittings as well as the lifting pad-eyes. Corrosion can lead to leaks which result in reduced air pressure to the diver/s. A lifting plan with correct lifting technique should be employed during loading and unloading of the quads or the cylinders. As the pressure of the cylinders ranges from 200-300 bars and the physical dimension, e.g. tall standing bottles which can be unstable, a risk assessment needs to be carried out to ensure their safe use.

Bail-out Cylinders

As a safe work practice, all divers shall carry bail-out cylinders as an emergency. If the CSCUBA diver is carrying a twin set, then it is normal to breathe one cylinder down and equalise from the second cylinder for reserve breathing air when required. Alternatively, a 'pony bottle' may also be attached to the HP cylinder for use with a dedicated second stage regulator. Bail-out cylinders for use under water shall be colour-coded correctly and labelled "diving quality air" with a clear and visible serial number, in-date two yearly hydrostatic test and accompanied with inspection certificate.

Diving supervisors are responsible to ensure there is sufficient emergency air supply for the diver to return to the surface. There is a need to calculate the time available in the bail-out cylinder such that there is a minimum of one minute of breathing air available for every 10 metres of umbilical provided from the tending point.

Figure 9: HP cylinders in quads.

Figure 10: Bail-out cylinder.

<u>Calculation of Free Gas Volume</u>

It is a recommended practice to calculate the total volume of air supply, known as free gas volume for gas cylinders supplied in quad.

Example

A 12 x 50 litre quad contains air at a pressure of 100 bar. What is the total volume of air in the quad? (Free gas volume = floodable volume x pressure)

Free gas volume = (number of cylinders x floodable volume) x pressure
= (12 x 50) x 100
= 600 x 100
= <u>60</u> m^3

4.3.2 1st Stage and 2nd Stage Regulators

Regulators are used to reduce the air pressure from high pressure of the air cylinders to a low pressure that can be used for breathing by the divers in stages, e.g. 200 bars to 10 bars and from 10 bars to ambient pressure.

Ensure the right type of regulators (1st stage or 2nd stage) with the correct fitting used on the connection points for the purpose of reducing the pressure. Failure to do so may result in injury to the diver. The oral nasal attachment needs to be properly checked for the condition that it has a good seal, and it is tight fitting before use by the diver.

Figure 11: 1st stage regulator.

Figure 12: 1st stage regulator connected to bail-out cylinder.

Figure 13: 2nd stage regulator on diver helmet.

4.3.3 Low Pressure (LP) and High Pressure (HP) Air Compressors

Diving contractor should ensure the air compressor [4] fulfil the compressed air purity standard of BS EN 12021. Refer SS511:2018, Para 9.8 Breathing Air Quality.

All the air compressors, air receiver, filters, regulators, piping and fittings need to be regularly maintained in line with Planned Maintenance System (PMS). For instance, it is recommended to conduct a minimum three-monthly periodic testing of the air quality to ensure the breathing grade. There should also be relevant records such as compressor certification and operation logs.

<u>Rating of Air Compressor</u>

Compressors are rated according to the volume and pressure of air that they can produce per minute. They are also known as free gas volume of air that is delivered to the diver.

For instance, an air compressor with rating of 11.5 ft^3/min @7.5 bar, supply air capacity of 11.5 cubic feet per minute at a pressure of 7.5 bar. For safety reasons, diving contractor needs to ensure the right air compressor is used to meet the job assigned with the required air supply pressure and supply volume.

Determining the supply pressure of air compressor

Example

At a maximum depth of 50 metres of sea water (165 feet of sea water) in a diving operation, the pressure is 6 bar absolute. With an allowable pressure of 10 bar (145psi) for the regulator, the compressor supply pressure required is at least 16 bar (235psi).

[4] Industrial air compressors and vessel air are not acceptable air supply sources due to the presence of substantial contaminants. Enriched air (Nitrox) or pure oxygen should not be used too. Refer 'Diver's breathing gas standard and the frequency of examination and tests' by Health and Safety Executive (HSE) on the frequency of air purity test.

Determining if the air supply capacity is sufficient for diver

Example

A LP compressor delivers 250 litres/min at a pressure of 15 bar is used for diving operation on-site. One diver plans to work at a depth of 20 metres of sea water (msw). Is the air supply sufficient for both him and the standby diver? The commercial diver is estimated to consume 35 litres (1.25ft^3) of air per minute[5].

$$\text{Absolute pressure} = \frac{\text{Depth (msw)}}{10} + 1 \text{ bar}$$

$$= \frac{20}{10} + 1 \text{ bar}$$

$$= 3 \text{ bar}$$

Allow 10 bar[6] for the demand valve:

$$\text{Pressure required} = (3 + 10) \text{ bar}$$

$$= 13 \text{ bar}$$

The compressor delivers 15 bar, so the delivery pressure is suitable.

Air consumption	= Absolute pressure (bar) x 35 litres/min
Absolute pressure	= 3 bar
Air consumption for 2 divers	= 3 x 35 x 2 litres/min
	= 210 litres/min

The compressor delivers 250 litres/min so the compressor's air delivery volume of 250 litres/min is adequate for the diving operation.

4.3.4 CSCUBA Replacement Package (SRP)

A typical CSCUBA Replacement Package (SRP) comprises a portable frame-mounted unit with three or four HP cylinders and two divers' umbilicals stowed on the frame. Together with the equipment will be the dive control panel, communications box, batteries/power supply, communication recording device and personal diving equipment.

The SRP encompasses safety features of SSDE/SSBA which include:

- Communications between the diver, standby diver and diving supervisor.

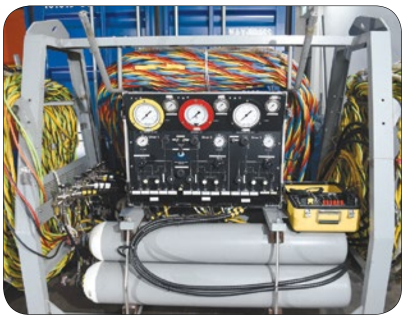

Figure 14: Typical frame-mounted SRP with dive control panel and communication box.

[5] For illustration purpose only. To adopt more stringent criteria in accordance with industry practice/guide where applicable.

[6] For illustration purpose only. To adopt recommendation in accordance with manufacturer/operation guide, where applicable.

- Independent air supply and quantity for the working diver, complete with back-up emergency air supply.

- Independent air supply and quantity for the standby diver, complete with back-up emergency air supply. (Note the back-up emergency air supply may be common with the diver's emergency supply)

- Ability by diving supervisor to perform suitable depth monitoring of the diver and to use lifeline to monitor the safety of the diver.

- Recording device that records all communications between the diver/s and diving supervisor.

4.3.5 Monitoring the Diver's Depth and Decompression Requirement of the Diver

The diving supervisor uses the diver's actual bottom time, depth reading from depth gauge and dive table to assess the need of any decompression requirement for the diver.

4.3.6 Deck Decompression Chamber (DDC)

A deck decompression chamber (DDC) is a pressure vessel for Human Occupation (PVHO) built to design standards which may include ASME PVHO-1, BS EN 14931 and be examined, tested and approved before use as required under the Workplace Safety and Health (General Provisions) Regulations.

A DDC allows the divers to complete their decompression stops at the end of a dive on the surface. As this is done on the surface, it eliminates the decompression risks and thermal stress to the diver due to cold or dangerous conditions underwater.

Refer to SS511:2018, Para 11.7 Requirement For On-site Chamber on the need for a DDC on planning of dive to or more than 30 metres in depth, and Section 9 of this document on Emergency Response Plan for details.

Figure 15: DDC (external) with control panel.

Figure 16: DDC (internal).

4.4 Planned Maintenance System

Planned Maintenance System (PMS) is a periodic maintenance programme for diving equipment used in safe diving operation. PMS is a systematic way to ensure diving equipment is well maintained to be fit for purpose and ready for use. This is a periodic inspection to ensure maintenance and testing are done in accordance with manufacturers' recommendations and the requirements of the diving contractor's own procedures.

The diving company/contractor should ensure all maintenance and repair of diving plant and equipment are carried out by trained and competent equipment technicians whilst the inspection and testing can be done by owner of the equipment. For instance, technicians working on diving helmets, masks and regulators should have completed an appropriate maintenance training course at a training facility approved by the manufacturer for the equipment.

Refer to Annex C on Recommended equipment periodic test and examination schedule. Refer to SS511:2018, Para 3.29 for more details on PMS.

4.5 Diver's Air Supply Volumes

To ensure a safe diving operation at all times which includes emergency, the diving contractor needs to make sure that there is sufficient air supply with the appropriate pressure from a suitable source, e.g. LP and HP diving air compressors so that there is no disruption and added risks to the assigned tasks carried out by diver due to the emptying of the air cylinders. HP air compressors are used to charge the divers bail-out cylinders and HP air storage cylinders for use.

Figure 17: Typical LP air compressor.

Figure 18: Typical HP air compressor.

Calculation of Air Capacities

To facilitate the calculations at a surface absolute pressure of one bar, we have considered the average breathing rate for diver is 35 litres/min of air under normal condition and 40 litres/min of air in the event of emergency.

The following examples will illustrate the various scenarios required to ensure there is sufficient air capacities for the diver(s) required in the diving operation.

1. Calculation of the volume of air required by diver:

Example

A diver is working at 20 metres of sea water (msw) for 30 minutes under normal condition. What volume of air will the diver require?

Solution

$$\text{Absolute pressure} = \frac{\text{Depth(msw)}}{10} + 1 \text{ bar}$$
$$= \frac{20}{10} + 1 \text{ bar}$$
$$= 3 \text{ bar}$$

$$\text{Gas consumption} = \text{Absolute pressure (bar)} \times 35 \text{ litres/min}$$
$$= 3 \times 35 \text{ litres/min}$$
$$= 105 \text{ litres/min}$$

For an assigned task of 30 mins, the amount of air consumed

$$= 30 \text{ min} \times 105 \text{ litres/min}$$
$$= 3150 \text{ litres}$$
$$= 3.1 \text{ m}^3$$

The diver will use 3.1 m^3 of air

(Note: air volumes in cubic metres).

2. Calculation of the duration of the air supply in the following forms before supply runs out:

a) Quad supply

The diver is now working at 20 msw, breathing from a quad at a pressure of 100 bar. Although the pressure is at 100 bar, the air is being supplied to the diver at 20 msw, where the pressure is 3 bar. The 3 bar is not available to the diver.

It also takes a certain amount of pressure e.g.10 bar to operate the demand valve. Altogether 13 bar of supply air pressure is not available to the diver. The net pressure that the diver can receive from the quad is 87 bar.

In practice, the diving supervisor would allow a considerable reserve pressure, and would normally change over to a new HP quad when the pressure drops to about 40 bar. In this case the available pressure would be (100 – 40) bar, or 60 bar. It is the available pressure that must be used in all calculations.

To find out how long the diver could work for, use this formula:

$$\text{Time available} = \frac{\text{Gas available}}{\text{Gas consumption}}$$

Example

A diver is working at 20 msw, breathing from a 12 x 50 litre quad at a pressure of 100 bar. How long could he work for? (Assume that the quad will be changed over at 40 bar)

<u>Solution</u>

$$\begin{aligned}
\text{Floodable volume} &= 12 \times 50 \text{ litres} \\
&= 600 \text{ litres} \\
&= 0.6 \text{ m}^3
\end{aligned}$$

$$\begin{aligned}
\text{Available pressure} &= (100 - 40) \text{ bar} \\
&= 60 \text{ bar}
\end{aligned}$$

$$\begin{aligned}
\text{Free gas volume} &= \text{floodable volume x available pressure} \\
&= 0.6 \times 60 \text{ m}^3 \\
&= 36 \text{ m}^3
\end{aligned}$$

$$\text{Gas consumption} = \text{Absolute pressure x 35 litres/min}$$

$$\begin{aligned}
\text{Absolute pressure} &= \frac{\text{Depth (msw)}}{10} + 1 \text{ bar} \\
&= \frac{20}{10} + 1 \text{ bar} \\
&= 3 \text{ bar}
\end{aligned}$$

$$\begin{aligned}
\text{Gas consumption} &= 3 \times 35 \text{ litres/min} \\
&= 105 \text{ litres/min}
\end{aligned}$$

$$\begin{aligned}
\text{Time available} &= \frac{\text{Gas available}}{\text{Gas consumption}} \\
&= \frac{36{,}000 \text{ litres}}{105 \text{ litres}} \\
&= \underline{342} \text{ minutes}
\end{aligned}$$

The diver has enough air available for 5.7 hours = 5 hours 42 minutes

Note

The above example only determines the amount of air (in minutes) available to the diver. The actual dive time of the diver (in minutes) is however limited by the dive times stated in the on-site industry dive tables, mentioned in Section 5.3.3.

The same calculation can be used if the diver is working with CSCUBA, as illustrated in the next example using HP cylinder.

b) HP cylinder

Example

A diver is working at 20 msw, breathing from a 1 x 10 litre CSCUBA cylinder at a pressure of 200 bar. How long could he work for? (Assume that the diver will surface when the CSCUBA pressure is 40 bar)

<u>Solution</u>

Floodable volume = 1 x 10 litres
= 10 litres

Available pressure = (200 – 40) bar
= 160 bar

Free gas volume = floodable volume x available pressure
= 10 litres x 160 bar
= 1600 litres

Gas consumption = Absolute pressure x 35 litres/min

$$\text{Absolute pressure} = \frac{\text{Depth (msw)}}{10} + 1 \text{ bar}$$

$$= \frac{20}{10} + 1 \text{ bar}$$

$$= 3 \text{ bar}$$

Gas consumption = 3 x 35 litres/min
= 105 litres/min

$$\text{Time available} = \frac{\text{Gas available}}{\text{Gas consumption}}$$

$$= \frac{1600 \text{ litres}}{105 \text{ litres}}$$

= <u>15</u> minutes

The CSCUBA diver has enough air available for 15 minutes, with a reserve of 40 bar to get him back to the surface.

c) Bail-out cylinder

The bail-out bottle serves as a back-up supply for diver in an emergency. The deeper the depth, the less time allowable for diver to get back to surface.

The dive project plan must include a pre-assessment that the divers' bail-out has sufficient capacity for the planned diving task.

Example

A bail-out bottle with working pressure of 180 bar used by a diver has a floodable volume of 12 litres. How much time has the diver have if his surface supply fails at 20 msw where the bail-out is activated?

Solution

The bail-out bottle is at a pressure of 180 bar. At 20 msw the pressure is 3 bar, add on 10 bar for the regulator and that is 13 bar that the diver cannot use.

Available pressure = (180 – 13) bar
= 167 bar

Free gas volume = floodable volume x available pressure
= 12 x 167
= 2004 litres

This is an emergency, so allow a consumption of 40 litres/min. The absolute pressure is 3 bar

Gas consumption = (40 x 3) litres/min
= 120 litres/min

$$\text{Time available} = \frac{\text{Gas available}}{\text{Gas consumption}}$$

$$= \frac{2004}{120}$$

$$= \underline{16} \text{ minutes}$$

The diver has about 16 minutes of air available from his bail-out cylinder.

5. Common Hazards

This section discusses common hazards encountered by commercial diver while working inland/inshore within Singapore territorial waters, which are relevant at various stages of diving operation, for example, at surface, descent bottom, ascent and at surface. These hazards include:

1. Environmental hazards
2. Operational hazards
3. Physiological hazards
4. Other hazards (flying after diving)

In line with the common hazards, Annex I summarises the possible risks associated with the hazards in commercial diving.

The risk management of the common hazards in commercial diving will be covered in Section 6 of this guideline.

5.1 Environmental Hazards

The types of environmental hazards that a diver will encounter is dependent on the conditions around the vicinity of diving operation as well as the associated activities in the dive site. These conditions may include but not limited to weather, sea state, wind, tide, currents, water temperature, depth and water condition while the associated activities comprise scheduled vessel movements (ship traffic), hull cleaning, crane operation where manual tools, hydraulics and other machinery may be used. All divers working both on land (above surface) and underwater may be affected by these environmental conditions which may subject the divers to unnecessary risks. For instance, currents and tidal effects both on the surface and underwater will affect the diver's normal activities as well as standby diver who may need to provide emergency rescue in the event of a diver in distress.

In the event of adverse environmental conditions, site owner, client and diving supervisor need to ensure the safety of the dive team and non-dive team personnel whereby decision is to be made on whether the dive operation is to be postponed or prematurely terminated based on the diving supervisor's advice.

Environmental hazards may arise from the following conditions:

- Currents, tides, tidal range and slack water
- Contaminated water diving
- Restricted surface visibility
- Restricted underwater visibility
- Sea state
- Weather
- Dangerous marine animals

5.1.1 Currents, Tides, Tidal Range and Slack Water

- Huge flowing masses of water within a body of water with periodic rise and fall, e.g. ocean currents, tidal currents, rip currents and river currents near estuary.

- Slack water reduce visibility underwater as there is little or no current to remove debris such as mud or sand.

Possible risks to divers:

- Diver may suffer fatigue due to drifting movements which requires energy to overcome additional forces of water.

- Diver's ability to make right judgement is affected due to the differences in the current readings e.g. speed and direction near surface and in deep waters; and variation of the low and high tide readings which changes daily.

5.1.2 Contaminated Water Diving[7]

Contaminants may include industrial toxins, chemicals, biological, effluents, pathogens, domestic and foreign pollutants such as mud, silt and sand.

Possible dive sites include sewerage systems, discharge systems of platforms, rigs, ships as well as outfalls from power plants or manufacturing facilities and the vicinity.

Possible risks to divers:

- Diver's visibility to perform work safely is affected.
- Added weight to diver due to the portable radiation probe or monitoring device carried by diver. The probe or monitoring device needs to be calibrated for accuracy and reliability.

5.1.3 Restricted Surface Visibility

<u>Day Diving</u>

Fog or mist caused by droplets of water suspended in the air. Inclement weather such as heavy storm contributes to restricted surface visibility.

<u>Night Diving</u>

In the event that diving is done during the night with restricted visibility on surface and underwater there may be a need for surface lighting to ensure there are no 'dark areas' at the work site. There is a need to avoid movements of other vessels/craft and other obstructions at the surface. Proper dive planning and scheduling of dive operation are critical in such situation. All band masks and helmets must be installed with underwater light in order to assist divers in safe passage ascent and descent.

[7] a) Organisation or appointed competent person to be engaged to check, test and confirm the presence of contaminants in the contaminated water. Useful information, if available, such as the safety data sheets on the nature of the contaminants with the hazards and risk control measures can ensure the safety of the divers.

b) Diving with or near radioactive materials will require specialist advice on radiation safety from National Environmental Agency with reference to Radiation Protection Act 2007.

Possible risks to divers:

- Visibility affects surface operation especially so for night diving. Divers may not be able to see the presence of nearby vessels/floating structures and may be prone to be hit by surface traffic, especially for night diving.

- Emergency rescue work is affected too. The personal lights carried by divers may not provide the required visibility in the presence of fog or mist or during night diving.

5.1.4 Restricted Underwater Visibility

The underwater visibility is affected by the strong currents and passage of large vessels/ships which create turbulence and agitation to the silt, sludge and industrial waste present in the water.

Possible risks to divers:

- Poor image resolution on the diver's camera which affects video communication between diver and diving supervisor at the dive control panel.

- Diver underwater may face difficulty of surfacing to the dive boat and prone to hit against submerged structures or other obstructions such as fallen scaffold structures, scrap metal or even entangled with debris caught by fishing nets.

- Slow down diver's response and agility to escape attack by the presence of dangerous marine animals.

5.1.5 Sea State

Rough sea condition with choppy waters affects work from a support vessel/floating structure before dive boat launch and recovery.

Possible risks to divers:

- Strong water currents affect divers when entering or leaving water as well as during decompression stops.

- Surface crew and diver prone to seasickness or potential injury due to rocky movement of dive boat.

5.1.6 Weather

Weather conditions caused by wind speed and direction, rain and fog, inclement weather e.g. cold/wet, extreme heat, storms and lightning which may affect operation on a support vessel/floating structure as well as on a dive boat.

Possible risks to divers:

- Hot weather: Risks of sunburn, windburn, and heat exhaustion to divers and non-dive team. Overheating of umbilical/lifeline stored on deck may take place. Extreme heat caused by direct sunlight can cause deck chamber's temperature to rise and affect the electronic equipment as well as the comfort and concentration levels of personnel.

- Cold weather: Diving operation in cold water causes diver to lose heat more than he gains. It can lead to muscle tension, increased intake of oxygen, hallucination, loss of consciousness, ventricular fibrillation and even death.

5.1.7 Dangerous Marine Animals

Potential dangerous marine animals include fire coral, jellyfish and invertebrates like blue ringed octopus, stonefish, sea snakes and shark.

Possible risks to divers:

- Injury due to bites or stings from marine animals which can be painful or venomous and may result in fatality.

- Electric eel when present in the vicinity of work site may cause electric shock to divers.

5.2 Operational Hazards

The types of operational hazards encountered by divers may result from the operational conditions in which task activities are carried out. These may include but not limited to the use of the tools, equipment, e.g. electrical, pressurised and hydraulic-driven lifting of loads/moving objects; working with dangerous goods and substances hazardous to health with potential hydrocarbon release; and working with high differential pressure environment.

Operational hazards may arise from the following conditions:

- Water Intake
- Differentials in pressure
- Confined space/overhead environment
- Entanglement/entrapment
- Electrical shock
- Explosion

5.2.1 Water Intake

The dive sites involve divers working near propellers, thrusters or intakes on operating vessels with underwater forces present, e.g. suction or turbulence.

Possible risks to divers:

- These water intake hazards produce movement of water where divers can be trapped or crushed by the moving machinery resulting in serious or fatal injuries.

5.2.2 Differentials in Pressures

Common diver accidents that occur are caused by differential pressure that exist between the water pressures on the two sides of a barrier, e.g. sluice gate or at the discharge outlet of a small body of water. For instance, diver working in a swimming pool of water depth of 1.5 metres may be subjected to this risk if there is discharge of water via any outlet.

Possible risks to divers:

- Due to the pressure difference, divers can be drawn in by the cyclical vortex movement and pinned against suction intakes, resulting in injuries like lost limbs or fatal accidents.

5.2.3 Confined Space/Overhead Environment

Divers underwater in a confined space situation is subjected to an overhead environment which obstructs direct vertical access to the open water surface. Similar to other confined spaces in terms of the limited number or size of openings for entry and exit, the typical underwater confined spaces and the corresponding activities include the following:

- Installation, repair and maintenance, e.g. sewer line.
- Shipyard diving, e.g. dock.
- Cleaning, e.g. ship hull with cleaning machine equipped with rotary brushes that come with hydraulic hoses.
- Irrigation siphon repair, maintenance, and debris removal.
- Underwater dredging and construction activities.
- Recovery and rescue operations in areas with limited access.

Prior to work activities involving confined space or overhead environment, a confined space entry permit which is part of the dive project plan needs to be issued. Some of the key provisions include the need to identify the safe routes of access to and egress from the confined space, provision of backup lights to ensure sufficient light intensity and continuous supply of breathing air. More details to be included in the Dive Project Plan in Section 7.

Possible risks to divers:

- Divers may panic and become confused as they lose sight of landmarks and the direction due to the existence of 'ceiling' or overhead environment which forms a barrier for diver to sense the surroundings.

- Risk of drowning due to faulty equipment, e.g. no/poor communication, breaking of umbilical and lifeline.

5.2.4 Entanglement/Entrapment

The diver is required to visually check that the lifeline/umbilical is clear and free from entanglement. This is especially important after crane activities where there was lowering of objects to the diver. All electrical cables, e.g. communication, light and camera need to be waterproofed and regular pressure testing should be done for the umbilical. The lifeline and/or umbilical used by divers can get entangled or entrapped if it is not properly maintained and managed. For instance, the tender or attendant can help to ensure the required length of the lifeline and/or umbilical to be used and any excess length should be retained on the deck. The diver and tender use line signals at two ends of the lifeline and umbilical to ensure the tender can 'feel' the diver moving at the other end of the line.

In the event that the diver becomes entangled or trapped the diver should try to free himself, while the diving supervisor will activate the standby diver if required. For more details, refer to Section 9 on Emergency Response Plan.

Possible risks to divers:

- Entrapment may result in possible run out of breathing air supply with breakdown in communications. Divers may panic, become disorientated and respond inappropriately. Drowning may occur thereafter.

5.2.5 Electric Shock

Divers may need to use powered electric tools when performing underwater activities, e.g. cutting, grinding, brushing and polishing activities.

Potential risks to divers:

- Divers may suffer possible electric shock or burns when using electric tools with exposed electric cable or improper connections.

5.2.6 Explosion

Explosion on surface or underwater can occur due to:

- Pressure build-up in the air cylinders
- Ignition of flammable gases

Possible risk to divers:

- Ear drum and bodily injuries caused by blast wave and flying shrapnel thrown out by an explosion.

5.2.7 Use of Crane when Diving

Injuries to diver may occur during crane activities used in:

- Handling of heavy loads
- Subsea installation works

Possible risk to divers:

- Struck by lifting load or moving machinery

5.3 Physiological Hazards

The types of physiological hazards may result from the physical environment faced by the divers followed by the divers' response and reaction which may not align with the standard operation procedures or safe work practices. As a result, these hazards may affect the normal bodily functions of the divers, resulting in possible common diver illnesses.

5.3.1 Drowning

Drowning can occur when a diver starts to panic underwater as a result of equipment failure where surface communication is severely affected, or the diver's breathing apparatus becomes detached. While it is very rare for a commercial diver using SSDE/SSBA and full-face masks/dive helmets to drown, this is a common occurrence with CSCUBA diver when the lifeline and umbilical are entangled, and the diver is unable to free himself before his air supply runs out.

All suspected near-drowning victims should be conveyed to hospital for observation for 24 hours.

Possible health effects that could occur in the diver include:

- Entry of liquid into the lungs of diver which may result in:

    - Immediate death due to suffocation (asphyxia) which impedes the absorption of oxygen leading to brain injury (cerebral hypoxia) and cardiac arrest.

    - Eventual death known as 'secondary drowning' resulting from a reaction to the inhalation of sea water. (Note: Diver may be conscious during initial stage of rescue/recovery).

5.3.2 Thermal Stress

Divers working at sea on surface and underwater are prone to thermal stress arising from exposure to a hot or cold environment. It is the responsibility of the diving supervisor to protect the divers and non-dive team against these hazards so that work activities can be carried out safely and without harm to all personnel. The pre-dive project plan or risk assessment should include the risk control measures to address the cold stress or heat stress problems anticipated by the dive team personnel.

Possible health effects that could occur in the diver include:

- Diver's body would respond accordingly leading to the following effect:

  Hyperthermia — raising of the body temperature as a result of heat stress.

    - Occurs when the body temperature rises above the normal 37°C due to exertion in a hot environment. A potential risk if the air temperature exceeds 32°C and the water temperature is above 27°C. Heat exhaustion and heat stroke may result if body temperature continues to rise further. For more information, refer to the Workplace Safety and Health Guidelines on Managing Heat Stress in the Workplace.

Hypothermia — lowering of the body temperature as a result of cold stress.

- A form of "thermal drain" due to prolonged heat loss from our body which try to maintain the body temperature of around 37°C. Further cooling of body temperature can cause serious though not life-threatening physiological changes. Refer to Annex D on the expected hypothermia symptoms at approximate core body temperatures.

5.3.3 Decompression Illness (DCI)

Decompression illness occurs when there is a reduction in the ambient pressure surrounding the body which is followed by the formation of bubbles within the body system. The two common types of DCI include Decompression Sickness (DCS) or bends and Arterial Gas Embolism (AGE). Refer to Annex E for more information on DCI.

As a precautionary measure, the use of on-site industry dive tables (with guidance on the timing to remain at a respective depth) and availability of Deck Decompression Chamber (DDC) should be part of the dive planning.

Possible health effects that could occur in the diver include:

- Musculoskeletal pain which affects the joints, e.g. shoulder, elbows, wrists, ankles and knees.
- Shortness of breath.

5.3.4 Barotrauma

Barotrauma, which means "pressure injury", is damage due to the differences in pressure between the various cavities in the diver's body and the surrounding water. Barotrauma may occur during ascent or descent. The type of pressure injury that a diver may be exposed to depends on the body system or tissue that is affected. Pre-dive project plan should emphasise the importance of dive tables for guidance on ascent rate.

Possible health effects that could occur in the diver include:

- Injuries to ears, nose, neck, heart, lungs as a result of presence of air pockets.

Refer to Annex F on recognising the signs and symptoms of barotrauma.

5.3.5 Shallow Water Blackouts

A shallow water blackout or underwater "faint" is a loss of consciousness caused by a lack of oxygen supply to the brain. This occurs towards the end of a breath-hold dive in water typically shallower than 5 metres (16 feet).

As a precaution, breath-hold dive and hyperventilation should not be practised concurrently during commercial diving operations.

Possible health effects that could occur in the diver include:
- Loss of consciousness due to the elevated carbon dioxide levels in the body.
- Brain damage or even death due to the deprivation of oxygen in the body.

5.3.6 Nitrogen Narcosis

Nitrogen narcosis can affect a diver's perception. The extent of nitrogen narcosis increases with the depth the diver takes. The diving supervisor needs to monitor the diver and if necessary, abort the dive if the diver exhibits signs of nitrogen narcosis at any time.

Refer to Annex G on recognising the signs and symptoms of nitrogen narcosis.

Possible health effects that could occur in the diver include:

- Affecting diver's motor skills, e.g. slowed-down thinking and reaction times.

- Abnormal mental functioning. For instance, diver may display at-risk behaviour such as removing the regulator oral nasal attachment or diving to unsafe depths.

- Impairment to body's thermoregulation (temperature control) system which can lead to hypothermia.

5.3.7 Oxygen Toxicity

Oxygen toxicity is a condition resulting from the harmful effects of breathing oxygen (O_2) at elevated partial pressures. Any deviation with oxygen used for breathing at a partial pressure greater than 1.6 bar may cause injury to the body's central nervous system and pulmonary system (affecting the lungs). Acute oxygen toxicity is characterised by convulsions followed by unconsciousness while chronic oxygen toxicity can cause difficulty in breathing and pain within the chest. This diver illness is common in DDC operations when treating the injured diver.

Possible health effects that could occur in the diver include:

- Affecting the brain, spinal cord and lungs due to the overdosage of oxygen by exceeding the recommended maximum exposure limits of partial pressure of oxygen in diving.

5.3.8 Carbon Dioxide Toxicity

In diving operation, carbon dioxide build-up or toxicity (hypercapnia) occurs as a result of too much of carbon dioxide in the breathing supply or respiratory system and body tissues such that carbon dioxide produced by the body is not eliminated properly by the equipment or by the diver.

Some of the factors leading to the carbon dioxide toxicity may include:

- Inadequate ventilation of surface supplied helmets.
- Inefficient diving equipment, e.g. faulty helmet/mask/oral nasal unit.
- Excess carbon dioxide in the helmet supply.
- Inadequate lung ventilation caused by controlled breathing.
- Over exertion during work and irregular breathing patterns.

Possible health effects that could occur in the diver include:

- Affecting hearing and causing nausea, slowing of responses, flushed skin, muscle twitching, convulsions, shortness of breath and may lead to unconsciousness.

Refer to Annex H on recognising the signs and symptoms of Carbon Dioxide Toxicity.

5.3.9 Carbon Monoxide Poisoning

Carbon monoxide (CO) is a product of combustion of organic matter with restricted oxygen supply. The difficulty to detect the presence of CO using our senses pose a hazard as it is colourless, odourless, tasteless and non-irritating. Carbon monoxide poisoning occurs through inhalation of the gas present in exhaust of internal combustion engines, generators, propulsion engines of boats. This is caused by drawing in of impure air e.g. near exhaust of engines or generators into air supply cylinder via the air compressor which may be improperly sited.

Refer to Annex I on recognising the signs and symptoms of Carbon Monoxide Poisoning.

Potential health effects that could occur in the diver include:

- Headaches, vertigo, nausea, and flu-like effects in mild poisoning, while severe poisoning can lead to impairment of the central nervous system, heart and even death.

5.4 Other Hazards

5.4.1 Flying After Diving

Travel to altitude following diving may be required upon completion of diving project. A recommended safe practice is to ensure diver observes a minimum delay time prior to flying after diving.

Refer to Annex J for more details.

Potential health effects that could occur in the diver include:

- Increased risk of decompression sickness caused by bubble formation in tissues due to the reduced ambient pressure at high altitude.

6. Risk Management

This section covers the risk assessment of common commercial diving hazards identified in Section 5.

The outline of this section includes Risk Management process with coverage on:
- Steps involved in Risk Assessment
- Risk evaluation using 5x5 risk matrix
- Suggested risk control measures for the common hazards

For more details, refer to the Code of Practice on WSH Risk Management, published by the WSH Council — termed as RMCP.

6.1 Risk Management (RM) Process

Under the Workplace Safety and Health (Risk Management) Regulations, prior to work commencement, it is a requirement to conduct risk assessments (RAs) to address the safety and health risks posed to any person who may be affected by the activities in the workplace. In commercial diving, all stakeholders in the diving project which include the client, diving company/contractor and diving supervisor, are required to manage risks at the worksite while dive team and non-dive team personnel should adhere to safe work practices at all times.

WSH RM is a systematic way to identify, assess, control and monitor risks associated with diving activities. This is followed by the effective two-way communication and consultation of these risks to all internal and external stakeholders as well as the divers and support personnel. The communication is done throughout all stages of the RM process and can take the form of toolbox talks, training, dialogues, notice boards or other electronic means. Refer to Figure 19 for the 5-stage RM process.

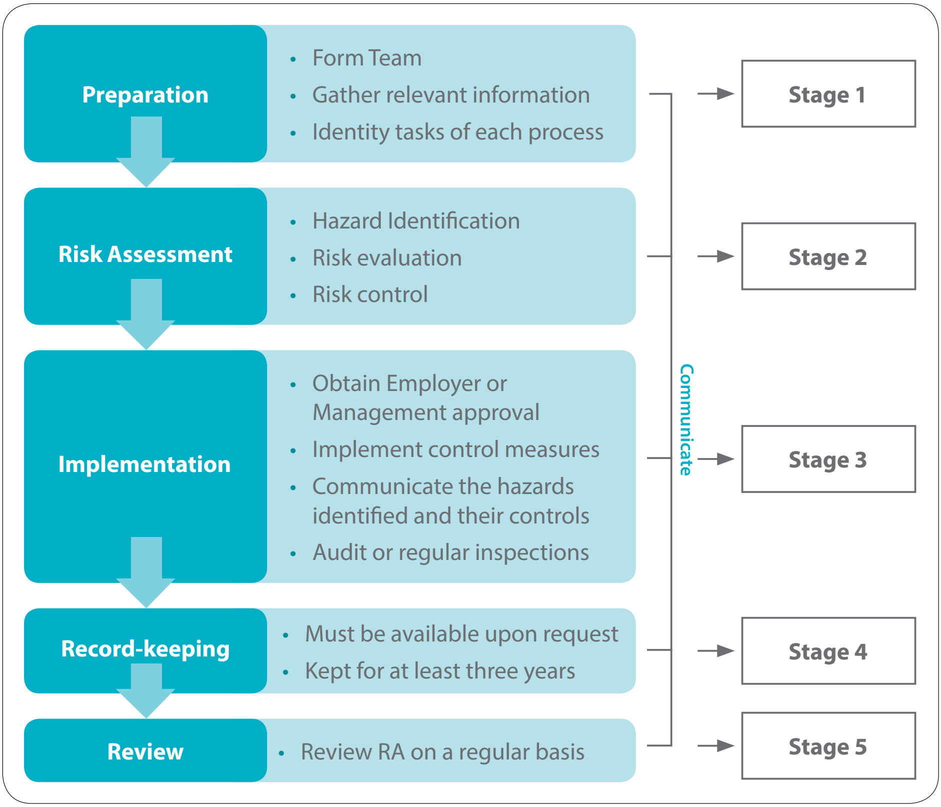

Figure 19: Risk Management (RM) Process.

The **five** stages in the RM process cover:

6.1.1 Preparation (Stage 1)

Prior to the conduct of an RA, there is a need to form a team with diverse experience and background. An RA leader is appointed to lead the team. This is followed by gathering of relevant information such as industry practice, accidents and near miss incidents useful for the understanding of the RA work process and identification of the tasks for each process.

6.1.2 Risk Assessment (Stage 2)

The RA comprises:

<u>Hazard Identification</u>

To identify hazards (as covered in Section 5) that can lead to incidents in commercial diving. These hazards are summarised under the following categories:

- Environmental hazards
- Operational hazards

- Physiological hazards
- Other hazards (flying after diving)

Risk Evaluation

This involves estimating the risk levels of the hazards and determining the acceptability of the risks to as low as reasonably practicable. This is followed by prioritisation of the actions with the risk control of these hazards to minimise the WSH risks encountered by the dive team or non-dive team personnel.

Existing risk controls need to be considered when assessing the risks to gauge the effectiveness of these controls. In the event of any WSH gaps identified, the risk of the activity/task can be reviewed and further assessed.

Based on the severity of risk[8] and the likelihood of an accident[9], a 5x5 risk matrix with numeric ratings or Risk Prioritisation Number (RPN)[10] can be used to determine the risk level at low, medium or high.

Guide to Severity and Likelihood Ratings for Determining RPN and Risk Levels

Table 4 provides a guidance on the severity level based on 5x5 risk matrix.

Level	Severity	Description
5	Catastrophic	Death, fatal diseases or multiple major injuries.
4	Major	Serious injuries or life-threatening occupational diseases (includes amputations, major fractures, multiple injuries, occupational cancers, acute poisoning, disabilities and deafness).
3	Moderate	Injury or ill-health requiring medical treatment (includes lacerations, burns, sprains, minor fractures, dermatitis and work-related upper limb disorders).
2	Minor	Injury or ill-health requiring first-aid only (includes minor cuts and bruises, irritation, ill-health with temporary discomfort).
1	Negligible	Negligible injury.

Table 4 : Guide to severity rating with the levels and the description of injuries.

[8] Severity (S) of risk — Degree or extent of injury or harm caused by the hazards or the result of an accident, which is classified as minor, moderate or major.

[9] Likelihood (L) of an accident, incident or ill-health — Probability of an incident will happen classified under remote, occasional or frequent.

[10] RPN is obtained by multiplying the values of Severity and Likelihood level, that is, RPN = S x L.

Table 5 provides a guidance on the likelihood level for a 5x5 risk matrix. Pre-existing medical conditions or other personal risk factors, if any, of person(s) who need to conduct the activity/task should be considered in the selection of likelihood level.

Level	Likelihood	Description
1	Rare	Not expected to occur but still possible.
2	Remote	Not likely to occur under normal circumstances.
3	Occasional	Possible or known to occur.
4	Frequent	Common occurrence.
5	Almost Certain	Continual or repeating experience.

Table 5 : Guide to likelihood rating with the levels and the description.

Numeric ratings or RPN can be determined by multiplying the severity and likelihood levels, RPN = S X L as shown in Table 6.

Likelihood / Severity	Rare (1)	Remote (2)	Occasional (3)	Frequent (4)	Almost Certain (5)
Catastrophic (5)	5	10	15	20	25
Major (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	15
Minor (2)	2	4	6	8	10
Negligible (1)	1	2	3	4	5

Table 6 : A 5x5 risk matrix with numeric ratings/RPN.

Recommended Actions at Risk Levels (Low, Medium, High)

Table 7 illustrates the recommended actions for implementation based on the risk level and the risk acceptability.

Checking the Risk Level (or RPN) for Acceptability

For risk level rated as High, additional controls need to be considered to eliminate the risk or reduce it to Medium level or Low level, where feasible. This is followed by re-evaluation of the severity, likelihood and RPN levels which should be lower than the initial levels.

Risk level	Risk Acceptability	Recommended Actions
Low	Acceptable	• No additional risk control measures may be needed. • Frequent review and monitoring of hazards are required to ensure that the risk level assigned is accurate and does not increase over time.
Medium	Tolerable	• A careful evaluation of the hazards should be carried out to ensure that the risk level is reduced to as low as reasonably practicable (ALARP) within a defined time period. • Interim risk control measures, such as administrative controls or PPE, may be implemented while longer term measures are being established. • Management attention is required.
High	Not acceptable	• High Risk level must be reduced to at least Medium Risk before work starts. • There should not be any interim risk control measures. Risk control measures should not be overly dependent on PPE. • If practicable, the hazard should be eliminated before work starts. • Management review is required before work starts.

Table 7 : Recommended actions for risk levels.

All outcomes of the re-evaluation are recorded in the RA form (Sample) as shown in Figure 20.

Department:		RA Leader:		Approved by:		Reference Number
Process:		RA Member 1:		Signature:		
Activity/Location:		RA Member 2:				
Assessment Date:		RA Member 3:		Name:		
Last review Date:		RA Member 4:		Designation:		
Next review Date:		RA Member 5:		Date:		

	Hazard Identification			Risk Evaluation				Risk Control						
Ref	Sub-Activity	Hazard	Possible Injury/ Ill-health	Existing Risk Controls	S	L	RPN	Additional Controls	S	L	RPN	Implementation Person	Due Date	Remarks
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

Notes:

Page ____ of ____ page(s)

Figure 20: **Sample Risk Assessment Form.**

Risk Control

Table 8 shows the hierarchy of controls which can be utilised to select the risk control measures for the work activity/task.

Control measures such as elimination or substitution in the higher level of hierarchy are more effective as the risk is reduced at, or close to the source. This measure needs to be considered first where possible.

Hierarchy of Controls	Effectiveness	Risk Control Examples
Elimination	Most Effective ↓	Eliminate the need to work directly with unknown hazards present in confined spaces or overhead environment. Consider using autonomous guided vehicle with remote operation.
Substitution		Replace all faulty equipment and parts with loose connection or exposed cables to mitigate the risk due to possible electric shock by divers underwater. Consider the use of direct current (DC) instead of alternating current (AC) for equipment and machinery.
Engineering Controls		Design a guard with screen or grids to cover drainage or discharge point to protect diver against hazards caused by differentials in pressure.
Administrative Controls		Implement safe work procedures for maintenance of diving tools and equipment, e.g. a checklist to ensure umbilical/lifeline is well maintained and does not result in entanglement.
Personal Protective Equipment (PPE)	Least Effective	Ensure PPE provided is fit for purpose, e.g. diving suit should be in good condition to provide thermal protection for underwater operation.

Table 8 : Hierarchy of controls.

6.1.3 Implementation (Stage 3)

Before implementation, all completed RA forms need to be approved by Management, e.g. manager of an area, function or activity where the risk is assessed.

The employer/diving contractor or manager is to ensure the following in the implementation of the risk control measures:

- Use of a detailed action plan with the timeline and the names of persons responsible for the implementation.

- All recommended measures are implemented as soon as possible with regular monitoring, inspections and process audits to ensure the effectiveness of the risk control measures.

- All persons exposed to the risks are well informed of the nature of the risks and the measures or safe work procedures implemented, if any.

- Updating of the RA form is done to reflect the implementation of additional controls, where applicable. For more information, refer to Appendix E, RMCP on Updating the RA Form After Implementation.

6.1.4 Record-keeping (Stage 4) and Review (Stage 5)

The manager shall assist the employer/diving contractor to ensure:

- RA records, including but not limited to the RA forms and control measure records, are available upon request and safe kept for at least three years.
- Risk Register is readily available for review on a regular basis by designated persons at the workplace and regulatory agencies.

6.2 Suggested Risk Controls for the Common Hazards

In line with the common hazards (identified in Section 5) for commercial diving, the suggested risk control measures are summarised in Table 9. Diving contractors are required to work closely with site owner/client/principal to ensure a safe diving operation.

S/N	Environmental Hazards	Possible Risk to Divers	Suggested Risk Controls
1	**Currents, tides, tidal range and slack water**	• Fatigue diver due to drifting movements. • Affects ability to make right judgement of the current readings, e.g. speed and direction; and variation of the low and high tide readings.	• Ensure diving is conducted only at slack times as part of dive project plan. • Ensure divers are provided with a harness and lifeline. • Check tides and current tables from Singapore Tide Tables (Figure 21) and NEA meteorological service for updates on the weather conditions.
2	**Contaminated water diving**	• Diver's visibility to perform work safely is affected. • Added weight to diver due to the portable radiation probe or monitoring device carried by diver.	• Provide diver with dry suit or disposable oversuits. • Ensure the risk assessment includes check on the contaminated water for odour, colour and appearance. • Ensure that after decontamination of diver and diving equipment are done, there is provision of medical evaluation, where necessary. • Consider the use of remotely operated vehicles (ROV) such as autonomous guided vehicles (AGV) or autonomous underwater vehicles (AUV) with remote function for diving operation.

3	**Restricted surface visibility**	• Visibility affects surface operation, resulting in the inability to see nearby vessel/floating structures and prone to be hit by surface traffic, especially for night diving. • Emergency rescue work is also affected. The personal lights carried by divers are not bright enough in the presence of fog/mist or during night diving.	• Maintain lookout for other activities, e.g. nearby vessels and divers. • Use radio communication to maintain safety. • Use dive flag, display lights 'red-white-red', light buoys to inform others that the diving operation is in progress. • Work closely with surface support personnel. • Include in the dive project plan the need to suspend dive operation due to severe restricted surface visibility, where the decision will be made by the diving supervisor. • For diving at night, ensure that the diver carries additional bright lights with a wide beam. This complements the light or any indicating/flashing strobe light or safety light on the diver's hat. • Provide adequate lighting to illuminate the area of work. • Proper dive planning and scheduling of night diving operation is critical to avoid movements caused by other vessel/craft or obstructions in the nearby vicinity.

4	**Restricted Underwater Visibility**	• Poor image affects video communication between the diver and diving supervisor. • The diver finds difficulty in surfacing to the dive boat and prone to hit against submerged structures or other obstructions. • Slow down response and agility to escape attack by dangerous marine animals.	• Conduct a pre-dive assessment to assess the need to look for alternative dive sites in view of the possible risks to divers. • Designate safe entry/exit points for diver. • Ensure diver maintains close contact with tender/attendant or buddy. • Inform diver to maintain communication with dive control. • Ensure diver and dive team are familiar with lost diver procedure. • Provide diver with shield to guard against dangerous marine animals. • Deploy additional diver(s) where necessary.
5	**Sea State**	• Strong water currents affect divers when entering or leaving water as well as during decompression stops. • Surface crew and diver prone to seasickness or potential injury due to rocky movement of dive boat.	• Check the NEA Meteorological Service for tides, currents. • Ensure diver and surface crew are seated and buckled up with seat belt during rough sea conditions. • Cancel or postpone dive if wave condition is not safe for diving.

6	**Weather**	• Hot weather — Sunburn, windburn, and heat exhaustion. Overheating of umbilical/ lifeline, deck chamber affects electronic equipment and concentration levels of personnel.	Hot weather • Conduct brief for diver and non-dive team to prepare them for dive in hot weather conditions. • Provide shady or cool place for rest. • Ensure divers are provided with liquids which are non-alcohol or non-caffeinated to keep them hydrated. Lightning • Ensure facility owner/operator and diving supervisor received a timely lightning alert notification in order to suspend diving operations, if necessary, for the safety of the dive team.
7	**Presence of Dangerous Marine Animals**	• Injury due to bites or stings from marine animals which are painful or venomous and may also result in fatality. • Electric eel when present in the vicinity of work site may cause electric shock to divers.	• Diver to maintain buoyancy to stay clear of possible encounter with dangerous marine animals, e.g. fire corals and sea urchins on the seabed. • Provide a first-aid box at the dive site. • Include risk assessment on contact with dangerous marine animals in dive project plan.

Table 9 : **Environmental hazards and potential risks to divers.**

Tide Tables

CSCUBA Diving Methods With Use Of A Lifeline

Location In water	Current (knots)	0.0 to 0.8kts	0.8 to 1.0kts	1.0 to 1.2kts	1.2 to 1.5kts	1.5 to 2.0kts and beyond
Mid-Water Work		Normal Work	**NB1	**NB2	Diving operations not permitted	
Bottom Work		Normal Work	**NB1	**NB2	Diving operations not permitted	

Surface Supplied Diving Equipment Diving Methods

Location In water	Current (knots)	0.0 to 0.8kts	0.8 to 1.0kts	1.0 to 1.2kts	1.2 to 1.5kts	1.5 to 2.0kts and beyond
Mid-Water Work		Normal Work	Observation	**NB1	**NB2	
Bottom Work		Normal Work	Light Work	Observation	**NB1	**NB2

Figure 21: **Working recommendations in currents.**

**NB1 — Diving by means of this method in these currents should not be a routine operation. The Diving Supervisor should consult with the divers involved and any other person he judges necessary about the best way to conduct such an operation.

** NB2 — Diving by means of this method in these currents should not be considered unless the operation has been pre-planned taking account of the presence of high current from the early stages of the project. Special solutions involving equipment techniques and procedures should have been evolved to overcome or protect the diver from the effects of currents and to provide contingencies for foreseeable emergencies.

Note:

In the above Figure 21, workplace experience and anecdotal evidence have been evaluated in order to:

- Indicate the increasing restrictions placed on diving operations by increaing current strength.
- Facilitate identification of certain conditions beyond which it would be unwise to continue diving.
- Operate purely on a routine basis.

It must be appreciated, however, that it is impractical to be definitive in identifying the restrictions imposed by certain current conditions since these are affected by so many variable factors. The values in the above tide tables should, therefore, be applied with a degree of flexibility taking account of diver feedback.

S/N	Operational Hazards	Possible Risks to Divers	Suggested Risk Controls
1	**Water intake**	• Water movements may cause divers to be crushed by the moving machinery.	• Ensure lock-out tag-out or other mechanical isolation e.g. suitable guard or screen with holes on suction intakes is installed, as part of engineering controls. • Ensure risk assessment includes no underwater obstruction hazards in the vicinity of diving project area.
2	**Differentials in pressure**	• Cyclical vortex movement can pin diver against suction intakes, resulting the loss of limbs or fatal accidents.	• Equalise any pressure differentials prior to commencement of diving project. • Before commencing dive operations, ensure the owner/ operator provides site facility for dive contractor to do joint on-site verification of all isolation locations with lock-out tag-out (LOTO) in place. • Isolate the hazard using LOTO and include it as part of the permit-to-work system. • Place signages to restrict access to such exclusion zone. • Identify the high and low-pressure sides underwater. Dive from the low-pressure side.

Table 10 : Operational hazards and the potential risks to divers.

			• Ensure any isolation valves present are positively identified, closed with LOTO tag in place to prevent unauthorised opening and are not leaking by checking at the low-pressure side. • Ensure only SSDE/SSBA equipment are used for diving project where differential hazards have been identified.
3	**Confined space/ overhead environment**	• Overhead environment or ceiling forms a barrier for diver. When diver loses sight of surroundings, he may panic and become confused. • Risk of drowning due to faulty equipment with breakdown in communication and breaking of umbilical and lifeline.	• Include in dive project plan the possibility of lost diver due to confined space/overhead environment hazards. • Consider other alternatives where available to replace dive in this environment. • Use tethered diving where diver in water is tended by surface personnel.
4	**Entanglement/ entrapment**	• Possible to run out of breathing air supply due to breakdown in communication. Diver starts to ascend rapidly, suffers lung injury, loses his way and becomes disorientated. Drowning may occur thereafter.	• Restrict the umbilical lengths. • Use of engineering control e.g. guard, screen on suction or moving machinery.

5	**Electric shock**	• Possible electric shock or burns due to use of powered tools with exposed electric cable or improper connections.	• Install Ground Fault Interrupter (GFI) for use with underwater electrical equipment. • Conduct proper inspection of underwater electric equipment before using the prepared daily equipment checklist. • Use of DC instead of AC for underwater use e.g. underwater cutting or welding. • Equip with proper PPE when handling electrical items. Do not place diver within the circuit.
6	**Explosion**	• Ear drum and bodily injuries caused by blast wave and flying shrapnel thrown out by an explosion.	• Provide adequate ventilation when recharging lead-acid batteries which may generate hydrogen gas. • Ensure a safe system in place for handling explosives which may be used in blasting operation. • Ensure no detonation of explosives while diver is in the water.
7	**Use of crane when diving**	• Struck by lifting load or moving machinery.	• Subsea crane operations with divers should be equipped with a lifting plan in line with company's standard operation procedures. • Ensure all lifting machine, lifting equipment and appliances are load tested and certified by MOM authorized examiner. Refer to MOM Examination and Testing Requirements for Statutory Lifting Equipment.

S/N	Physiological Hazards	Possible Risks to Divers	Suggested Risk Controls
1	**Drowning**	• Entry of liquid into the lungs can lead to Immediate death due to suffocation (asphyxia) or eventual death known as 'secondary drowning' caused by inhalation of sea water.	• Ensure all divers undergo safe diving practices to prevent drowning. • Introduce tethered diving. • Ensure regular maintenance of diving equipment.
2	**Thermal exposure**	• Hypothermia (lowering of the body temperature below 37° C) or hyperthermia (raising of the body temperature above 37° C) due to exertion in a hot environment. • Heat exhaustion and heat stroke may result if body temperature continues to rise further.	Hypothermia • Conduct pre-inspection of zip and seals on dive suit to ensure no leak leading to insulation loss. Hyperthermia • Ensure diver and dive team are constantly hydrated before dive.
3	**Decompression illness (DCI)**	• Musculoskeletal pain which affects the joints. Shortness of breath due to the difficulty to exhale the gas bubbles trapped in the lungs.	• Ensure divers who enter water are medically or physically fit. • Inform divers who are trained to ascend slowly and to avoid multiple ascents.
4	**Barotrauma**	• Injury to ears, nose, neck, heart and lungs as a result of air presence.	• Ensure dive project plan includes safe ascent and descent by divers. • Maintain physical fitness and hydration.

5	**Shallow water blackouts**	• Loss of consciousness due to the elevated carbon dioxide levels in the body. • Brain damage or even death due to the deprivation of oxygen in the body.	• Include in Dive Project Plan that breath-hold diving, and hyperventilation should not be practised in commercial diving operation.
6	**Nitrogen narcosis**	• May affect motor skills and thermoregulation (temperature control) system. • Display of at-risk behaviour.	• Ensure diving supervisor is trained to identify signs and symptoms of Nitrogen Narcosis exhibited by diver. • To abort the dive if diver exhibits signs of Nitrogen Narcosis at any time.
7	**Oxygen toxicity**	• Affect brain, spinal cord and lungs due to exceeding the recommended maximum exposure limits of oxygen in diving.	• Ensure breathing air grade is in line with industry standard e.g. BS EN 12021 especially on the specified partial pressure and concentration of oxygen.
8	**Carbon dioxide toxicity**	• Affect hearing and cause nausea, slowing of responses, flushed skin, muscle twitching, convulsions, shortness of breath and may lead to unconsciousness.	• Design breathing apparatus e.g. SSDE/SSBA with minimum dead space. • Ensure sufficient volumetric oxygen supply to regulator/helmets. • Ensure breathing of pendulum type to maximise amount of air being inhaled and exhaled.

9	**Carbon monoxide poisoning**	• Cause headaches, vertigo, nausea, and flu-like effects in mild poisoning while severe poisoning can lead to impairment of the central nervous system, heart and even death.	• Ensure the air compressor is correctly sited to prevent carbon monoxide intake into compressor which compresses contaminated air into the diver's air cylinder. • Ensure dive site is located at a safe distance from combustion systems, e.g. generators and propulsion engines to prevent divers from breathing in carbon monoxide.

Table 11 : Physiological hazards and the potential risks to divers.

S/N	Other hazards	Possible Risks to Divers	Suggested Risk Controls
1	**Flying after diving**	Increase risk of decompression sickness caused by bubble formation in tissues due to the reduced ambient pressure at high altitude.	Ensure there is follow-up session with appointed hyperbaric and diving specialist/physician after diver undergoes therapy for DCI. Ensure diver follows the Annex J guideline on the minimum time to avoid flying after diving.

Table 12 : Other hazards and the potential risks to divers.

7. Dive Project Plan

This section covers the procedures involved in dive planning and organising to minimise the extent and duration of the diver's exposure to risk during the diving operation. It helps diving company/contractor to address the hazards with the risk controls to ascertain the readiness of the dive team before embarking on the dive project.

The outline of this section covers:
- Elements in Dive Operations Planning
  - Preparation and Support Documents
- Assessment for Readiness in Dive Operations
  - Dive Briefings, Pre-dive Check
- Post-dive/Debrief

7.1 Dive Operations Planning

Preparation

A diving project plan agreed by all parties involved is prepared prior to a dive and followed throughout the dive unless the dive is aborted. A copy of the dive project plan should be available at the dive site, understood by divers and within their competencies. Relevant documents/records, e.g. risk management, management of change, near misses and incident reporting, diving equipment and maintenance procedures should be included.

The dive project plan should minimally cover but not limited to the following aspects of the diving operations planning:

Elements	Description
Planned diving method	The planned diving method for the tasks includes the use of diving equipment, other equipment and tools, e.g. checklists for pre-dive/post-dive.
Breathing air	Use of safe breathing air with sufficient quantities required and in compliance with BS EN 12021 with at least a three-monthly frequency of air purity test.
Work procedures	Step-by-step work procedures which may include ascent and descent of divers, planned bottom times and decompression profiles within the limits of diving decompression tables and the procedures (refer Annex K on Sample Decompression Procedures), and deck decompression sheet (refer to Annex L for a sample).

Dive rota	The dive rota of dive team personnel with the duties involved in the task, medical fitness[11] and competency.
Assessment of hazards and specific task hazards	Assessment of hazards and specific task hazards with risk control measures which may include environmental and water conditions, e.g. visibility, tidal, presence of contaminates, pressure differentials and obstructions.
Dive register or training matrix	A diver register or training matrix with training records such as qualification, certification, years of diving experience, and issuing authority of training.
Emergency Response Plan	The Emergency Response Plan with the contingencies and evacuation procedures, e.g. recovery of an injured/unconscious diver from working depth to a safe place for medical treatment and facilities; decompression illness and the treatment. Contingency and response plans need to be executed regularly by the diving contractor and respective parties involved.

Table 13: **Elements in dive operations planning.**

Training and competencies of dive team

Divers are required to attend the dive medical first aid and all dive team personnel shall be trained and qualified in Occupational First Aid certification (subjected to a two-year refresher) or equivalent and equipped with the specific competencies on the application of the diving techniques for the diving equipment and the use of safe work procedures. For instance, the following course certification or equivalence is relevant for the diver and diving supervisor:

- Workforce Skills Qualifications (WSQ) Commercial Diving Competency Standards Diver Course certification or its equivalence for CSCUBA and/SSDE/SSBA.

- WSQ Commercial Diving Competency Standards Diving Supervisor or its equivalent for CSCUBA and/SSDE/SSBA.

There should not be more than 12 months between the last medical assessment and any dive undertaken by diver and standby diver, to ensure their health and medical fitness for the assigned task(s). (Refer to SS511:2018 Annex D, Table D.4 Guidelines For Medical Examination)

Note

Recreational SCUBA diving qualifications and military diver training shall not be suitable for commercial diving operations outlined in these WSH Guidelines.

[11]All divers undergo a rigorous medical examination conducted by a qualified medical practitioner or doctor who is registered as a Medical Physician with Ministry of Health. The doctor should have attended a local occupational medicine course and attained a certificate in Diving and Hyperbaric Medical Physician with chamber operation. Dive team member who is required to dive shall possess a valid dive medical certificate issued by the doctor.

Support Documents

To support the dive project plan the following documents should be available for use and for reference:

Documents	Description
Risk Management Process Records	Includes records such as Job Hazard Analysis. (Refer Sample in Annex M and Toolbox Talk Sample Checklist in Annex N)
Management of Change Procedure	A systematic approach with proper documentation of the changes, rationale and communication process.
Safety Management Interface Document	Includes bridging documentation.
Documentation	Diving operations manual and records, e.g. logbook, log sheet, diver certification/qualification and diver's medical record.
Diving equipment maintenance procedure	Includes Planned Maintenance System.
Operational plans	Mobilisation or demobilisation plans.
Relevant code of practice, standards	Includes guide with safe diving practices.
Setup of organisation structure	Organisation chart with line of authority and level of responsibility.
Permit to Dive	Diving permit-to-work system and records.
Hazard communication	Use of warning signages, e.g. vessel Lock-Out Tag-Out and display of flags and diving signals at diving location. Refer to Annex O on Sample Signage on Divers At Work.

Table 14: Documents to support elements in dive operations planning.

Refer to SS511:2018 for more details on Diving Operations Manual (Para 6.1.3), Dive Project Plan (Para 6.1.4) and Dive Log Sheet (Annex A).

7.2 Assessment for Readiness in Dive Operations

In diving projects, site owner/client is required to seek clearance from authority, e.g. Maritime and Port Authority of Singapore via dive proposal submission based on a Diving Permit-to-work. The diving permit requires a comprehensive risk assessment and safety management system in place for the diving activities involved. Refer to Annex F on Sample Diving Permit-to-work.

The risk assessment for the submission which comes with pictorial attachments may include but not limited to:

- Ensure buoyancy is provided for heavy equipment and tools required for the diving operation to mitigate the risk of handling heavy loads by diver (refer to Section 5).

- Provide 'hogging' lines as leverage for divers to be kept close while working under ship hulls, near sea chests and intakes/discharge openings (refer Section 5).

- Ensure designated diving location, e.g. reservoir, sewerage system, dam and sea; and the specific hazards, e.g. sea state, weather, pressure differentials, contaminates, are addressed (refer to Section 6).

- Suitability of diving platform, e.g. dock side, barges and crafts for diving, and its safety characteristics, i.e. sufficient size, seaworthy stability, safe egress/access routes, and equipped with first-aid, fire-fighting and life supporting facilities.

7.2.1 Dive Briefings

Before commencing any diving operation, the dive team including the standby diver is to be briefed via a Project Briefing off-site on the mission. The briefing is to be further done via toolbox talks on-site by the diving supervisor, with the purpose of sharing the objectives of the diving operation based on the dive project plan, and pre-dive checklists, risk assessment, diving team and equipment involved, emergency response, evacuation procedures, and other relevant supporting documents.

The planned diving operation comprises individual tasks which are further broken down into steps for completion. Reference will be made to Risk Assessment of the hazards in Section 6.

7.2.2 Pre-dive Check

Before the diver enters the water, both the standby diver and diver need to conduct pre-dive checks which includes but not limited to:

Pre-dive check items	Standby Diver	Diver
Emergency air supply is working and of suitable pressure	X	X
Main air supply is on and working	X	X
Communication is set up and ready	X	X
Umbilical is secured to the harness	X	X
Fins are available	X	X
Helmet/mask is secured properly		X
Helmet/mask ready to put on immediately if required to enter the water	X	X
Pneumofathometer is available at chest level	X	X
Wet suits/overalls which include fins or boots, and gloves are not torn or loose	X	X
Tools such as knife and safety light are provided for the tasks	X	X

Table 15: **Summary of pre-dive checks for standby diver and diver.**

Following the pre-dive check, further verification for air leaks is required as follows:

- When the diver or standby diver enters the water, check for leaks at the first stage regulator by observing for bubbles around the valve/bail-out area.
- Rescue diver to perform wet helmet check and diver to check bail-out pressures during the dive.
- Only when there are no leaks, may the diver proceed to the work site.

Refer to the following Annexes for more samples on pre-dive check lists:

- Annex Q — Sample Diving Permit-To-Work Pre-Dive Checklist for Use by Site Owner/Client and/or Diving Contractor
- Annex R — Sample Pre-Dive Checklist for Use by Diving Supervisor
- Annex S — Sample Pre-Dive Checklists for Use by Diver and Diver's Attendant/Tender

7.3 Post-dive/Debrief

After the diver has recovered from the water and accomplished the task, he should:

- Confirm with the diving supervisor that he is feeling well.
- Remove his diving equipment aided by the tender.
- Update the diving supervisor during debrief session, especially on the hazards and risk controls adopted during the dive.

As part of good housekeeping practice, the dive team is required to:

- Clean thoroughly the mask oral nasal with a mild sanitising solution followed by flushing with fresh water.
- Check if any items of the dive equipment are damaged and require repair or maintenance, e.g. charging of the bail-out bottle, if necessary.
- Check the status, e.g. air pressure, leaks of the HP air supply cylinders.
- Carry out post-dive equipment checks.

In the event of another dive taking place on the same worksite, the diver is required to brief the next diver on the status of any tools/equipment that are still on-site. This can be done concurrently with the diving supervisor's debriefing.

8. Communications

This section covers the day and night signals to be displayed by a vessel engaged in diving operations and the diving lifeline signals used in communication between diver and attendant. The day and night signals are in accordance with the International Regulations for Preventing Collisions at Sea 1972 (COLREGs), and the Maritime and Port Authority of Singapore (Port) Regulations (Part III Signals, Para 17, Exhibition of Navigational Lights, Shapes and Signals).

8.1 Diving Signals and Flags

Diving signals and flags need to be displayed during a diving operation involving a vessel/craft. By displaying the signals, other vessels in the vicinity will be warned of ongoing work. The day and night signals to be displayed by a vessel engaged in diving operations (COLREGs Rule 27) include:

- A rigid replica of the International Code flag "A" not less than 1 metre in height. Measures shall be taken to ensure its all-round visibility. (Note: Applies to vessel whose size makes it impracticable to exhibit all the shapes prescribed in COLREGs Rule 27d); or

- Three shapes in a vertical line where they can best be seen in the day. The highest and lowest of these shapes shall be balls and the middle one a diamond. (Note: Not required if the size of the vessel makes it impractical to display all the lights and shapes prescribed in COLREGs Rule 27d); or

- Three all-round lights in a vertical line where they can best be seen at night. The highest and lowest of these lights shall be red and the middle light shall be white. (Note: Applies to vessel whose size makes it impracticable to exhibit all the shapes prescribed in COLREGs Rule 27d)

Figure 22 shows Diving Flag Alpha[12] while Figure 23 and Figure 24 show Vertical Shapes in diving signals (Day) and Vertical Shapes in diving signals (Night) respectively.

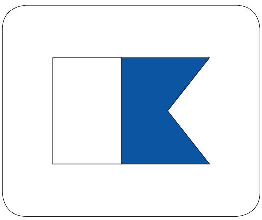

Figure 22: Diving flag alpha.

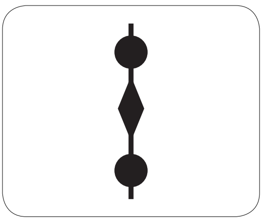

Figure 23: Vertical shapes diving signal (day).

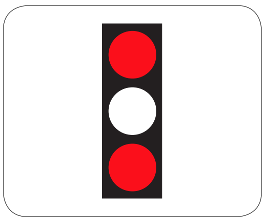

Figure 24: Vertical shapes diving signal (night).

[12] The Alpha flag in the International Code of Signals means "I have a diver down; keep well clear at slow speed slow speed." (https://www.flagandbanner.com/nautical/international-code-signals.asp)

8.2 Diving Lifeline Signals

Hard-wired voice communication between diver and diving supervisor is the primary means of communication. This mode of communication is preferred over through-water communication due to the interference caused by presence of sediments, water temperature differences and air bubbles turbulence. Lifeline signals are used as a secondary/emergency mean of communication between diver and attendant/tender at the surface using the lifeline and umbilical that is attached to the diver's harness. There is a need to ensure proper umbilical management to prevent fouling of lifeline, e.g. entrapment/entanglement which may affect lifeline signal communication.

In essence, all signals received must be acknowledged by repeating the signal until a correct acknowledgement is received. For instance, all signals from the attendant/tender to the diver are to be preceded by one pull to attract attention after the diver has answered with one pull.

As a diver at work may not acknowledge all signals immediately at all times, the attendant/tender should wait a few moments before repeating the signal.

Lifeline Signals

These include but not limited to the following:

General Signals

Attendant To Diver

- 1 pull — To call attention; are you OK? Stop!
- 2 pulls — Am sending down a rope's end or as previously arranged.

Diver To Attendant

- 1 pull — To call attention; made bottom; left bottom and OK.
- 2 bells — Send me down a rope's end or as previously arranged.

Direction Signals

Attendant To Diver

- 1 pull — Stop. Search where you are.
- 2 bells — Go out to the end of distance line or jackstay.

Working Signals

Diver To Attendant

- 1 pull — Stop. Call Attention.
- 2 bells — Pull up.

For more details of **Lifeline Signals** which also include **Emergency** Signals for Diver To Attendant, refer to SS511:2018 Annex E (Lifeline Signals).

9. Emergency Response Plan

This section covers the Emergency Response Plan (ERP) and procedures which involve dive personnel, support team and others who are working to assist in an emergency situation. The ERP needs to be prepared prior to any diving operation and should be made available at the dive site until all diving activities have ceased.

The outline of this section includes diving protocol in responding to a diver incident with coverage on incident reporting process, contacts of emergency response personnel and/or facility for underwater recovery of diver under various scenarios. Refer to SS511:2018, Para B.1.7 (Annex B) for more information on the Emergency Response Factors.

9.1 Emergency Diving Protocol

9.1.1 Emergency Response and Contacts

The Diving Contractor's Emergency and Contingency Manuals should include a flowchart (Refer to Figure 25 for a sample) that indicates the process for liaison in the event of a diving emergency (refer to Figure 26 on the sample format) specific to each diving worksite, with the inclusion of contact details.

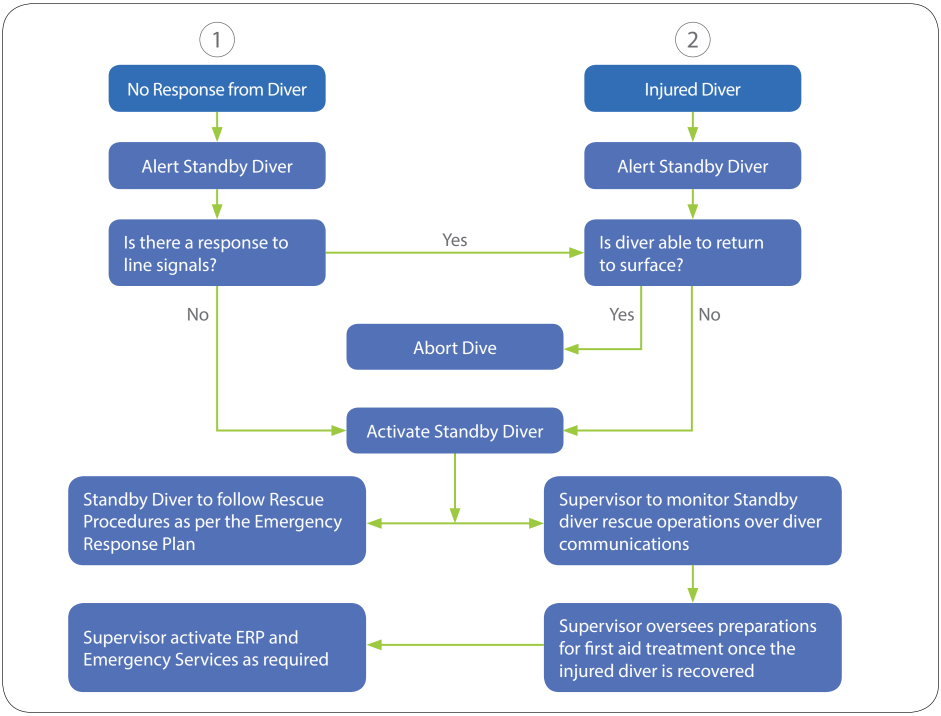

Figure 25: Sample flow chart on diving emergency.

Note: In the event of imminent danger to the diver/diving operation or when the diver is showing symptoms of serious injury, e.g. decompression injury/illness, the diving supervisor is required to make the decision to abort the dive.

Agency Emergency Support Services	
Coast Guard Location: Ph Number:	**Fire Service** Location: Ph Number:
Ambulance Location: Ph Number:	**Navy** Location: Ph Number: Mobile Number:
Port Authority Location: Ph Number: Response Time:	**Harbour Master** Location: Ph Number: Mobile Number:
Diving Emergency Support Checklist	
Emergency Services # **Radio Frequency**	**Port Authority#** **Radio Frequency**
Recompression Chamber Location: Operator Name: Ph Number:	**Client** Location: Name: Ph Number:
Emergency Transportation Location: Name: Ph Number:	**Nearest Hospital** Location: Name: Ph Number:
Driving Doctor Location: Name: Ph Number: Mobile Number:	**Weather Centre** Location: Name: Ph Number:

Figure 26: Sample format on emergency contact list.

9.1.2 Emergency Recovery of a Diver

When carrying out diving operations, there must be a system for recovering a distressed/injured diver back to the diving site platform/location. The diver recovery method must not expose the surface personnel or diver to an elevated risk of incurring personal injury during the recovery process. The recovery of a diver includes the use of ladders with handhold extended to 2 metres below water, and use of recovery davits mounted on boat which should be properly designed, built, examined and load-tested prior to use as well as any other safe means of recovery. Refer to SS511:2018, Para 10 Dive Site Requirements on the access to and egress from water where it covers the use of ladder and davit recovery winch and their requirements.

Ensure all lifting equipment and appliances undergo regular examination in line with statutory requirements. Refer to the MOM-issued circular on Examination and Testing Requirements for Statutory Lifting Equipment and WSH (General Provisions) Regulations.

Figure 27: **Small boat dive ladder.**

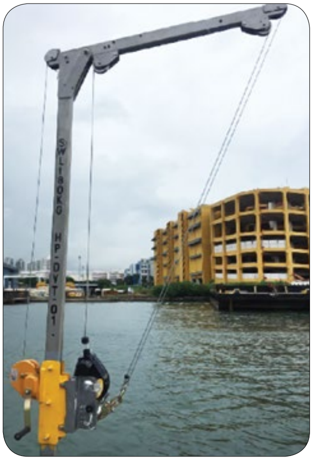

Figure 28: **Diver recovery davit.**

9.1.3 Deck Decompression Chamber Requirements and Transportation of Injured Diver

For planned in-water decompression dive, a deck decompression chamber (DDC) should be available on site and used in accordance with the decompression table. The diving contractor should assess the risk of decompression illness for dives in relation to the depth and duration of diver underwater.

For instance, for dives planned with in-water decompression greater than 20 minutes, or where risk assessment requires a two compartment DDC, such DDC should be available for use on-site. The injured diver should undergo treatment by an appointed hyperbaric diving specialist using first aid and medical equipment e.g. On-site AED[13] (Refer to SS511:2018, Para 9.6.3), stretcher and oxygen providing set with suitable quantity of oxygen to last throughout the journey. Refer to SS511:2018, Para 11 Decompression Diving and Para 4.2 Roles and Responsibilities of Diving Contractor for details.

As part of emergency response, planned, no decompression dives shallower than 30 metres of sea water (100 feet of sea water), a two compartment DDC should be available within two hours of travelling from the dive site to transport the injured diver for treatment.

9.1.4 Incident Reporting and the Requirements

In line with WSH (Incident Reporting) Regulations, the diving company is required to equip with a documented procedure for Incident Report and Recording whereby the Incident Reporting Requirement is fulfilled by the client company.

Refer to MOM's website at https://www.mom.gov.sg/workplace-safety-and-health/work-accident-reporting/what-and-when-to-report on reporting work-related accidents.

Companies can login using their Corporate Access or Personal Access to MOM's website at https://www.mom.gov.sg/eservices/services/wsh-incident-reporting#what-can-i-do to submit a work-related incident reporting.

For follow-up investigation of incidents, refer to SS511:2018, Para 14 Incident Reporting and Investigation for more details.

[13] As AED is not intrinsically safe, safety considerations must be in place where AED should not be used. These include: Injured diver who is wet or in the presence of water; explosive environment with flammable gases or vapour present; injured diver lying on a base/floor made of conductive metal (refer to Dos and Don'ts for using AEDs).

9.2 Underwater Emergency Procedures

This section includes the emergency situations and requirements to be considered in planning a diving operation.

9.2.1 Loss of Primary Air Supply for Diving Equipment

CSCUBA equipment

- Due to limited air supply in the cylinders, the CSCUBA diver should be mindful and vigilant of the remaining air by constantly monitoring the contents gauge.

- During emergency when there is a depletion of primary air supply, the diver should immediately switch over supply from a secondary cylinder or a pony cylinder.

- Once the diver is on the secondary air supply, he is to ascend to the surface in a controlled manner.

- The diver should signal to the tender that he is surfacing and the diving supervisor be informed of the diver's status and his intentions via communications.

SSDE/SSBA equipment

- During an emergency when the SSDE diver loses his primary air supply due to trapped or severed umbilical, the diving supervisor needs to be informed. At the same time, the diver is to switch to breathing from the bail-out by opening the bail-out emergency supply valve.

- The diving supervisor will immediately open an alternative secondary air supply/emergency air supply on the supply panel. Refer to SS511:2018, Para 12.6.3, Diver's primary and secondary breathing air supplies.

- The dive should be terminated by the diver returning to the surface on his emergency air supply, by following his umbilical back to the surface.

- In all instances of a loss of the diver's primary air supply, the standby diver may be required to enter the water to assist the diver. This is followed by an investigation to determine the cause of the air loss and the actions required to prevent a reoccurrence.

9.2.2 Entanglement, Confined Space and Overhead Obstruction

Generally, during any emergency when the diver's umbilical becomes entangled due to confined space or overhead obstruction, the diver should perform the following steps to prevent being trapped:

- Stop movement.
- Remain calm.
- Carry out "Look-Think-Do" risk assessment:
  - Look around and be vigilant of other hazards.
  - Think of feasible risk control measures.
  - Signal the tender/inform the diving supervisor of the problem.
- Follow the umbilical back along to the entanglement.
- Attempt to free himself without panicking.

The diving supervisor should review the situation, assess his options, and decide if there is a need to deploy a standby diver.

For entanglement when using CSCUBA equipment, the diver's air supply may not be sufficient to conduct a lengthy dis-entangling procedure, especially nearing the end of the dive. As part of safe-dive planning, all CSCUBA divers should return to the surface with 500 psi (34 bar) of air remaining in the tank [source: PADI's Open Water Diver Manual, 20–40 bar (300-500 psi)].

Under no circumstances should a diver disconnect or cut off the umbilical to swim freely to the surface. This is an unsafe act which will impede the ability of the standby diver to locate the diver as the diver's position becomes unknown. The diving supervisor should emphasise the importance of correct umbilical management where both the diver and attendant/tender will know of each other's presence with the 'feel' of the umbilical's tautness and the use of lifeline signals to reduce the possibility of entanglement.

9.2.3 Loss of Communication/Lost Diver

Loss of communication with diver should be discussed as part of the pre-dive briefing. The procedure involves:

- Diver to stop dive immediately and to signal to tender that he is leaving the bottom.
- Tender, on instruction by the diving supervisor, should signal the diver to 'come up' using line pulls signal.
- Diving supervisor to decide if there is a need to deploy the standby diver to assist the diver.

In the event of a missing diver, a lost-diver plan should be activated.

10. References

Code of Practices, Standards, Guides

1. Singapore Standards SS 511:2018 — Code of Practice for Diving At Work.

2. Singapore Standards SS 639: 2018 — Code of Practice for the filling, inspection, testing and maintenance of gas cylinders for the storage and transport of compressed gases — Part 1: Seamless steel and aluminium alloy cylinders (excluding dissolved acetylene) — Inspection at the time of filling, periodic maintenance and testing — Annex A (Periodic Inspection and Test Periods).

3. British Standard BS EN 12021 Respiratory Protective Devices — Compressed Air For Breathing.

4. Code of Practice For Inland Diving and Inshore Diving by Health and Science Authority (UK) Commercial Diving Projects Inland/Inshore, Diving at Work Regulations 1997 (2014) by Health and Safety Executive (HSE).

Local WSH Legislations

1. Workplace Safety and Health (WSH) Act and subsidiary legislations:
   a) WSH (General Provisions) Regulations
   b) WSH (Risk Management) Regulations
   c) WSH (Incident Reporting) Regulations
   d) WSH (First-Aid) Regulations

Other publications and resources

1. U.S. Navy Diving Manual — Revision 7 Change A (30 April 2018)

2. Differential Pressure Hazards In Diving, Health and Science Executive, Diving Information Sheet No 13 (rev1)

3. Guidance For Diving In Contaminated Waters, US Navy Sea Systems Command (15 March 2008)

4. FACT SHEET No.23 — Shallow Water Blackout, Royal Life Saving Society, Australia

5. International Association of Oil & Gas Producers (OGP) Diving Recommended Practice, Report No. 411 (June 2008)

6. International Association of Oil & Gas Producers (OGP) Lifting & hoisting safety recommended practice, Report No. 376 (April 2006)

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Mr Daniel Devadason	KBA Training Centre Pte Ltd
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- Divetech Marine Services Private Limited (Figures 5 and 14)
- KBA Training Centre Private Limited (Figure 25)

12. Annexes

Annex A: Terms and Definitions

Common terms with definitions relevant for use with the guidelines.

Terms	Definitions
Air/Compressed air	Breathing medium used by the divers.
Accident	An unintended event which causes bodily injury to a person.
Acute Illness	An illness characterised by the symptoms having a rapid onset.
ADCI	Association of Diving Contractor International. An American Diving Contractors Association that promotes consensus standards amongst members, organises training standards and diver's certification.
AGE	Arterial Gas Embolism is a form of decompression illness which is a result of gas bubbles in the bloodstream. This is caused by either bubble nucleation and growth by dissolved gas into the blood on depressurisation, or by gas entering the blood mechanically as a result of pulmonary barotrauma. AGE is most often caused by the expansion of respiratory gases during ascent; it can also occur when the breath is held during ascent from a dive.
AODC	Association of Underwater Engineering Contractors (formerly the Association of Offshore Diving Contractors, the abbreviation for which has been retained).
Atmospheric Pressure	The atmosphere exerts a pressure on the earth's surface in the same way as water exerts pressure, i.e. it is produced by the weight of air above the earth.

Terms	Definitions
Absolute Pressure	Before a diver leaves the surface, he is already under a pressure of 1 bar or 100,000 N/m^2 (atmospheric pressure). For every metre he descends, the pressure on him will increase by 0.1 bar. Thus, the total pressure on the diver at any depth will be the pressure of the water at that depth plus atmospheric pressure, 1 bar. For example, a diver at a 40-metre depth will be subjected to a pressure of 1+(40 x 0.1) bar = 5 bar (absolute).
Ambient Pressure	The pressure of the surrounding medium, such as a gas or liquid, which comes into contact with an object, e.g. diver and apparatus.
ALARP	As Low As Reasonably Practicable. For a risk to be ALARP, it must be possible to demonstrate that the cost involved in reducing the risk further would be grossly disproportionate to the benefit gained.
Audit	A systematic examination to determine whether activities and related results conform to planned arrangements and whether these arrangements are implemented effectively and are suitable for achieving the organisation's policy, the audit may be of a management system, equipment, or a marine vessel.
Appointed Hyperbaric and Diving Specialist/ Physician	A doctor appointed by the diving company trained in hyperbaric medicine and competent to manage diving injuries and illnesses. Often referred to as a "diving doctor".
Appropriate Medical Facility	A Medical Facility with an appointed Hyperbaric and Diving Specialist/Physician in attendance and Emergency Medical Facilities for treatment of (a) serious and/or life-threatening conditions (b) Diving related illness e.g. DCS, Barotrauma etc.
BC/BCD	Buoyancy Compensator or Buoyancy Compensator Device. An inflatable harness worn and controlled by the diver, that allows him to achieve neutral buoyancy. This is especially helpful when working on smooth surfaces that do not have handholds for the diver.

Terms	Definitions
Barotrauma	The physical damage to body tissues caused by a pressure differential between an air space inside the body and the ambient pressure. Also known as Pressure Injury.
Black Box	A recording device, e.g. DVD/HD of the diver's breathing pattern and communications between the diver and diving supervisor. The recording is required to ensure traceability in the event of any incident/accident involving the diver.
Bottom Time	The total elapsed time from when a diver leaves the surface to the time (next whole minute) at which ascent is commenced, measured in minutes.
Breathing Air	The supply of compressed air for respiration by the diver delivered via cylinder/s carried by the diver or air from the surface via an umbilical.
Breathing Hose	Hoses attached to a regulator also known as divers' umbilical are designed to supply compressed air from the air source to the diver at low pressure (near ambient pressure).
Certification Package	A folder or file that contains signed certificates which show that the diving equipment has been tested and/or checked by competent personnel. In the case of the DDC, the testing will normally be witnessed by a surveyor acting on behalf of a classification society.
Competent Person	A person who by virtue of his qualifications, training or experience, or a combination of these, has such practical and theoretical knowledge and to be able to perform the task at hand.
Chronic Illness	A chronic illness is defined as any disease/illness that develops slowly and lasts a long time.
Combined Dive	The bottom times of more than one dive, added together and treated as a bottom time of a single dive to the deepest depth for the purpose of determining the diver's decompression schedule/requirements.

Terms	Definitions
CSR/CWR	Company Site Representative/Company Worksite Representative. Oversees the diving project on the client's behalf, help prevent loss and maintain contractual integrity for the client.
CVI	Close Visual Inspection of a detailed, recorded inspection of an item, using measuring instruments and tools to validate observations.
CSCUBA	Commercial self-contained underwater breathing apparatus. Open-circuit diving equipment that supplies the diver with breathing air from the cylinders carried by the diver while using a full-face mask, lifeline, and hard-wire or through a water communications system.
DDC	Deck Decompression chamber. A pressure vessel for human occupancy (PVHO) built to design standards which may include ASME PVHO-1, BS EN 14931 and to be examined, tested and approved before use as required under the Workplace Safety and Health (General Provisions) Regulations, governing framework for statutory pressure vessels used for air divers surface decompression and/or decompression treatment.
Decompression Illness	A common term for acute illness resulting from decompression. This term covers the condition known as decompression sickness also known as bends and arterial gas embolism. Bends results from metabolically inert gas dissolved in body tissue under pressure precipitating out of solution and forming bubbles during decompression.
Decompression Table	A specific table of pre-determined depths and times used to calculate the decompression requirements for a particular dive.
Decompression Schedule	A specific decompression procedure for a given combination of depth and bottom time as listed in a decompression table. It is normally described as a series of stops at specified depths in metres or feet for specified times in minutes.

Terms	Definitions
Decompression Sickness (Bends)	The development, during or after diving, of any abnormality which is a direct result of a reduction in the pressure of inert gases dissolved in the body, with the production of gas bubbles. Any organ may be involved, and its presentation can vary from acute to chronic. (Note: It is common for decompression sickness to show up before or very soon after completion of the dive).
Decompression Stop	The specific length of time that a diver must hold his ascent at a specified depth to eliminate sufficient inert gas from his body to allow a safe ascent to the next decompression stop or to the surface.
Demand Air Supply Device/ Regulator	A device that provides a flow of breathing air on demand to the diver via a mechanism to the diver when he inhales and exhales. It is also known as a regulator.
Depth Gauge	Used to indicate the depth of a dive. Usually refers to the maximum depth attained during the dive, measured in either feet or metres of seawater.
Diving Operation	A diving operation identified in the diving project plan or dive plan.
Dive Control Position	A dedicated position where a supervisor controls the diving operation and is able to supply and monitor life support functions, communications and safety to a diver in the water and the dive team in general. The dive control position is normally situated near to the divers' launch and recovery area.
Dive Team	The personnel on site that are directly involved in and responsible for the safety of the diving operations. The dive team includes diving supervisors, divers, tenders/attendants and technicians (system and medical).
Diver	A person who is trained and certified to perform work underwater using commercial diving breathing equipment, whether as an employee or self-employed person.
Diver's Umbilical/Hose	Umbilical used in Surface Supplied Diving Equipment to carry breathing air to the diver from the dive control panel and may include hard-wired communications and possibly cables for hat camera and light.

Terms	Definitions
Diving Contractor	Employer who assembles a dive team with appointment of diving supervisor(s), non-dive team/support personnel and appointed Dive Project Management Representative where applicable to support services for the diving operation. Note: Where applicable, appointed Dive Project Management Representative will assume the role and responsibilities of the diving contractor/company in diving operation.
Diving Helmet[14]	A hard-shell helmet with the following characteristics: (a) Material of construction is tough and rigid (b) Able to cover the whole head area from the neck up (c) Comprises an integrated breathing system (d) Includes an integrated communication system that comprises both hard-wire/verbal communication
Diving Work	Work in which diving is conducted using underwater or under compression using underwater breathing apparatus and other life support equipment such as life vest and lifeline, supported by the dive team.
DOM	Diving Operations Manual. The Diving Contractors manual that specifies how he carries out his diving operations.
Employer	A person who in the course of the person's trade, business, profession or undertaking, employs any person to do any work under a contract of service.
ERP	Emergency Response Plan
Exceptional Exposure Dive	A dive in which the risk of decompression sickness, oxygen toxicity, and/or exposure to the elements is substantially greater than a normal working dive. Exceptional exposure dives should not be planned.
Float Line	A line connecting the diver to a high visibility float on the surface of the water enabling the approximate location of the diver to be known at all times.

[14] Includes adapter hard shells that are worn over the soft band masks.

Terms	Definitions
Free-flow system	A breathing method used in SSBA diving operations whereby breathing gas enters the full-face mask or incompressible helmet in a continuous flow and is not controlled by a demand gas supply device.
FSW	Feet of sea water. A measurement of water depth.
Full-face Mask (Band Mask)	A full-face mask such as a band mask with following features: (a) Covers the whole area of the face such as mouth, nose and eyes. (b) Includes an integrated breathing system. (c) Includes an integrated communication system.
Gauge Pressure	A pressure gauge is normally graduated to read ZERO when the gauge is at atmospheric pressure. This is because a pressure gauge normally records only 'difference of pressure'; i.e. the difference between that of the high-pressure source and atmospheric pressure.
GVI	General Visual Inspection. A recorded inspection of an item, normally looking for gross damage or deformation.
Hazard	Anything or any source or situation with the potential to cause harm or injury.
Hazard Identification	Process of recognising that a hazard exists and defining its characteristics.
IMCA	International Marine Contractors Association. The international trade association representing offshore, marine and underwater engineering companies. It promotes good practice, particularly in the areas of health, safety and environmental standards, quality and efficiency and technical standards, through the publication of activity specific manuals, guidelines, safety flashes and audit documents.

Terms	Definitions
Inland Diving	Defined geographically as diving in areas that are accessible and surrounded by land, such as lakes, reservoirs, dams, flooded tunnels, ponds, marsh, rivers, canal, culverts. Inland diving may take place inside refineries, cooling towers, industrial collection ponds, and tanks.
Inshore Diving	Defined as at sea, but close to shore. Some jurisdictions may further define "inshore" as diving within the area 12 nautical miles off the coastal waterline. Diving may take place in locations such as terminal piers, jetties, docks, anchorage, and harbours.
Incident	An event that gives rise to an accident or has the potential to lead to an accident.
JHA	Job Hazard Analysis. A safety management tool that can be used to define and control the hazards associated with a job or procedure.
LARS	Launch and Recovery System. A means of the diver accessing to and exiting from the water in a safe and controlled manner.
Lazy Shot	A rope which has a weight tied to the end and is submerged into the water by hanging and securing it from the side of the vessel at the required depth and position as a marker to the diver to hang on to for decompression schedules.
Lifeline	A rope line that is attached to the diver and tended by the surface dive team to be used to recover the diver in the event of an emergency or to be used for communication — signalling in the event of lost voice communications.
Limiting Line	A line shown in some decompression tables which indicates time limits (bottom times) beyond which the use of the decompression schedule is less safe.
Live Boating	Term applied to supporting diving operations from a vessel while the vessel is underway.
msw	Metres of sea water. A measurement of water depth.

Terms	Definitions
NEA	National Environmental Agency (Singapore)
Near-miss	An unplanned event that did not result in any injury, illness or damage, but had the potential to do so.
No Decompression Limits	The maximum time which can be spent at a given depth such that a safe ascent can be made directly to the surface at a prescribed rate with no decompression stops.
OGP	Oil & Gas Producers
Oxygen	Within a range of 20 – 22% by volume of breathing air mixture for diving operation, in line with BS EN 12021.
PADI	Professional Association of Diving Instructors
PMS	Planned Maintenance System. A systematic, recorded and verifiable equipment maintenance regime, carried out by a competent person, to ensure that plant and equipment used in diving operations is properly maintained in accordance with the manufacturers' recommendations and manuals as well as diving contractor's operation procedures for a safe and efficient operation of the equipment (Refer to SS511:2018 for more details of PMS).
Plant and Equipment	Air supply equipment, e.g. compressor, cylinders, pressure gauges, regulators, inflator hose and diver's umbilical, Buoyancy Compensator Device, Compression/Recompression/ Deck Decompression Chamber, equipment for two-way communication, First-Aid and Medical Equipment, e.g. Oxygen resuscitation, automated external defibrillator and diver's equipment.

Terms	Definitions
PVHO	Pressure Vessel for Human Occupancy. A pressure vessel that encloses a human being within its pressure boundary while it is under internal or external pressure that exceeds a differential pressure of 2 psi. PVHOs include, but are not limited to, submersibles, diving bells, personnel transfer capsules, decompression chambers, recompression chambers, hyperbaric chambers, high altitude chambers, and medical hyperbaric oxygenation facilities.
PPE	Personal Protective Equipment
PTW	Permit-to-work
Pull	A signal used on a lifeline of the diver, the diver to tender or tender to diver, to make a slow, deliberate pull action on the lifeline to gain attention or communicate between each other.
Quick Release Mechanism	An easily operated mechanism that enables the immediate release of an otherwise secured piece of diver's equipment by single operation of one hand. The mechanism is to be designed to minimise the risk of accidental or unplanned release.
Repetitive Dive	Any dive conducted while the diver still has some residual nitrogen in his tissues from a prior dive.
Residual Nitrogen Risk	Nitrogen gas that is still dissolved in a diver's tissues after surfacing. A risk is the possibility that someone or something will be harmed by an identified hazard. The extent of the risk includes the numbers of people who might be affected by the risk.
Risk Assessment	The process of estimating the magnitude of risk and an evaluation of precautions that can be taken to prevent harm and deciding whether the level of risk is tolerable.
ROV	Remotely Operated Vehicle
SDS	Safety Data Sheet. Contains product information along with safe means of handling, storage, disposal, hazards, exposure controls and first aid treatment. SDS must be reviewed (i) within five years from the date of issue; and (ii) when there is new information or change in properties of the chemical.

Terms	Definitions
	Refer to details in MOM's website at https://www.mom.gov.sg/faq/hygiene-monitoring/what-is-the-validity-period-of-safety-data-sheet-in-singapore.
Single Dive	Any dive conducted more than 12 hours after a previous dive.
Shall	Indicates a compliance with a statement, e.g. WSH Act or subsidiary legislations, Code of Practice/Singapore Standard SS511:2018 is required. Compliance with this set of guidelines does not exempt users from legal obligations under the Workplace Safety and Health Act.
Should	Indicates a recommendation
SMS	Safety Management System
SSDE/SSBA	Surface-Supplied Diving Equipment (SSDE) or Surface-Supplied Breathing Apparatus (SSBA). Equipment which supplies the divers breathing air at the required pressure from a source on the surface via an umbilical to the diver which shall include integrated system for diver to surface communications and to monitor the divers' depth with a black box recording at the dive control position.
Standby Diver	A diver fully dressed and equipped to enable immediate entry into the water to provide aid or assistance to the working diver.
SWL	Safe Working Load. The load which can be safely lifted. This term is being replaced with WLL (refer to definition of WLL).
Tolerable Risk	Risk that has been reduced to a level that can be endured by the organisation having regard to its legal obligations and its own OH&S Policy.
Toolbox Talk/ Meeting	A meeting to ensure that everyone clearly understands what the job entails along with its hazards and the precautions to be put in place.
WLL	Working Load Limit. The maximum load that may routinely be applied to an assembly or component in straight tension.

Annex B: Personal Diving Equipment Components

1) Diving suits

Diving suits are overalls that serve as a personal protection equipment (PPE) that guard divers against thermal stress, injury such as cuts and abrasion from physical contact, or other harmful exposures when working around marine encrusted surfaces. The suits are designed with required thickness and water-sealing ability so that the diver is protected against cold water temperatures.

2) Wet suit

Made of insulating material, the wet suit acts as a barrier against the cold water and keeps the divers warm by maintaining the body temperature. Generally, a wet suit is suited to short-term exposures and is a form of PPE which provides a barrier to the skin and soft body tissues of the diver. A wet suit is often used despite its limitations with regards to thermal protection in colder waters.

3) Dry suit

A dry suit is used on an 'as-required' basis for diving operations in cold waters providing an additional thermal protection and used when diving in contaminated waters such as caused by pollutants from industrial, agricultural, domestic activities as well as foreign bodies. The dry suit keeps the diver dry and protects him from any contamination in the water. The diver wears a layer of underclothes which enables the suit to trap and hold air between the fibres to keep the diver warm under the suit. A dry suit should be sized to fit the diver comfortably and have no holes/tears and provides a dry seal, e.g. neck or cuff seals with zips in good working condition. Divers need to be trained on the use of dry suit, suit inflation mechanism, e.g. inflation and dump valves, and the consequences of inappropriate use. A dry suit is not normally used in tropical waters where the temperature is higher than that of temperate waters. The hazards of using a dry suit in warm climates include heat exhaustion, dehydration and suit squeeze.

4) Under suits

Under suits of 1 millimetre thickness are worn in tropical waters that provide extra protection to the diver.

5) Fins/boots

The open heel or jet type fins used normally are industrial strength grade with fin straps and buckles which fit comfortably over diving booties.

6) Gloves

The gloves need to fit the diver's hand and the material may include Kevlar, leather or cotton, depending on the planned diving task/s.

7) Hood

Ensure the hood is made of neoprene and is not too tight around the neck, as it may restrict blood circulation around the ears, which can lead to equalisation problems during the descent.

Annex C: Recommended Equipment Periodic Test and Examination Schedule

S/N	Item	Competent Person	Frequency	Type of test	Test Standard
1.0	Surface compression chambers	Person specialising in such work	Two years	Pressure leak test at maximum rated working pressure, using typical gas or gas mixture	To a recognised standard.
			Once every five years or in accordance with design code or standard	Pressure test	To a recognised standard.

S/N	Item	Competent Person	Frequency	Type of test	Test Standard
2.0	Statutory pressure vessels, e.g. pressure vessels for human occupancy, air receivers, compressors with air receivers attached.	Authorised Examiner	Two years	1. Visual examination; and 2. Running test	1. To a code or standard of which the vessel is designed to, and acceptable to the Ministry of Manpower[15]; and 2. In accordance with the Ministry of Manpower's requirements for regular inspections of pressure vessels. (https://www.mom.gov.sg/work place-safety-and- health/pressure-vessels/regular-inspections)
			10 years	1. Hydrostatic pressure test at a test pressure stipulated by the code of which the vessel is designed to; and 2. Thickness gauging test of the shell enclosing the pressurised medium.	1. To a code or standard of which the vessel is designed to, and acceptable to the Ministry of Manpower[16]; and 2. In accordance with the Ministry of Manpower's requirements for regular inspections of pressure vessels. (https://www.mom.gov.sg/work place-safety-and- health/pressure-vessels/regular-inspections)

[15] Design codes acceptable to the Ministry of Manpower include ASME, BS EN, JIS standards, DIN standards, AD2000 and PD 5500.
[16] Design codes acceptable to the Ministry of Manpower include ASME, BS EN, JIS standards, DIN standards, AD2000 and PD 5500.

S/N	Item	Competent Person	Frequency	Type of test	Test Standard
3.0	Umbilicals: • Surface demand hoses • Divers’ umbilicals • Other hoses (pressure retaining parts only)	Person specialising in such work	Two years	Either • A pressure leak test, or • An internal hydraulic pressure test. A pressure leak test should be carried out if the item normally carries a gas and the test pressure should be at the maximum rated working pressure of the item using typical gas or gas mixture. An internal hydraulic pressure test should be carried out if the item normally carries a liquid and the test pressure should be in accordance with the relevant design standard.	To a recognised standard.
4.0	All items above	Person specialising in such work, e.g. dive equipment technician	Six months	Visual Examination and function test.	To a recognised standard.

S/N	Item	Competent Person	Frequency	Type of test	Test Standard
5.0	Gauges, e.g. depth gauges, dive computers, pressure gauges	Person specialising in such work — normally a third-party company or in-house master gauge test by technician	Six months 12 months (Master Gauge)	Calibration test and necessary adjustments, including the production of a calibration chart if appropriate. Tests to be carried out over the full range of the gauge using the typical gas, gas mixture or fluid medium that is used in practice.	In accordance with equipment suppliers' standard procedures.
6.0	Compressors	Person specialising in such work	At least once in three months	Breathing air testing in line with breathing air quality in SS511:2018, Para 9.8.1.2.	To a recognised standard with particular emphasis on the purity of pressurised gas produced – BS EN 12021.
7.0	Diver's helmets, masks, first stage and second stage regulators	Person specialising in such work	Six months	Visual examination, inspection and test in accordance with manufacturer's guidelines.	In accordance with manufacturer's requirements.
			Annual	Annual examination, inspection and test in accordance with manufacturer's guidelines.	In accordance with manufacturer's requirements.

S/N	Item	Competent Person	Frequency	Type of test	Test Standard
8.0	Electrical systems	Person specialising in such work, e.g. dive equipment technician	Six months	All electrical circuits and equipment must be tested for insulation resistance and correct functioning using suitable instrumentation.	To a recognised standard, but also taking into account relevant specific recommendations in recognised codes or guidance notes.
9.0	Fire extinguishing equipment (in line with SCDF directive)	Person specialising in such work	12 months or such shorter periods as may be required for proprietary items	For fixed and mobile sprinkler or drench systems, a functional test and examination, as required. For proprietary fire extinguishing and equipment, the test and examination should be stipulated and carried out by an authorised representative of the supplier.	To a national standard.
10.0	Portable gas analysing equipment	Person specialising in such work	Three months	The equipment should be tested using standard test kits compatible with the equipment and the possible environmental hazards.	In accordance with equipment supplier's standard procedures /manufacturer's recommendations.
11.0	Gas cylinders (under water)	Person specialising in this type of work	Six months Two years	Internal and external visual examination. Internal hydro pressure test, together with detailed examinations of the cylinder internally and externally and all associated and constituent parts.	To a recognised standard, such as SS 639:2018 (Part 1) — Annex A and IMCA D018/AODC 307.

S/N	Item	Competent Person	Frequency	Type of test	Test Standard
12.0	Gas cylinders (on surface)	Person specialising in this type of work	Five years	Internal hydro pressure test together with detailed examinations internally and externally of the cylinder and all associated and constituent parts.	To a recognised international or national standard as determined by the competent person.
13.0	First aid kit	Person specialising in such work	Six months or such shorter periods as may be required for proprietary items	Inspection that the equipment is in good condition and in date.	WSH (First-Aid) Regulations
14.0	Lifting equipment used in rescue of injured diver or used in the lifting of dead loads	Authorised Examiner	One year	1. Thorough visual examination of all components to ensure that they are in good working condition. 2. Functional test at safe working load through the full working range to ensure that brakes and all other components are in good working condition.	In compliance with the Ministry of Manpower's requirements. (https://www.mom.gov.sg/workplace-safety-and-health/lifting-equipment/regular-inspections)
			Four years	Load test at 125% of the safe working load or otherwise stated in the relevant Singapore Standards.	In compliance with the Ministry of Manpower's requirements. (https://www.mom.gov.sg/workplace-safety-and-health/lifting-equipment/regular-inspections)

Annex D: Thermal Stress

A. Heat Stress (Hyperthermia or Heat Illness)

What is it?

In diving, the effects of thermal (temperature) stress plays a big part in the performance of the diver. Heat stress can result in a condition known as hyperthermia where the core body temperature rises above 38 degrees Celsius (38°C) or more. On the other hand, cold stress can result in hypothermia which occurs when the core body temperature drops below 35°C. These conditions can occur regardless of the ambient temperature when it comes to diving. Divers may also suffer from both hot and cold stress simultaneously during the same dive.

When does it occur?

Thermal stress, i.e. hyperthermia or hypothermia, is dependent on factors such as:

- Ambient temperature the diver is exposed to.
- Presence of wind or water movements.
- Body composition.
- Type of work performed.
- Type of protective clothing worn (coveralls, wetsuit, dry suit) by the diver.

As such, it can be dangerous as symptoms may not present itself till the condition is severe and this can occur at any point during the dive.

How does it occur?

Exposure to extreme heat or cold ambient temperatures over a prolonged period will bring about an increase or decrease in the body's core temperature respectively.

Effects of Hyperthermia

When carrying out work during diving, heat is generated by the diver, especially during heavy or intense physical exertion. On land, when there is an excess of heat, the human body tries to lose the excess heat mainly through evaporation of sweat from the surface of the skin. However, in water, heat loss is less efficient if the surrounding water is warm. The diver also loses water and electrolytes (salts) through sweating, causing dehydration. This can result in a range of symptoms from headaches to muscle cramps from mild dehydration, to loss of consciousness and organ damage from heat stroke. Heat stroke is a medical emergency resulting from high core body temperatures and is life-threatening.

Why does it occur?

Heat illness or hyperthermia may occur in divers when they are performing their work underwater while wearing thick wet suits, or when working in contaminated waters while wearing occlusive dry suits. It may be aggravated when working in an environment with extreme heat, dehydration from breathing dry compressed gas, and perspiration from prolonged heavy underwater work.

Recognising heat illness (hyperthermia)

Members of the dive team, including diving supervisors and divers, should be trained to recognise the early signs and symptoms of heat illness so that the affected diver can be treated promptly.

Some of the signs and symptoms associated with heat illness are:

Table D1: Signs and Symptoms

Signs (visible to diving supervisor and fellow divers)	**Symptoms** (experienced by the affected diver)
General appearance • Fainting spells, especially after a change in body position, e.g. from sitting to standing or after prolonged standing • Walking unsteadily or staggering on surfacing • Unconsciousness or experiencing a seizure Behaviour • Confused, disoriented • Irritable, anxious • Aggressive Cardio-respiratory (heart and lung) • Rapid, shallow breathing Musculoskeletal (limbs and muscles) • Muscular cramping Gastrointestinal (stomach) • Vomiting • Sudden loss of bladder or bowel function	General condition • Feeling faint or 'seeing stars' • Feeling dizzy or giddy, loss of balance • Feeling weak • Feels like vomiting (nausea) • Headache • Sensitivity to light, blurring of vision Cardio-respiratory (heart and lung) • Shortness of breath • Chest discomfort • Palpitations (fast heartbeat) Musculoskeletal (limbs and muscles) • Cramping in lower limbs • Tingling sensation or numbness in the hands

Dermatological (skin)	Gastrointestinal (stomach)
• Dehydrated with dark sunken eyes and/ or parched lips Note: Skin symptoms can be deceptive as heat casualties may appear pale or flushed, and/or their skin may feel cool or hot, and wet or dry to touch.	• Dry mouth • Vomiting • Abdominal pain

(Source: WSH guidelines on managing heat stress in the workplace)

Note that signs and symptoms of hyperthermia can vary among individuals, and divers may not exhibit typical signs and symptoms of heat stress as for land exposures.

- Heat stress can induce heat syncope (fainting), heat cramps and heat exhaustion, and in severe cases, heat stroke.

- Heat stroke is an injury when a diver's mental status is altered with high core body temperatures usually about 40°C or above. This is a medical emergency as high core body temperatures can cause death or permanent disability if not promptly recognised and treated.

Prevention of heat illness

- Acclimatisation to hot weather or hot working conditions can be lost quickly. Divers who have not dived in Singapore tropical waters for more than 14 days should undergo an acclimatisation programme initiated and monitored by the Appointed Hyperbaric and Diving Specialist/Physician.

- Divers who meet any of the following criteria should undergo a review with the Appointed Hyperbaric and Diving Specialist/Physician:
  a) Have been on prolonged medical leave for more than three days.
  b) Have developed illnesses affecting the Ear, Nose, Throat (ENT), Respiratory System or Cardiovascular System.
  c) Had recent treatment for a serious medical condition.
  d) Are taking any medication.
  e) Have not dived for more than 14 days.

The medical evaluation must be done prior to return to diving with emphasis upon ENT, pulmonary and cardiac function as well as exercise capacity.

- Divers who experience any heat illness should:
  - Suit up in a shaded area and enter the water safely and quickly to prevent overheating.
  - Dress and stay in shaded areas especially for standby diver.
  - Ensure adequate hydration while working with the consumption of fluids such as plain water or electrolyte drinks at regular intervals.
  - Avoid alcohol and caffeine.

Onsite Management:

- Should any divers experience any heat illness, the diving supervisor should:
  - Abort the dive and instruct the diver to surface.
  - Review the diver for signs and symptoms of:
    - Hyperthermia.
    - Presence of any other diving illness such as barotrauma and decompression illness.
  - Contact the Appointed Hyperbaric and Diving Specialist/Physician (diving doctor) immediately to render medical assistance.
  - Arrange to evacuate the injured diver to the nearest appropriate medical facility for treatment of both hyperthermia and decompression illness.
    - The diving vessel which is in anchorage or outside port limits must head for the closest port such as Marina South Pier, West Coast Pier or Tanah Merah Ferry Terminal to transfer the injured diver to the diving doctor and/or the nearest appropriate medical facility.

- While awaiting evacuation, cool the diver per hyperthermia protocols:
  - Move diver to a sheltered and well-ventilated place.
  - Loosen or remove excess clothing/wet suit/coveralls/dry suit and place a cool or wet cloth/ice compress on the diver's forehead/underarms/groin.
  - The diver should be given cool water or electrolyte drinks if conscious. If the diver is unconscious, do not administer any fluids orally.
  - The diver should be given cool water to drink and have a cool shower, if available.

- If the diver is short of breath or has breathing difficulties, administer 100% surface oxygen to the injured diver in accordance with emergency diving first aid guidelines/protocols for either conscious or unconscious diver.

- Use of medications from the emergency diving first aid kit for occupational divers, must be prescribed by the diving doctor.

- Adopt 7R approach for first-aid treatment for heat stress as follows:

Recognise symptoms	Recognise symptoms of heat stress and report early.
Rest casualty	Get the worker to sit or lie down in a cool shaded area with good ventilation.
Remove clothing	Loosen or remove excess clothing as appropriate (while preserving the modesty of the worker).
Reduce temperature	Reduce body temperature as fast as possible by applying ice packs, wet towels or cool water. Other measures include fanning the casualty (to promote evaporative cooling), the use of cooling blankets and subjecting the worker to cold water immersion.
Rehydrate	Rehydrate by providing fluids. If casualty is unconscious, do not provide fluids by mouth as this may result in choking.
Resuscitate	If the worker becomes unconscious, call for help immediately and resuscitate using principles of cardiopulmonary resuscitation (CPR) if first-aider is trained to do so.
Rush to hospital	Rush worker to the nearest hospital if the worker is not alert.

(Source: Table 8: First-aid treatment for heat injuries using the 7R approach, WSH Guidelines on Managing Heat Stress in the Workplace)

B. Cold Stress (Hypothermia)

What is it?

Heat loss through the skin occurs through radiation and speeds up with exposure to wind or moisture. If the cold exposure is due to being immersed in cold water, loss of heat in the head region can occur 20 to 27 times faster than it would, if exposed to the same air temperature. During cold temperature exposure, shivering is a protective response to produce heat through muscle activity. Under normal conditions, the activities of the heart and liver produce the most of the body's heat. However, as core temperatures drop, these organs produce less heat by causing a protective "shutdown" to preserve heat and protect the brain. This low body temperature can slow brain activity, breathing and heart rate, which can become deadly.

Why does it occur?

Hypothermia usually occurs due to exposure to cold environments. It can also occur in warm environments for divers in a phenomenon called warm-water hypothermia especially during long dives, and repetitive dives made without adequate rewarming between dives. In such cases, slow cooling can take place in water temperatures as warm as 27°C to 33°C.

The diver may not experience typical symptoms such as shivering, as the drop in core temperature may not be rapid enough to activate the body's thermoregulator defence mechanism. There may also be a discrepancy between the inputs of the receptors in the body's shell and core, making the diver's skin feel warm while the core temperature drops.

Effects of cold stress (hypothermia[17])

Hypothermia is a lowering of the core body temperature and can occur when the body loses more heat than it can produce, when exposed to a cool/cold environment. A diver's response to immersion in cool/cold water depends on the degree of thermal protection worn and water temperature. A water temperature of approximately 33°C is required to keep an unprotected, resting man at a stable temperature. The unprotected diver will be affected by excessive heat loss and become chilled within a short period of time in water temperatures below 23°C.

Recognising hypothermia

Members of the dive team, including diving supervisors and divers should be trained to recognise the early signs and symptoms of hypothermia so that the affected diver can be promptly treated.

[17] U.S. Navy Diving Manual Revision 7 Change A, Volume 1, page 3-53

Table D2: Signs and Symptoms

Some of the signs and symptoms associated with hypothermia are:

Core Body Temperature	**Severity of Hypothermia**	**Signs** (visible to diving supervisor and/or fellow divers)	**Symptoms** (experienced by the affected diver)
37ºC	Normal temperature	Nil	Nil
33ºC – 35ºC	Mild hypothermia	• Shivering • Behaviour change • Appears clumsy, lack of muscular coordination • Appears to be inattentive/apathetic	• Shivering • Increased blood pressure • Amnesia (forgetfulness) • Unable to speak clearly • Poor judgement • Feels uncomfortably cold • Apathy
29ºC – 32ºC	Moderate hypothermia	• Appears weak and drowsy • Unconsciousness	• Stupor • Shivering stops • Pupils dilate • Cardiac arrhythmias (heart rhythm irregularity) • Unconsciousness
Less than 28ºC	Severe hypothermia	• Slow breathing • Unable to follow commands • Loss of consciousness • Appears dead	• Ventricular fibrillation (heart rhythm irregularity) • Hypoventilation (reduced breathing) • Loss of reflexes and voluntary motion • Death

(Source: Prevention of Cold Injuries during Exercise. Castellani JW, Young AJ, Ducharme MB, et al. Medicine & Science in Sports & Exercise. Nov 2006, Vol 38 Issue 11, pp 2012 – 2029)

How to prevent it from occurring?

- Wear adequate thermal protection.
- Put on dry clothes after a dive.
- Stay well hydrated and avoid alcohol and caffeine.
- Do not do repeated dives until the diver has been rewarmed, and his body temperature has returned to normal.

Onsite Management:

Should any divers experience cold stress, the diving supervisor should:

- Abort the dive and instruct the diver to surface
- Review the diver for signs and symptoms of:
  - Cold stress resulting in hypothermia.
  - Presence of any other diving illness such as barotrauma and decompression illness.
- Contact the Appointed Hyperbaric and Diving Specialist/Physician (diving doctor) immediately to render medical assistance.
- Arrange to evacuate the injured diver to the nearest appropriate medical facility for treatment of both hypothermia and decompression illness.
- The diving vessel which is in anchorage or outside port limits must head for the closest port such as Marina South Pier, West Coast Pier or Tanah Merah Ferry Terminal to transfer the injured diver to the appointed diving doctor and/or the nearest appropriate medical facility.
- While awaiting evacuation, commence rewarming the patient as per hypothermia protocols:
  - Remove the diver's wet clothing and replace with warm dry clothing if available.
  - Begin rewarming the patient with extra clothing and warm blankets, and other warm items such as hot packs and heating pads.
  - Use diver's own body heat if nothing else is available.
  - Use a space blanket to try to raise the diver's body temperature.
  - Offer warm liquids, and avoid alcohol and caffeine.
- Provide 100% surface oxygen to the injured diver if he/she has breathing difficulties or shortness of breath, delivered in accordance with emergency diving first aid guidelines/protocols for either conscious or unconscious diver.
- Use of medications from the emergency diving first aid kit for occupational divers, must be prescribed by the appointed diving doctor.

Do note that severe cases of both hypothermia and hyperthermia can cause loss of consciousness as well as cardiac arrest. Cardiopulmonary resuscitation (CPR) with the use of automated external defibrillation (AED) and administration of 100% medical oxygen (if available) should be performed in accordance with emergency diving first aid resuscitation guidelines.

Annex E: Decompression Illness (DCI)

What is it?

The term "Decompression illness (DCI)" includes both decompression sickness (DCS) and arterial gas embolism (AGE). These are serious conditions and require medical evaluation and treatment.

DCS is a serious condition where air bubbles develop inside the body, and can end up lodging in various regions of the body like the joints, muscles, skin, neurological system like the brain, spinal cord, spinal nerves resulting in conditions commonly known as "the bends".

AGE is a rare and life-threatening condition which can occur following a rapid ascent without adequate exhalation or when holding a breath. This results in barotrauma to the lungs, releasing gas bubbles into the arterial bloodstream. These bubbles can cause tissue damage to all organs in the body. Those that are more susceptible are the brain (central nervous system) and the heart. Pneumothorax may also occur.

When does it occur?

DCS occurs when there is "bubble overload" in the tissues/organs and blood stream of the diver and this occurs when the diver is ascending from depth.

How does it occur?

When the diver is at the surface, the body tissues and blood are fully saturated with air at normal atmospheric pressure (1kg/cm^2).

During diving, the diver descends into depth while breathing compressed air, which is subjected to the ambient pressure that the diver is at. The air, comprising mainly of oxygen (21%) and nitrogen (78%) is dissolved into the tissues/organs systems of the diver's body.

Most of the air that is dissolved is mainly nitrogen, as oxygen is utilised by the tissues. Nitrogen is fat soluble and more of it is dissolved in fat containing tissues such as the brain, spinal cord and fat. The amount of nitrogen dissolved in the body tissue/organs is proportionate to the depth the diver is at, and the duration of the dive. The longer he/she is at depth, the larger the amount of nitrogen gas that will dissolve in the body tissues.

When the diver leaves bottom, and starts ascending, the ambient pressure decreases, and the dissolved gas in the tissues/organs comes out of solution and forms bubbles in the diver's tissues/organs. Some of these bubbles move to the blood stream. The dissolved oxygen gas is readily utilised by the body, while the dissolved nitrogen gas in the blood is carried to the lungs and exhaled.

Should there be a large amount of nitrogen "off-gassing" from the tissues/organs to the blood, there is an increased risk of bubble formation in the venous blood. These bubbles can cause "chokes" when there is high bubble load in the blood supplying the lungs.

Why does it occur?

During ascent, if the diver missed the stipulated decompression stop or ascended too rapidly, bubbles form rapidly in the blood and cannot be "off-gassed" quickly enough by the lungs. Bubble formation can also occur in divers who have certain medical conditions putting them at increased risk of DCI. These bubbles can block blood flow in various tissues resulting in the manifestation of DCI.

Recognising Decompression Sickness

Members of the dive team, including diving supervisors and divers should be trained to recognise the early signs and symptoms of decompression sickness so that the affected diver can be promptly treated.

DCS can be classified into Type 1 and Type 2 decompression sickness. In general, Type 1 DCS is mild and affects primarily joints, skin and lymphatic systems. On the other hand, Type 2 DCS can be life threatening and can affect vital organs such as the brain and spinal cord, lungs (breathing system) and heart system.

Symptoms of DCS usually manifest within 24 hours of the dive, and divers should contact the appointed diving doctor immediately for a medical review and treatment.

Table E1: Common Signs and Symptoms

Signs (visible to diving supervisor and/or fellow divers)	**Symptoms** (experienced by the affected diver)
Type 1 DCS	
• Reduced movement at affected joint • May affect walking and movement • Skin rash	Joint and Muscle Pain (Bends) • Deep, aching pain in large joint, commonly the hips, elbows, shoulders, and knees • Muscle pain • Symptoms generally can occur within several minutes (20 minutes) to within 24 hours of surfacing from a dive. Skin Rash • Skin rash (mild) with deep seated discomfort

Type 2 DCS	
Systems usually affected	Systems usually affected
General • Lethargy	General • Fatigue • Weakness
Neurological • Change/impaired gait • Difficulty walking • Has problems with physical coordination • Confusion • Lack of alertness • Unconsciousness	Neurological • Numbness • Tingling • Altered sensation • Altered vision (tunnel vision, double vision) • Muscle weakness • Problems with physical coordination • Difficulty controlling bladder function • Feeling confused
Cardiopulmonary (heart and lungs) — The Chokes • Dry cough • Shortness of breath • May appear "blue" due to lack of oxygen	Cardiopulmonary (heart and lungs) — The Chokes • Dry cough • Burning pain behind the sternum • Breathing difficulty/shortness of breath
Inner ear • Loss of balance • Vomiting • Not able to hear normally	Inner ear • Dizziness • Vertigo • Nausea • Vomiting • Impaired balance • Tinnitus (ringing in the ear) • Hearing loss
Skin • Cutis marmorata (red-blue discoloration of the skin giving it a mottled or marbled appearance)	Skin • Cutis marmorata (red-blue discoloration of the skin giving it a mottled or marbled appearance)

Arterial Gas Embolism (AGE) Signs and symptoms typically occur within 10 – 15 minutes of surfacing and may include:	
• Bloody froth from mouth or nose • Paralysis or weakness of limbs • Convulsions (fits) • Unconsciousness • Death	• Numbness • Large areas of abnormal sensations (paresthesias) • Weakness • Extreme fatigue • Loss of coordination • Tremors • Paralysis • Loss of control of bodily functions • Convulsions • Unconsciousness • Difficulty in thinking • Dizziness • Vertigo • Nausea and/or vomiting • Vision abnormalities • Hearing abnormalities • Personality changes • Sensation similar to that of a blow to the chest during ascent • Bloody sputum

Note

Symptoms of subcutaneous/mediastinal emphysema, pneumothorax and/or pneumopericardium may also be present. In all cases of arterial gas embolism, the possible presence of these associated conditions should not be overlooked.

Risk factors for development of DCI

Factors that increase diver's chance of getting DCI while at work:
1. Consumption of alcohol before dive. (Refer to SS511:2018, Para 15.2.7)
2. Stress, lack of rest or sleep.
3. Exercising or involved in strenuous activity after dive.
4. Excessive moderate to heavy exercises performed during diving.
5. Flying after diving and not in compliance with guidelines. (See Annex J)
6. Repetitive or multiple dives.

Note

Symptoms of DCI will usually manifest within 24 hours of a dive. If you feel unwell or have symptoms which may be similar to decompression-like symptoms, please contact your Appointed Hyperbaric and Diving Specialist/Physician.

Prevention of DCI

- Planning
  - Risk assessment for the dive should include considerations of environmental hazards like sea state and weather conditions.
  - Proper dive planning, with proper pre-dive briefing/checks and proper protocols and procedures to follow in the unforeseen event of an emergency.
  - Use appropriate commercial diving tables for planning of dives, nature of work and calculations.
  - Ensure that equipment is fit for use and there is a regular maintenance regime.
  - Diver training so that divers understand the basis for a controlled ascent when leaving bottom, with the necessary decompression stops as per the Commercial Diving Table used.

- Dive operations
  - Comply with commercial diving tables selected.
  - Divers should be medically fit to dive.

- Medical fitness of divers:
  - Divers must undergo medical screening periodically by an appointed hyperbaric and diving specialist /physician to ensure they are medically fit to dive.

  - Divers who:
    a) Have been on prolonged medical leave for more than three days.
    b) Had recent treatment for a serious medical condition.
    c) Have developed illnesses affecting the ear, nose, throat (ENT), respiratory system or cardiovascular system.
    d) Are taking any medication.
    e) Have not dived for more than 14 days.

- These divers should undergo a review with the Appointed Hyperbaric and Diving Specialist/Physician for a medical evaluation prior to return to diving with emphasis upon ENT, pulmonary and cardiac function as well as exercise capacity.

  - Prior to the dive, the diving supervisor should check with the diver that he/she is free from any acute medical conditions such as fever, respiratory symptoms, sinus and nasal congestion.
  - After diving, divers should adhere to a rest period of at least 24 hours at sea level prior to air travel.

Note

Recreational or Technical diving Tables are NOT to be used for Commercial Diving.

Onsite Management:

1. Should a diver experience DCI, the diving supervisor should:

   a) Review the diver for:
      - Signs and symptoms of decompression illness.
      - Presence of any other diving illness such as barotrauma.

   b) Ensure that the injured diver is provided with 100% surface oxygen immediately (if available), delivered in accordance with emergency diving first aid guidelines/protocols for either conscious or unconscious diver.

   c) Contact the Appointed Hyperbaric and Diving Specialist/Physician immediately for medical assistance.

   d) Arrange to evacuate the injured diver to the nearest appropriate medical facility for urgent medical review by the appointed diving doctor and recompression treatment if necessary.

      - The diving vessel which is in anchorage or outside port limits must head for the closest port such as Marina South Pier, West Coast Pier or Tanah Merah Ferry Terminal to transfer the injured diver to the appointed diving doctor.

   e) If a deck decompression chamber is available, recompression treatment can be carried out after review and as instructed by the appointed diving doctor.

Annex F: Barotrauma

What is it?

Barotrauma, which literally means "pressure injury", is damage caused by differences in pressure between the various cavities in the diver's body and the surrounding water. Barotrauma may occur during ascent or descent. The type of pressure injury that a diver may be exposed to depends on the body system or tissue that is affected. It can range from non-life-threatening dental barotrauma, painful and bleeding sinuses, middle ear barotrauma to life threatening Pulmonary (Lung) Barotrauma.

When does it occur?

When the pressure in the diver's body cavity, e.g. sinuses, middle ear, air space beneath fillings or dental caps, and in the lungs are at a different pressure to the ambient pressure. This occurs when the diver holds his/her breath and/or does not perform the equalisation manoeuvre during ascent from depth and descent to depth.

How does it occur?

During descent to depth, the volume of gas in a diver's body cavity contracts. Conversely, during ascent from depth, the volume of gas in a diver's body cavity expands. These changes in the volume of gas during ascent or descent result in a corresponding change in pressure. According to Boyles Law, the change in the ambient pressure is inversely proportional to the volume of the body cavity. The effects of this can be seen on rigid hollow structures, e.g. sinuses; partially rigid structures e.g. middle ear; and non-rigid structures, e.g. lungs.

Rigid Structures (e.g. Sinuses)

Structure of Sinuses

- Sinuses are cavities in the forehead and cheekbones, which are connected to the back of the nose. These are rigid structures lined with a tissue layer (the mucosa).

Sinus Barotrauma

- Changes in the volume of gas during descent or ascent exerts pressure changes and can cause damage to this layer resulting in nose bleeds and/or inflammation. Increase in pressure can also be felt and may cause pain in the sinuses.
- The cavity and the connections to the noise can also become blocked by mucus. In such a scenario, the diver will be unable to equalise the pressure in the cavities with the ambient pressure on descent/ascent.

Dental Barotrauma

- Dental barotrauma occurs when there is an air space between a filling or a cap on the teeth.
- When diving, this air space is also subject to pressure differentials.

- The diver may suffer pain on descent and during the dive, gas can become trapped in the tooth cavity while the diver is at depth.

- On ascent, the tooth filling may be forced out by gas over pressure.

- It is important that divers maintain good dental hygiene. If tooth pain is felt, a dental check-up should be carried out, and the diver must inform the dentist of his profession.

- Care must also be taken if dentures are worn, as loose dentures can be a choking hazard. If required, dentures should be removed prior to carrying out the dive.

Partially Rigid Structures (e.g. Middle Ear) — Ear Barotrauma

The most common problem associated with diving is middle ear barotrauma, caused by inadequate pressure equalisation between the middle ear and the external environment during diver ascent.

- The middle ear is located between the outer and inner ear. It is a cavity with bony walls on one side and a soft distensible membrane on the other. This distensible membrane is called the tympanic membrane or ear drum, which helps with the conduction of sound from the external ear to the inner ear for hearing. The middle ear is also connected to the back of the throat via the eustachian tube. This tube aids in equalisation of the middle ear pressure to the ambient pressure that the diver is physically at.

- As the diver descends to depth, the volume of gas in the middle ear reduces, and the ear drum bulges inward due to the pressure difference on either side of the ear drum. This is commonly known as "ears".

- If the Eustachian tube becomes blocked by swelling or mucus, the diver will have difficulty equalising the pressure in the middle ear with the ambient pressure.

- If descent is continued there may be bleeding in the drum as the small blood vessels are torn, and relief will be obtained only when the drum perforates.

- "Ears" is usually caused by:
  - Mucus or a cold.
  - Clearing the ears too late. In this case, ascending a few feet may clear the ears and allow the descent to be continued.

- In some instances, the diver may have blocked Eustachian tubes at depth, often from poor equalisation. On ascending, the volume of gas expands and the ear drum bulges outwards. The tension on the ear drum cause discomfort or even pain in the ear. If the diver is unable to equalise pressure on ascending, the pressure volume changes to the ear drum will worsen the discomfort to pain with bleeding and the ear drum may tear/perforate. Barotrauma occurring during ascent is less common than during descent.

- The diver can equalise the pressure in the middle ear with ambient pressure as he ascends or descends by various techniques, such as Valsalva or equivalent manoeuvres.

Non-Rigid Structures (e.g. Lungs) — Pulmonary Barotrauma

Pulmonary (Lung) barotrauma is usually regarded as a form of decompression illness and can be a life-threatening condition.

- The lungs are a pair of soft spongy air-filled delicate structures located in the chest region and protected by the ribs. The lungs are also lined by a double layered membrane called the pleura. Between this double layer there is a space called the pleural space.

- Lung barotrauma occurs mainly when there is an ambient pressure change resulting in a change in volume of the lung which cannot be compensated, e.g. breath-holding during ascent when breathing compressed air.

- This volume change results in lung over expansion and subsequent tearing of the fragile lung tissue. The air escapes the lung to the surrounding space in the chest cavity resulting in complications such as:
  - Pneumothorax
  - Tension pneumothorax
  - Mediastinal emphysema
  - Subcutaneous emphysema
  - Cerebral Artery Gas Embolism (CAGE)*

*The air can also escape into the blood vessels entering the arterial blood stream causing arterial gas embolism (AGE), which is a medical emergency. If the air bubbles then travel to the brain, this is then known as cerebral arterial gas embolism (CAGE).

- Pulmonary barotrauma mainly occurs during ascent and requires urgent immediate medical attention.

- A similar non-compensated (holding of breath) pressure induced change in the lung volume occurs during descent to depth this is lung squeeze and should be differentiated from lung barotrauma.

Why does it occur?

Some risk factors for pulmonary and non-pulmonary barotrauma are as follows (not exhaustive):

Condition	Risk Factors
Dental barotrauma	• Air under the filling or cap
Middle ear barotrauma **Sinus barotrauma**	• Poor equalisation technique • Too rapid a descent (common) or ascent • Presence of an upper respiratory tract infection, e.g. common cold and influenza • Allergies resulting in the diver experiencing blocked or runny nose (rhinitis) or symptoms relating to the sinuses • Medical conditions such as polyps, use of medications, history of broken nose or deviated septum (for sinus barotrauma)
Pulmonary barotrauma	• Breath-holding during ascent • Rapid ascent • Certain lung diseases causing an increased risk, e.g. poorly controlled asthma, chronic obstructive pulmonary disease (COPD) from smoking, lung conditions with scarring or inflammation, bullae or blebs in the lungs Note: Smoking damages the lung tissues (air sacs, airways and lining of the lungs) and is the leading cause of COPD.

Recognising Barotrauma

Members of the dive team, including diving supervisors and divers, should be trained to recognise the early signs and symptoms of barotrauma so that the affected diver can be promptly treated.

Table F1: Signs and Symptoms

Signs (visible to diving supervisor and/or fellow divers)	**Symptoms** (experienced by the affected diver)
Dental barotrauma	
No signs	• Sudden discomfort in the tooth. • Filling or veneer/cap coming loose.
Sinus barotrauma	
• Diver may have blood or blood-stained mucus dripping from the nose	• Headache (expanding in nature) on frontal, over the cheek bones, between the eyes or at the back of the ear lobes. • Squeaking noises in the head over the sinus areas. • A sensation of fullness and/or throbbing pain/ discomfort over the sinus areas of the head. o Bleeding nose o Taste of blood in the mouth o May have referred pain over the eye
Middle ear barotrauma	
No signs	• Fullness or pressure in ear canals • Pain, discomfort in the ears • Muffled hearing • Ringing in the ears (tinnitus) • Blood in the ear (if ear drum ruptures) • Vertigo (dizziness and nausea)
Pulmonary barotrauma — with AGE Complication (AGE: Arterial gas embolism or Cerebral arterial gas embolism)	
Occurs within 10-15 minutes of surfacing • Shortness of breath • Breathing difficulties • Chest pain and chest tightness • Shoulder pain • Neck pain and discomfort • Dizziness	Occurs within 10-15 minutes of surfacing • Numbness • Large areas of abnormal sensations (paraesthesia) • Weakness • Extreme fatigue • Loss of coordination • Tremors • Paralysis

• Bloody froth from mouth or nose • Paralysis or weakness of limbs • Convulsions (fits) • Unconsciousness • Cessation of breathing • Death	• Loss of control of bodily functions • Convulsions • Unconsciousness • Difficulty in thinking • Dizziness • Vertigo • Nausea and/or vomiting • Vision abnormalities • Hearing abnormalities • Personality changes • Sensation similar to that of a blow to the chest during ascent • Bloody sputum

Note

Symptoms of subcutaneous/mediastinal emphysema, interstitial emphysema (crackling under skin), pneumothorax and/or pneumopericardium may also be present. In all cases of arterial gas embolism, secondary to pulmonary barotrauma, the possible presence of these associated conditions should not be overlooked.

Do note that pulmonary barotrauma may or may not be associated with AGE or CAGE.

How to prevent it from occurring?

<table>
<tr><th>Condition</th><th>Preventive Measures</th></tr>
<tr><td>Dental barotrauma</td><td>• Regular dental check-ups
• Proper dental hygiene</td></tr>
<tr><td>Sinus barotrauma</td><td rowspan="2">• Do not dive if unwell, e.g.
  ◦ Have a cold or upper respiratory tract infection.
  ◦ Have nasal congestion and/or allergies.
  ◦ On medications that can interfere with equalisation.
  ◦ Unable to equalise.
• Descend and ascend slowly.
• Equalise frequently during descent or ascent.
• See your diving doctor if you are unwell or had recovered from recent barotrauma.</td></tr>
<tr><td>Middle ear barotrauma</td></tr>
<tr><td>Pulmonary barotrauma (Arterial gas embolism and/or cerebral arterial gas embolism)</td><td>• Do not hold breath during ascent.
• Controlled ascent with the necessary decompression stops following the Commercial Diving Table used.
• Do not smoke.
• Undergo a proper Diving Medical Examination regularly for assessment of lung function and medical conditions like COPD and, asthma, to ensure fitness to dive.</td></tr>
</table>

Onsite Management:

A. For pulmonary barotrauma/arterial gas embolism:

The diving supervisor should:

a) Abort the dive and bring the diver to surface.

b) Review the diver for signs and symptoms of pulmonary barotrauma/arterial gas embolism.

c) Provide the injured diver with 100% surface oxygen immediately, delivered in accordance with emergency diving first aid guidelines/protocols for either conscious or unconscious diver.

d) Contact the Appointed Hyperbaric and Diving Specialist/Physician immediately to render medical assistance.

- The use of medications from the emergency diving first aid kit for occupational divers must be prescribed by the appointed diving doctor.

e) Arrange to evacuate the injured diver immediately to the nearest appropriate medical facility for treatment of pulmonary barotrauma.

- In the event the diving casualty sustains Cerebral artery Gas Embolism (CAGE or AGE), appropriate onsite emergency recompression management should be undertaken, and injured diver should be taken to the closest appropriate hyperbaric recompression facility.

- The diving vessel which is in anchorage or outside port limits must head for the closest port such as Marina South Pier, West Coast Pier or Tanah Merah Ferry Terminal to transfer the injured diver to the appointed diving doctor and the nearest appropriate medical facility.

B. For sinus, middle ear and dental barotrauma:

The diving supervisor should:

a) Review the diver for signs and symptoms of sinus, middle ear and dental barotrauma or other forms of barotrauma.

b) Check for presence of decompression sickness.

c) Provide the injured diver with 100% surface oxygen immediately, delivered in accordance with emergency diving first aid guidelines/protocols for either conscious or unconscious diver.

d) Contact the Appointed Hyperbaric and Diving Specialist/Physician immediately to render medical assistance.
   - The use of medications from the emergency diving first aid kit for occupational divers must be prescribed by the appointed diving doctor.

e) Arrange to evacuate the injured diver to the nearest appropriate medical facility for treatment of sinus, middle ear and dental barotrauma.
   - The Diving Vessel which is in anchorage or outside port limits must head for the closest port such as Marina South Pier, West Coast Pier or Tanah Merah Ferry Terminal to transfer the injured diver to the appointed diving doctor and the nearest appropriate medical facility.

Annex G: Nitrogen Narcosis

What is it?

Nitrogen is an inert gas and is a main component of the atmosphere (78% of air). It is not involved in biochemical reactions in the body, and thus is considered as inert. Nitrogen narcosis, the most common form of inert gas narcosis, causes impairment of performance, confusion, delayed response time to visual and auditory cues, as well as hallucinations, and impairment of judgement. It is also known by names such as "Narks", "Rapture of the Deep", and "The Martini Effect".

When does it occur?

This occurs when divers are breathing compressed air at ambient pressures of around 30 metres (about 100 feet) or more. A recent study has shown that nitrogen narcosis can cause effects such as reducing inhibitory control at 20 metres of water or deeper[18].

How does it occur?

It is a condition produced by the breathing of compressed air at depth resulting in increased partial pressures of oxygen and nitrogen in the body.

- Inert nitrogen by itself at sea level pressure has no effect, however, when under pressure, nitrogen when inhaled produces unusual symptoms that often makes the person appear drunk. The exact mechanism is not well understood.

One theory is that at depth and increasing ambient pressure, the dissolved nitrogen may affect the nerves and brain, resulting in impairment of intellectual capacity, judgement, manual dexterity, memory, orientation to time, place and person. In divers, the effects could interfere with the diver's perception of depth, orientation and job performance while underwater, hence increasing the risk of accidents underwater.

The risk of impairment from nitrogen narcosis increases with depth of the dive and is usually first noticed at around 27 metres up to and beyond the 30-metre depth. Nitrogen narcosis worsens with depth. However, this is reversed on ascending to a shallower depth, and divers do not recall any symptoms when they come to the surface.

The dangers of nitrogen narcosis may be made worse by carbon dioxide toxicity, fatigue/tiredness, anxiety, cold/hypothermia, alcohol use, and the use of certain medications.

Why does it occur?

Inhaling inert gases at high pressure (more than or equal to 30 metres or 100 feet) affects the nervous system and brain resulting in the clinical signs and symptoms described, which could resemble "drunk-like" symptoms.

Recognising Nitrogen Narcosis (Inert Gas Narcosis)

Members of the dive team, including diving supervisors and divers should be trained to recognise the early signs and symptoms of inert gas narcosis so that the affected diver can be promptly treated.

[18] Frontiers in Psychology. 2017; 8: 1000 (Published online 2017 June 20).

Table G1 — Common Signs and Symptoms

Signs (visible to diving supervisor and/or fellow divers)	**Symptoms** (experienced by the affected diver)
• Observations often inaccurate • May make incorrect decisions about what to do • Disregard for personal safety	• Loss of judgment or skill • A false feeling of well-being • Lack of concern for job or safety • Apparent stupidity • Inappropriate laughter • Tingling and vague numbness of the lips, gums and legs

Note

For a dive on air, narcosis usually appears at a depth of approximately 40 metres of sea water (130 feet of sea water) and is very prominent at a depth of 61 metres of sea water (200 feet of sea water). There is a wide range of individual susceptibility to narcosis. There is limited evidence that adaptation may occur with repeated exposures.

How to prevent it from occurring

Planning

Diving supervisors running dives of more than 20 metres must take in consideration the sea state, and various environmental effects that the diver will be subjected to while underwater.

If there are new divers, they should be gradually acclimatised to deeper depths more than 20 metres.

Work practices

Communications

Regular communications procedures with the diver while descending to depth will help in recognising nitrogen narcosis.

Reduce factors that can worsen nitrogen narcosis:

- Regular flushing of the diving helmet with air, can help prevent build-up of carbon dioxide which can worsen the effects of nitrogen narcosis.

- Ensure the divers are not overly tired or anxious (especially for new divers) when performing deep dives.

- Use of proper wet suits when diving to reduce risk of hypothermia or exposure to cold temperatures.

- Ensure strict no-alcohol policies are implemented, and that the diver did not consume alcohol before a dive or at least 12 hours before a dive. (Refer to SS511:2018, Para 15.2.7)

Fitness to dive

Divers who meet any of the following criteria should undergo a review with the Appointed Hyperbaric and Diving Specialist/Physician for a medical evaluation prior to return to diving:

a) Have been on prolonged medical leave for more than three days.

b) Have developed illnesses affecting the Ear, Nose, Throat (ENT), Respiratory System or Cardiovascular System.

c) Had recent treatment for a serious medical condition.

d) Are taking any medication.

e) Have not dived for more than 14 days.

The medical evaluation should have an emphasis on ENT, pulmonary and cardiac function as well as exercise capacity.

Onsite Management:

If the diving supervisor suspects that the diver has nitrogen narcosis, he should:

- Immediately ascend the diver to a shallower depth and review the diver's condition.
- Consider aborting the dive if the diver:
  - Is at risk to himself while underwater or
  - Has signs and symptoms of other conditions such as barotrauma and/or DCI.

Upon surfacing, the diving supervisor should:

a) Review the injured diver for signs and symptoms of nitrogen narcosis, and any other diving illness such as barotrauma and/or decompression illness.

b) Provide the injured diver with 100% surface oxygen immediately, delivered in accordance with emergency diving first aid guidelines/protocols for either conscious or unconscious diver.

c) Contact the Appointed Hyperbaric and Diving Specialist/Physician immediately to render medical assistance.

d) Use of medications from the emergency diving first aid kit for occupational divers must be prescribed by the appointed diving doctor.

e) Arrange for immediate evacuation of the injured diver to the nearest appropriate medical facility/hospital for treatment of nitrogen narcosis.
   - The diving vessel which is in anchorage or outside port limits must head for the closest port such as Marina South Pier, West Coast Pier or Tanah Merah Ferry Terminal to transfer the injured diver to the appointed diving doctor and the nearest appropriate medical facility.

Annex H: Carbon Dioxide Toxicity (Hypercapnia)

What is it?

Also known as "Hypercapnia", carbon dioxide retention is a condition where excess carbon dioxide (CO_2) builds up in the body, and results in elevated carbon dioxide levels in the blood. This can become life threatening resulting in seizures, a loss of consciousness or even cardiac arrest when the CO_2 levels in the body get too high.

When does it occur?

This occurs when the diver is performing heavy work, resulting in more CO_2 production by the body. This leads to an increase in the rate of breathing (increased ventilatory effort). The CO_2 is exhaled into the diving helmet. If the diving helmet is not routinely/regularly flushed with fresh air, this would lead to the build-up of CO_2 within the helmet, hence resulting in rebreathing of exhaled CO_2.

How does it occur?

Carbon dioxide is a natural by-product of the body's energy production. When at work the body produces more CO_2 and this is taken by the blood to the lungs for exhalation. The normal respiratory rate and depth of breathing of a normal person is adequate to exhale the CO_2. Hypercapnia occurs when there is excess CO_2 production or a reduction in the CO_2 exhalation.

In diving, the increase of carbon dioxide when diving can be due to:

- Excessive carbon dioxide in the breathing gas (a contaminant).
- Poor elimination by the diving equipment.
- Poor elimination by the diver who is operating the equipment.

Why does it occur?

In commercial diving, the carbon dioxide is from the build-up of exhaled air in the dead spaces of the diving helmet, resulting in CO_2 being rebreathed by the diver.

As the diver continues to perform the task under water, carbon dioxide is produced and exhaled by the diver in the diving helmet.

As CO_2 level rises, the diver starts to feel that he is short of breath, and then breathes more rapidly to eliminate the excess CO_2 from the body. However, if there is accumulation of CO_2 within the dead spaces of the helmet, this will result in rebreathing of the diver's own exhaled air which has a lower oxygen content and a higher CO_2 content. This could result in continued build-up of CO_2 in the blood of the diver.

At times, the diver may deliberately breathe slowly, and CO_2 may not be removed fully from the body resulting in CO_2 build up in the blood.

Recognising carbon dioxide toxicity (hypercapnia)

The signs and symptoms would depend on how fast the carbon dioxide level rises. If the CO_2 level rises rapidly, the diver may lose consciousness without being aware of the early symptoms.

If the CO_2 level rises gradually, the diver may have the following symptoms:

- Headache.
- Fatigue, confusion, or feeling of euphoria.
- Inability to think clearly or concentrate.
- Drowsiness, dizziness.
- Flushed skin.
- Slowing of response.
- Shortness of breath, sensation of difficult breathing or suffocation (Dyspnoea).
- Increased breathing rate.
- Increased heart rate.
- Convulsions/seizures.
- Loss of consciousness.
- Death.

How to prevent it from occurring

The following measures can reduce the likelihood of carbon dioxide toxicity:

- Dive companies procuring dive equipment can consider:
    - Procuring dive equipment where the breathing apparatus is designed with minimum dead space.

- Diving supervisors must ensure
    - All diving equipment including air supply equipment, are properly and regularly maintained.
    - Equipment should be checked before each dive.
    - Sufficient volumetric supply of air to the regulator/helmets.
    - Breathing gas is not contaminated with CO_2.
    - Diver is flushing the helmet regularly and breathing normally.

- The diver should:
    - Pro-actively flush the helmet regularly to introduce fresh air into the helmet and prevent the build-up of CO_2.
    - Breathe normally. Do not practise slow breathing or skip breaths.
    - Reduce or quit smoking.
    - Avoid diving if he/she has respiratory (lung) issues.

Onsite Management:

If the diving supervisor suspects that the diver has carbon dioxide toxicity (hypercapnia) he/she should:

- Instruct the diver to flush the helmet with fresh air immediately and at regular intervals.
  - Wait for diver to regain the normal breathing pattern.

- Slow down or stop the work.

- Consider aborting the dive if
  - Diver is at risk to himself while underwater or
  - Diver has signs and symptoms of other conditions such as barotrauma and/or DCI.

Upon surfacing, the diving supervisor should:

a) Review the injured diver for signs and symptoms of carbon dioxide toxicity, and any other diving illness such as barotrauma and/or decompression illness.

b) Provide the injured diver with 100% surface oxygen immediately, delivered in accordance with emergency diving first aid guidelines/protocols for either conscious or unconscious diver.

c) Contact the Appointed Hyperbaric and Diving Specialist/Physician immediately to render medical assistance.
   - Use of any medications from the emergency diving first aid kit for occupational divers must be prescribed by the appointed hyperbaric and diving specialist/physician.

d) Arrange for immediate evacuation of the injured diver to the nearest appropriate medical facility /hospital for treatment of CO_2 toxicity.
   - The diving vessel which is in anchorage or outside port limits must head for the closest port such as Marina South Pier, West Coast Pier or Tanah Merah Ferry Terminal to transfer the injured diver to the appointed hyperbaric and diving specialist/physician and the nearest appropriate medical facility.

Annex I: Carbon Monoxide Poisoning

What is it?

Carbon monoxide (CO) is a colourless, odourless, tasteless, non-irritating and poisonous gas which exerts a toxic effect on the human body. The symptoms of exposure to this gas may go unnoticed but the effects of carbon monoxide poisoning are serious and could be fatal.

When does it occur?

CO is a product of incomplete combustion of organic matter such as natural gas, petrol, kerosene, oil, propane, coal or wood. One of the most common sources of exposure in workplaces is the internal combustion engine.

CO poisoning occurs when breathing air is contaminated with CO.

This contamination can take place during the filling of the air banks or bail-out cylinders. The intake of air by the compressor to fill the air banks can be contaminated by exhaust fumes from:

1) Dive boat.
2) Internal combustion of the compressor engine.
3) Partial combustion of lubricating oil of the compressor.
4) Low flash point oils/lubricant in the compressor.
5) Poorly maintained compressor.
6) Poorly operated compressor.
7) Low intake valve location of the air compressor.

How does it occur?

CO poisoning occurs when CO in the breathing gas, such as surface supplied air banks or air in the bail-out bottle is inhaled. CO diffuses from the lung to the blood stream and displaces oxygen from the red blood cells. Blood containing CO is then carried to the body's organs and tissues, thus reducing the availability of oxygen, e.g. in the heart, brain, muscles and other vital organs.

Why does it occur?

CO in the breathing gas such as surface supplied air banks or the air in the bail-out bottle is inhaled and levels of CO build up in the bloodstream.

CO binds strongly to haemoglobin in the red blood cells and displaces oxygen, making it less available.

Blood containing CO is then carried to the body's organs and tissues, thus reducing the availability of oxygen, e.g. in the heart, brain, muscles and other vital organs.

This can be fatal.

The effect of carbon monoxide increases with depth due to the increased pressure. This increased effect at depth is not affected by any increase of oxygen pressure at depth.

Recognising carbon monoxide poisoning

Members of the dive team, including diving supervisors and divers should be trained to recognise the early signs and symptoms of carbon monoxide poisoning so that the affected diver can be promptly treated:

- Dull headache
- Dizziness and light headedness
- Weakness and lethargy
- Nausea or vomiting
- Shortness of breath
- Impaired judgement
- Confusion
- Blurred vision
- Seizures
- Irregular heartbeats
- Loss of consciousness
- Bluish coloration of the nails and lips
- Death

The mention of the "Classic Cherry Red Lips" in textbooks, particularly non-commercial diving books, is a very late sign of carbon monoxide poisoning, when displayed by an individual who has been breathing gas contaminated with carbon monoxide.

How to prevent this from occurring?

The key is to ensure that the breathing air is not contaminated.

The diving contractor should ensure:

- Air intake for charging of the air banks is devoid of any exhaust fumes or toxic gases. An example is to place the designated air intake point for charging of air banks at the highest point on the dive boat. Proper maintenance of the air bank charging equipment such as compressors and filters.

- Filters must be replaced regularly in accordance with the manufacturer's instructions.

- Non-toxic oils are used in compressors that are used to charge the air banks. Electric compressors are beneficial in reducing the risk of CO poisoning.

- Machinery and equipment that may produce CO are periodically maintained.

The diving supervisor should ensure:

- Proper operation of compressors and charging procedures of the air banks.

Onsite Management:

If a diver is suspected to have carbon monoxide poisoning, it is deemed as a medical emergency.

The diving supervisor should:

- Abort the dive and bring the diver to surface.

- Once the diver has been brought to surface, provide 100% surface oxygen immediately by a non-rebreather mask, in accordance with emergency diving first aid guidelines/protocols for either the conscious or the unconscious diver.

- Use an oximeter to monitor blood oxygen levels and heart rate.

- Contact the Appointed Hyperbaric and Diving Specialist/Physician immediately to render medical assistance.

- Arrange to evacuate the injured diver to the nearest appropriate medical facility/hospital for treatment of CO poisoning.
  - The diving vessel which is in anchorage or outside port limits must head for the closest port (Marina South Pier, West Coast Pier or, Tanah Merah Ferry Terminal) to transfer the injured diver to the appointed diving doctor and/or the nearest appropriate medical facility.

- Monitor the diver for signs and symptoms of CO poisoning, e.g. seizures, shortness of breath and dizziness.

- Start pre-hospitalisation protocol for the management of these symptoms after confirmation with the appointed diving doctor.

Divers with severe carbon monoxide poisoning will have to be hospitalised and monitored in the hospital even when symptoms have subsided.

Annex J: Flying after diving

What is it?

Air travel (flying) after diving is an important issue as Singapore's geographical location is on an international route.

The medical aspect of flying and diving is related to the "off-gassing" or releasing of nitrogen bubbles in the body and performance of equalisation of the various body cavities (sinuses, middle ear) during take-off and landing of the aircraft.

When does it occur?

Flying soon after a dive can result in DCI occurring. This is because during take-off, a plane climbs rapidly to higher altitudes and the sudden drop in air pressure has the potential for the residual inert gases in the blood to form bubbles. It is recommended that a diver should not fly for at least a full 24 hours after a dive; this should give ample time for the body to off-gas the inert gases from the blood as well as providing a safe buffer for unexpected problems, such as a loss of cabin pressurisation during a flight.

How does it occur?

After a dive, the body tissues and organ systems still have residual nitrogen even after surfacing to sea level pressure of one bar. This residual nitrogen will gradually off-gas from the body tissues and organ systems into the blood and be transferred to the lungs for exhalation.

All flights out of Singapore are international flights. For short flights, e.g. one hour, the cruising altitude is typically at 22,000 feet. Cabin pressure at this cruising altitude will be maintained at 6,000 feet or about 0.8 bar. Generally aircraft pressurisation systems[19] are designed to keep the interior cabin pressure between 12 and 11 psi at cruise altitude. On longer flights, as the aircraft climbs to an altitude of 36,000 feet, the interior of the plane "climbs" to between 6,000 to 8,000 feet, i.e. 0.75 bar to 0.8 bar.

At the cruising altitude of an aircraft, the cabin pressure is generally 0.8 bar, i.e. 0.2 bar lesser than sea level pressure. During the climb of the aircraft to cruising altitude, the aircraft cabin pressure is gradually decreased to this lower pressure (0.8 bar) so as to reduce the differential pressure between the cabin pressure and ambient pressure (the plane is flying at around 32,000 to 38,000 feet) to ensure passenger safety and comfort.

This process of reduction in cabin pressure, will subsequently result in off-gassing of the residual nitrogen that is dissolved in the body tissues and organ systems of the diver. While the aircraft is climbing to cruising altitude, the off-gassing of residual nitrogen will be rapid, and is similar to a rapid ascent from depth. Hence the bubbles that are formed rapidly in the in the body would not be filtered by the lungs and end up being lodged in the joints, muscles, skin, brain, spinal cord and spinal nerves, resulting in decompression illness while on flight.

[19] Advisory Circular — Pressurization, Ventilation and Oxygen Systems Assessment for Subsonic Flight including High Altitude Operation by US Department of Transportation, Federal Aviation Administration.

Why does it occur?

The formation of bubbles in the body while on flight is due to the pressure differential from 1 bar (at sea level) to 0.8 bar (cruising altitude). Decompression usually occurs due to the diver ascending too fast, especially if they have been diving for long periods or at greater depths before the ascent. The same scientific principles apply to flying soon after a dive, as flying to a higher altitude brings you to an area with a lower pressure, much like ascending from a dive. Thus, the inert gases still dissolved in the blood can form bubbles if the reduction in pressure is not slow enough for the lungs to release the gases safely. Using this basis, staying at ground level after a dive and before a flight technically works as a "decompression stop" that a diver makes while ascending to surface. Deeper and longer dives will leave more residual inert gases, which will in turn require longer pre-flight surface intervals.

Recognising Decompression Illness (DCI)

Members of the dive team, including diving supervisors and divers should be trained to recognise the early signs and symptoms of decompression illness so that the affected diver can be promptly treated.

The signs and symptoms of DCI precipitated by flight will be similar to DCS Type 1 and Type 2 signs and symptoms.

Table J1: Common Signs and Symptoms

Signs (visible to diving supervisor and/or fellow divers)	**Symptoms** (experienced by the affected diver)
Type 1 DCS	
• Reduced movement at affected joint • May affect walking and movement • Skin rash	Joint and Muscle Pain (Bends) • Deep, aching pain in a large joint, commonly the hips, elbows, shoulder and knees. • Muscle pain. • Symptoms generally can occur within several minutes (20 minutes) to within 24 hours after surfacing from a dive. Skin Rash • Mild skin rash with deep-seated discomfort.

Type 2 DCS	
Systems usually affected	Systems usually affected
General • Lethargy	General • Fatigue • Weakness
Neurological • Change/impaired gait • Difficulty walking • Has problems with physical coordination • Confusion • Lack of alertness • Unconsciousness	Neurological • Numbness • Tingling • Altered sensation • Altered vision (tunnel vision, double vision) • Muscle weakness • Problems with physical coordination • Difficulty controlling bladder function • Feeling confused
Cardiopulmonary (heart and lungs) — The Chokes • Dry cough • Shortness of breath • May appear “blue” due to lack of oxygen	Cardiopulmonary (heart and lungs) — The Chokes • Dry cough • Burning pain behind the sternum • Breathing difficulty/shortness of breath
Inner ear • Loss of balance • Vomiting • Not able to hear normally	Inner ear • Dizziness • Vertigo • Nausea • Vomiting • Impaired balance • Tinnitus (ringing in the ear) • Hearing loss
Skin • Cutis marmorata (red-blue discoloration of the skin giving it a mottled or marbled appearance)	Skin • Cutis marmorata (red-blue discoloration of the skin giving it a mottled or marbled appearance)

How to prevent this from occurring?

- For uneventful dives, i.e. no DCI nor barotrauma, divers should take note:
  - At least 24 hours have elapsed after surfacing from the last dive before flying.
  - Avoid alcohol during these 24 hours "decompression stop" at ground level before a flight.
  - Keep hydrated for the 24 hours before the flight.

- If divers experience mild symptoms of DCI, even after many hours have passed since the last dive, contact the Appointed Hyperbaric and Diving Specialist/Physician to seek immediate medical help. Do NOT proceed to fly even if you have been at ground level for more than 24 hours.

What should be done?

Divers are advised to:

- Speak with your appointed diving doctor prior to booking your air travel.

- Wait at least 24 hours after surfacing from the last dive before flying. This can be achieved by proper planning.

- Inform the cabin crew on the aircraft if you experience joint pain or muscle discomfort with a skin rash of a mottled discolouration.

- Seek approval for use of the inflight 100% medical oxygen if you have the above symptoms.

- Consult a diving doctor when you arrive at the destination airport as you may require recompression therapy in a hyperbaric chamber.

- Inform and update your appointed diving doctor of your medical condition.

- Consult your appointed doctor if you wish to continue air travel after undergoing hyperbaric chamber treatment.

Annex K: Sample Decompression Procedures

The diver's decompression procedures are based on diving decompression tables used by diving contractor.

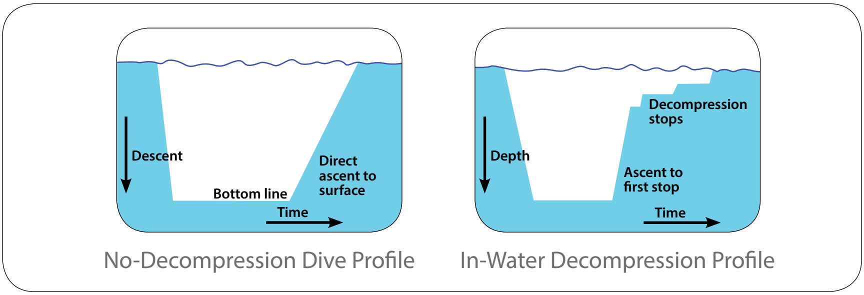

Figure K1: Illustration of a No-Decompression Dive Profile and an In-Water Decompression Profile.

<u>Exposure Limitations for Surface Orientated Diving</u>

Maximum Bottom Time Limitation for Surface Decompression and In-water Decompression		
Depth	**Bottom Time Limits (Minutes)**	
Metres	Feet	Surface Decompression and In-water Decompression
0–12	0–40	240
15	50	180
18	60	120
21	70	90
24	80	70
27	90	60
30	100	50
33	110	40
36	120	35
39	130	30
42	140	30
45	150	25
48	160	25
51	170	20

Suggested bottom time limitations adopted to mitigate the risk of DCI by reducing diver's exposure to pressure, as a good diving practice.

Annex L: Sample Deck Decompression Sheet

Sample Deck Decompression Sheet No:											Diving Contractor Logo Here	
NOTE: THIS 'GENERIC' RECORD SHEET TO BE MODIFIED BY THE DIVING CONTRACTOR AS REQUIRED FOR USE												
Date:				Project No:							Location:	
Client:						Vessel:						
Diver Name:						Dive Number:						
Chamber Operator:						Dive Time (Bottom time):						
PRE-DIVE CHAMBER AIR & OXYGEN STATUS												
LP Comp:	%	Receiver Press		Line Press			%	Bottle Press		Line Press		
Chamber Oxygen 1	%	Bottle Press		Line Press		Chamber Oxygen 2	%	Bottle Press		Line Press		

Clock Time at Chamber Depth				Notes, including Chamber Venting Times
Depth	Elapsed Time	Clock Time	Mix (Air/O_2)	
Clock Time Chamber Reached the Surface				

Accident/Incident Report required: Y / N (circle as required)	**Diver's Condition after Chamber Decompression:** **Well/Unwell** (circle as required)
Diver's Name (print):	**Chamber Operator's Name (print):**
Signature: **Date:**	**Signature:** **Date:**

Annex M: Sample Job Hazard Analysis

Diving Company Logo Here	Job Hazard and Risk Assessment (JHA) WORKSHEET	JHA No:	JHA-XXX
Area of Work/JHA Title:	LAUNCH AND RECOVERY OF WORK BOAT		
Last Updated By:		Last Updated On:	

Job Step	Hazards Identified	Controls & Checks Required	Action By
Rig Up and Launch the Boat	Poor Weather Conditions Personal Injury Rigging Failure Launch Position Asset Damage	Lee to be provided when possible Monitor weather conditions, obtain weather forecast. Good communications and awareness Correct PTW for over the side operations	Deck Foremen Deck Crew
Personnel Transfer to Boat	Failing from Heights Falling Objects Poor Visibility Pinch Points Work Boat Movement Crush Injuries	Correct PPE to be worn at all times as stated on PTW Deployment area to have adequate lighting at all times During night time operations or in limited visibility personnel to wear personal EPIRBS and carry light sticks Weather limits to be monitored Good communication during boat launch	Deck Foremen Deck Crew

Type of Permit Required (please indicate by ticking box)	**Additional PPE Requirements** (Please list)	**Special Tools or Equipment Required**
Diving	1)	1)
Hot Work	2)	2)
Confined Space	3)	3)
Isolation / Electrical	4)	4)
Working at Height	5)	5)

REVIEW / UPDATE RECORD

Participants	Date	JHA Updated	Participants	Date	JHA Updated

Annex N: Sample Toolbox Talk Checklist

Hazard/Risk Management	Hazard/Risk Management	Toolbox Talk Risk Identification Card
Can all personnel in the group answer YES to the following questions? Have all the significant hazards involved with the work been identified? Have control measures been identified for these hazards? Have the people responsible for implementing these control measures been identified and are the controls in place? Has the method of communication been agreed and tested? Is everyone aware of what is being done at the worksite? Does everyone know that any changes to the work plan have to be communicated to everyone involved in the work? Does everyone know that any new people joining the work party must be given a full and thorough handover? **If the answer to any of these questions is NO, then the safety of people is at risk.** **The talk leader should confirm the understanding of the group by asking open questions on the above points.**	**Will the work involve:** The use of lifting equipment? Working in noisy areas? Line breaching or potential hydrocarbon release? Environmental impact? Manual handling-moving objects/loads? (If yes, obtain/complete a manual handling assessment) Working near objects that may move? Working in an area with poor lighting or a tight/confined space? Working at height? Working near areas that could cause personnel to slip, trip or fall? Using portable electrical equipment? Working with equipment or connections under pressure? Working with dangerous goods and substances hazardous to health? Personnel who are new to each other? Equipment which is potentially dangerous? Pressure differentials? **If so the work may be hazardous and care should be taken to ensure that the work is done safely.** **Remember everyone is responsible for:** • Using the correct tools for the job. • Being aware of the hazards around them and remaining vigilant to change. • Using the correct PPE for the job. • Making themselves aware of, and working within the requirements of the PTW system, Procedures, RISK/COSHH/ Manual Handling Assessments.	Location ____ Worksite ____ Talk Leader ____ Dive Supervisor ____ Task ____ Date and Time ____ **Attendees** 1. ____ 2. ____ 3. ____ 4. ____ 5. ____ 6. ____ 7. ____ 8. ____ 9. ____ 10. ____ **Reviewed by:** Talk Leader ____ Dive Supervisor ____ **Action Required:** Update Procedures Y/N Update RA Y/N Other Y/N

Annex O: Sample Signage on “Divers At Work”

Annex P: Sample Diving Permit-To-Work

Diving Permit To Work					
Date:	**Time:**	**Permit No.:**			
Area Authority:		**Vessel:**			
Location:		Planned Work Schedule			Date
			Start		
			Finish		
Diving Contractor	**Name:**	**Contact (Tel):**			
Diving Supervisor In-charge of Worksite	**Name**(print):	**Signature:**			
Sea State:	Wind Dir/Spd:	Swell:	Current Dir/Spd:		
Description of Work:					
Description of Diving Equipment/Plant/Tools to be Used:					

Supporting Documents / Permits Attached:					
Isolating Mechanical	Y / N	No:	Isolating Electrical	Y / N	No:
Hot Work Permit	Y / N	No:	Entry Permit	Y / N	No:
Diver Down boards in place: Y / N			Equipment Tagged Out/Locked Out: Y / N		
Risk Assessment Completed:			Y / N		
Pre-dive Checks Completed:			Y / N		
Toolbox Talk Completed:			Y / N		
Special Precautions Required:			Y / N (if Yes, list)		

Personal Protective Equipment:				
Hard Hat	Safety Footwear	Safety Glasses	Coveralls	Gloves
Additional PPE	Life Jacket, Safety Harness, Ear Protection, Work Vest, Other (specify)			
Is a First Aider available on site?			Yes	No
Is a First Aid kit available on site, has it been checked?			Yes	No

Permit Issue	Applicant	Issuing Authority	Approval Authority
Date/Time			
Name/Sign			
Revalidation	Applicant	Issuing Authority	Approval Authority
Date/Time			
Name/Sign			
Permit Cancellation	Applicant	Issuing Authority	Approval Authority
Date/Time			
Name/Sign			

Annex Q: Sample Diving Permit-To-Work Pre-Dive Checklist for use by Site Owner/Client and/or Diving Contractor

Site Owner / Client Diving Operations Pre-Dive Hazard Checklist	Circle as necessary	
1. Risk Assessment Has a Diving Project Risk Assessment been completed for this diving project? Have the diving personnel reviewed and signed off on the Risk Assessment?	Y	N
2. Permit to Work Is a Permit to Work required for this diving activity Is a copy of the Permit to Work displayed on-site?	Y	N
3. First Aid Requirements Is a First Aider available? Is First Aid kit available? Is the First Aider qualified to the minimum standard? Is the First Aider training still valid ?	Y Y Y Y	N N N N
4. Personal Protective Equipment Do all the project personnel have PPE? Are any specialist items of PPE required for this task? List…………………………………………………………..	Y Y	N N
5. Are There Any Other Hazards not Listed in the Risk Assessment Working at Height Working in a Confined Space Chemical/Contamination Hazard Inlets / Discharges Radioactive Sources Asbestos Other………………………………………………………….	Y Y Y Y Y Y	N N N N N N
6. Manual Handling Have the personnel been instructed in correct manual handling techniques?	Y	N
7. Has a ToolBox Talk been Completed?	Y	N
8. Is a Diver Competency Matrix Available? Is it in-date? Have the diver's training certification been checked? Have the diver's medicals been checked?	Y Y Y Y	N N N N

9. Has the Port Authority Approved the Diving Operation?	**Y**	**N**
10. Worksite Check		
• Is a copy of the work procedures available on site?	**Y**	**N**
• All the diving equipment appears to be in working order.	**Y**	**N**
• The diving equipment Certificate Register is available for inspection.	**Y**	**N**
• A copy of the latest weather forecast is available.	**Y**	**N**
• "Diver at Work" signs are displayed as appropriate- Flag Alpha.	**Y**	**N**
• There are no crane operations in progress nearby.	**Y**	**N**
• There is no scaffolding ongoing nearby.	**Y**	**N**
• All inlets / discharges have been secured — lock out/tagout.	**Y**	**N**
• All engines / propellers/ rudders have been secured — lock out/tagout.	**Y**	**N**
• Is the site clear of falling objects?	**Y**	**N**
• Have primary mans of communication been tested?	**Y**	**N**
• Have secondary means of communication been tested?	**Y**	**N**
• Where appropriate, has all Marine Traffic been notified of the planned diving operations?	**Y**	**N**
• Have all the boat checks been completed?	**Y**	**N**
• Is the boat Emergency Survival Kit in the boat?	**Y**	**N**
11. Are all the Controls in Place?	**Y**	**N**

12. Signatures:

Site Owner/Client Representative: ……………………………………………… Date: ………………

Diving Supervisor: ………………………………………………………………… Date: ………………

Annex R: Sample Pre-Dive Checklist for Use by Diving Supervisor

S/N	Site Owner / Client Diving Operations Pre-Dive Hazard Checklist	Check
1.	Is the PTW in place? PTW Number:	Y/N
2.	"Diver Down" board placed close to the main engine starting device and to bridge control panel	Y/N
3.	All vessel seawater intakes located and divers advised	Y/N
4.	All vessel thrusters secured — lock out/tagout	Y/N
5.	Vessel main engine port and starboard secured — lock out/tagout	Y/N
6.	Vessel steering motors secured — lock out/tagout	Y/N
7.	Watchkeeper standing by on bridge at all times during diving operations	Y/N
8.	Diving flag/signs displayed	Y/N
9.	Vessel diving PTW in place and valid	Y/N
10.	No bilge to be pumped or material dumped overboard	Y/N
11.	No dumping of food scraps	Y/N
12.	Weather forecast obtained	Y/N
13.	Weather and mooring arrangement reviewed prior to diving	Y/N
14.	Dive boat fully functional	Y/N
15.	Weather and sea state is suitable to carry out the diving operation	Y/N
16.	No other vessel to approach within 500 m of the diver	Y/N
17.	JHA for dive boat operations carried out	Y/N
18.	All tools on and above worksite to be secured during diving	Y/N
19.	Dive equipment operational and checked	Y/N
20.	Cables, hoses, whips and umbilicals to be kept tidy and to a minimum length	Y/N
21.	All communications to be tested prior to diving. Alternative means of communication and command to be considered	Y/N
22.	JHA and Toolbox Talk for diving operations carried out	Y/N

Declaration
Diving Supervisor
I understand that the work will only take place when all the above safety precautions are complied with.

Name____________________________Signature____________________________Time______________ Date______________

Completion Certificate (Dive Supervisor)
I declare that the underwater work specified above has been completed/not completed and all underwater equipment has been recovered and the diving site has been left safe.

Diving Supervisor:
Name____________________________Signature____________________________Time______________ Date______________

Annex S: Sample Pre-Dive Checklists for Use by Diver and Diver's Attendant

For Use by Diver

No.	Item	Action	Check
1.	Comunication between the diver and dive control radio	Ensure the diver communications system is working	Y/N
2.	Black box recording device	Ensure it is on and working. Start recording dive from dive checks to end of the dive	Y/N
3.	Mask/helmet attachments, spider and hood liner, face mask strap	Inspect for corrosion, wear, tear or damage	Y/N
4.	Mask/helmet non-return valve	Check for correct operation	Y/N
5.	Mask/helmet air supply	Check that air is available on demand and also free flow	Y/N
6.	Diver weight belt	Check for corrosion or damage. Ensure correct amount of weight for the diver	Y/N
7.	Diver harness	Check for tear or damage. Fitted with crutch straps and a lifting 'D' ring	Y/N
8.	Boots/fins and gloves	Check for damage and ensure it is a correct fit	Y/N
9.	Knife and scabbard	Inspect knife for corrosion, damage and sharpness. Knife is positioned within easy reach of the diver's hands	Y/N
10.	Torch/hat light/camera	Function check	Y/N
11.	Umbilical safety carabina	Inspection for corrosion and damage. Check for operation and if secured to diver's harness	Y/N
12.	Bail-out cylinder	Check contents pressure. Check correct operation to helmet/mask	Y/N
13.	Air/as quad valves	Ensure the quad valves are fully open	Y/N
14.	Air/gas supply	Check air/gas is supplied to the diver's helmet/ mask. Check the reserve supply is available	Y/N
15.	Tools	Ensure the necessary tools are available and in good condition. Fitted with a securing lanyard	Y/N
16.	Diver overalls	Complete with full length sleeves. A light-weight, 'Lycra' under-suit to be worn	Y/N

Note

The diving supervisor notes in the Dive Log that the diver's pre-dive checks have been completed

For Use by Diver's Attendant/Tender

No.	Action	Check
1.	Diver coveralls correct, under-suit worn	Y/N
2.	Diver harness fitted and secured	Y/N
3.	Diver bail-out fitted. On at the bottle, off at the hat/ready for use	Y/N
4.	Diver bail-out contents gauge reading bar	Y/N
5.	Diver helmet/mask fitted, safety pin in	Y/N
6.	Diver umbilical/lifeline secured to his harness and checked	Y/N
7.	Diver breathing from his gas supply	Y/N
8.	Diver has a knife	Y/N
9.	Diver weight belt secured	Y/N
10.	No bilge to be pumped or material dumped overboard	Y/N
11.	Diver gives OK and ready to dive	Y/N
12.	Diver understands his task, has been briefed and is ready for the water	Y/N

Declaration
Diving Supervisor
I understand that the work will only take place when all the above safety precautions are complied with.

Name__________________________Signature__________________________Time_____________ Date_____________

13. List of Tables

14. List of Figures

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