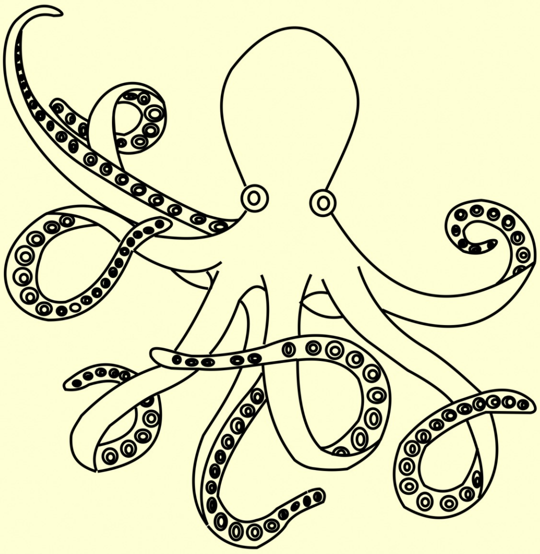

Diving & ROV specialists

Surface supplied diving using MT-92/2019 tables Book #2 Elements for preparation

30 December 2022

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This document is book number two of the ensemble of three books constituting the "Surface-supplied diving handbook using MT 92 tables" described underneath.

Books	Description
Book #1: Description and prevention of diving accidents	This document describes the accidents linked to surface-supplied diving and the procedures to solve and avoid them.
Book #2: Definition and elements for preparation	The document describes the scope of surface supplied diving procedures, the MT92 decompression tables, and some elements to consider when organising a surface supplied diving project such as the necessary personnel, organization of the maintenance of the diving system, weather conditions, surface supports, systems of communications, work procedures with ROV, documents that must be available, etc.
Book #3: Air and nitrox procedures using in-water & surface decompression	This document describes procedures for safe air and nitrox dives using in-water air decompression, in-water nitrox decompression, in-water oxygen decompression at 6 m, and surface oxygen decompression.
Complementary books that have not yet been published but are planned shortly.	
Book #4: Air & nitrox diving procedure using scuba replacement	Diving using SCUBA replacement systems has widely evolved throughout the years. A particular organization is necessary for these operations, whose limitations are more stringent than normal surface-supplied diving operations and require specific diving systems. In addition, these procedures include the conception or the organization of relevant surface supports, and this aspect of the organization is essential. For these reasons, it appears logical to describe the organization of such operations in a separate book.
Book #5: Air & nitrox procedures using O2 decompression in wet bell	Wet bells provide numerous advantages over diving baskets when they are well-designed. That includes bells that are sufficiently light and as compact as baskets to be easily operated from lightweight surface supports, which is not the case for many units currently in use. In addition to setting up the elements for designing adequate wet bells, the document will provide procedures for using them and their limitations.

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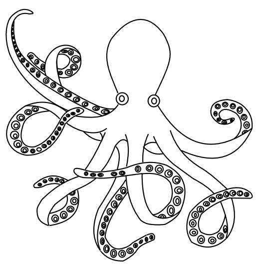

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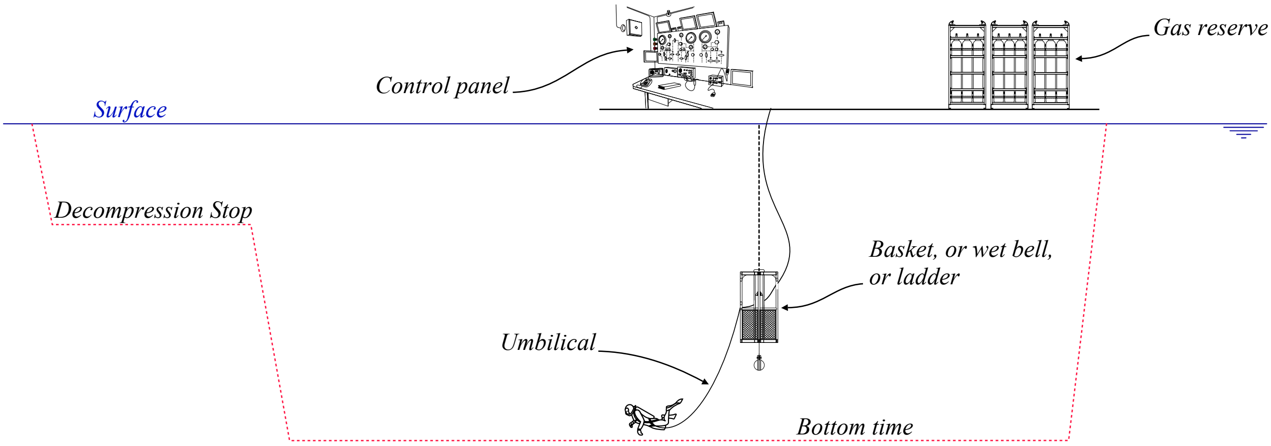
A - Procedures described in this handbook

1 - Surface supplied diving operations described in this handbook

"Surface supplied diving procedures", also called "Surface orientated diving procedures" by IMCA (International Maritime Contractor Association) and NORSOK (Norsk Sokkels Konkuranseposisjon - Norway), are incursion diving methods where the diver is deployed from the surface using systems such as ladders, baskets, and wet bells, and is supplied by gas using an umbilical by compressors and gas tanks, stored on the deck of the ship or the facility from which the diving operations are organized. This technic provides the advantage that the dive duration is not limited by the gas reserves the diver can carry and that he is not obliged to carry extra bottles. Also, even though the umbilical slightly restricts the diver's movements, it allows him not to be lost in the water and always return to its means of deployment. It also allows to keep him at a safe distance from identified hazards and not go too far from his means of deployment. In addition to breathing gas, the umbilical carries voice communications, video signals, depth control systems, electricity for the diver's light, and hot water for heating him in case of operations in cold water.



Having substantial gas reserves and heating systems to control the cooling-off of the diver gives the possibility of performing long dives. However, the diver will be physiologically limited by the decompression to perform due to the accumulation of gas in his organism, depending on the depth and the duration of exposure. Fatigue is also a phenomenon to take into account. For these reasons, statutory instruments of countries and guidelines published by professional organizations provide limitations linked to the gas breathed and the system of deployment used. Note that the advantage of surface supplied operations is that they do not require complex equipment like the two methods described below and can be quickly organized.

Transfer Under Pressure (TUP), is usually considered a surface supplied (or surface orientated) diving procedure. This method consists of transferring the divers to the working depths using a closed bell, which is then connected to a chamber where they perform their decompression. The difference with other methods of surface-orientated diving operations is that there is no decompression phase in the water, so the divers are isolated from the external conditions, which is an advantage in rough seas.
However, as a closed bell is used, I think it is a method between incursion and saturation diving that can only be performed by people trained to use such a bell. For this reason, it is not discussed in this handbook.
For information, the principle of saturation is based on the fact that if a diver stays for a sufficiently long time at a given depth, the breathing gas which is absorbed by the diver's body will gradually reach the ambient pressure at this depth. When this state is reached, the diver is said to be in a state of saturation. As a result, the decompression will be the same regardless of the time spent at this depth, and the diver can work at the depth he is stored without the need to perform decompression stops as long as he is maintained at this pressure. Thus, the divers live in chambers kept at the bottom's pressure and are transferred to the bottom using a pressurized closed bell. The decompression is done at the very end of the project. This diving method allows to dive a long time and at depths that are unreachable using incursion dive techniques from the surface. Saturation procedures are discussed in our “saturation diving handbook”.

2 - Limitations of the surface supplied procedures described

2.1 - Limitations linked to the gasses used

Five types of gas mixes are employed for surface supplied operations:

2.1.1 - Air

Air is the mixture of gases that makes up the earth's atmosphere. It consists of 78.08% nitrogen, 20.98% oxygen, 0.90 % argon, 0.03% CO2, 0.17% of other gases, and water vapour that varies depending on the area (arid areas or wetlands such as the maritime zones). To make things more simple, it is usually said that air is composed of 78% Nitrogen, 21% oxygen, and 1% of other gasses in addition to moisture.
Air can be the natural earth's atmosphere or be a synthetic gas fabricated in specific plants. It can be delivered to the divers by Low-Pressure (LP) compressors or from high-Pressure (HP) gas containers where it is stored.
The limitation arising from this gas are of three natures:

- Nitrogen is a gas that provokes narcosis, a reversible alteration in consciousness that occurs while diving at depths deeper than 30 m.
- Due to its molar mass (28.9647 g/mol) and its density (1.292 kg/m3), air becomes uncomfortable to breathe past 50 m - 60 m, and obliges efforts of the thoracic cage that quickly fatigue the diver.
- Nitrogen is also a neutral gas that is not used by the organism and accumulates in it depending on the depth and duration of exposure. As a result, decompression stops may be necessary to gradually eliminate it when returning to the surface to avoid the effects of decompression illness that may damage parts of the organism and may trigger permanent disabilities or fatalities.

To control the problems above, the designers of diving tables limit the depths and bottom times in the documents they publish. Also, work labour ministries of countries often impose a maximum operational depth and limited bottom times. It is, for example, the case with the UK-HSE, which sets a maximum operating depth of 50 m with air and maximum bottom times based on the recommendations from the report "The incidence of decompression sickness arising from commercial offshore air-diving operations in the UK sector of the North sea during 1982/83" issued in December 1997 by doctors Shields and Lee. These UK HSE limitations have also been adopted by other countries and organizations such as the International Organization of Oil and Gas producers (IOGP). Note that some states and professional organizations apply operational air diving depth limits between 50 and 60 m. As an example, such as the Association of Diving Contractors International (ADCI) authorizes air dives up to 57 msw (190 fsw).
For consistency with all organizations, the procedures recommended in this handbook are based on the guidelines recommended by the UK-HSE.

2.1.2 - Nitrox

Scientifically speaking, a "nitrox" is a mix of oxygen and nitrogen. Thus, air is a "nitrox". However, in divers' language "nitrox" means mixtures nitrogen-oxygen with a percentage of oxygen more elevated than air. They are used to reduce the decompression time that is linked to the elimination of the nitrogen dissolved in the body. Thus a diver breathing a nitrox mix at a given depth will have less stops to perform than when breathing air. Usually, the decompression to be performed is calculated by using the Equivalent Air Depth (EAD) formula which allows to evaluate the equivalent depth on the air table: (nitrogen % x absolute depth)/79 - 10 msw or (nitrogen % x absolute depth)/79 - 33 fsw. However, some decompression table sets are provided with pre calculated equivalent air depths.
Nitrox mixes have also their limitations:

- They can trigger an acute oxygen poisoning if the partial pressure of this gas is too elevated, or chronic oxygen poisoning if a mix that does not trigger acute poisoning, but with a partial pressure of O_2 above 0.5 bar, is breathed too long a time. As a result, the maximum partial pressure must be limited, and also the duration and the frequencies of exposure.
- Another limitation is that such mixes lost their efficiency as we go deeper due to the fact that the percentage of oxygen that can be used diminish with the depth. Thus, we can say that nitrox mixes are ideal for dives above 30 m, and that the advantage they provide is widely more reduced below this depth.

The decompression table designers usually limit the maximum Partial Pressure (PP) oxygen breathed in the water to values between 1.6 and 1.4 bar. Also, the maximum times of exposure are usually given in the decompression table. They may, however, consist of a specific table such as the one provided by the "Diving standards and safety manual" published by NOOA (National Oceanic and Atmospheric Administration - USA), explained in book #1.
Note that the statutory instruments of many countries limit the maximum PPO_2 to values between those indicated above. However, some countries such as the United Kingdom and organizations such as IOGP, IMCA, and the Diving Medical Advisory Committee (DMAC) strictly limit the maximum PPO_2 to 1.4 bar, which also limits the efficiency of this procedure. This limitation is based on the theoretical equation of Morrison and Reimers, but also numerous experiments that prove that 1.3 bar is a limit below which acute oxygen poisoning does not happen. For compatibility with most published procedures and standards, this handbook's recommended maximum PPO_2 is 1.4 bar, and the times of exposure are those recommended by the UK-HSE operational limits, based on the works of doctors Shields and lee.

2.1.3 - Heliox

Heliox is a binary mix of helium and oxygen (HeO_2) that is used to limit the effect of the narcosis, a reversible alteration

in consciousness that occurs while diving at depth (> 30 m) with air or mixes using nitrogen or other narcotic gasses. Thus, with such mixtures, helium merely replaces the nitrogen of nitrox mixes. Another advantage of using helium in place of nitrogen is that it is a light gas that allows breathing comfortably at the depths where air becomes difficult to breathe. Note that heliox mixtures can be used from the surface to the planned depth of work, provided that the PPO_2 of the mix is appropriately calculated not to provoke hypoxia or acute oxygen poisoning (Hypoxia is generally considered to occur when the PPO_2 is less than 160 Mb).
The main inconvenience of heliox mixtures is that because helium is a light gas, it diffuses more quickly and deeply in the tissues that compose the body and is longer to restitute. As a result, diving with heliox requires longer decompression times than with air. For example, for a dive of 30 minutes at 39 metres, 40 minutes of decompression is necessary if using a heliox mix 22-24% oxygen, and 20 minutes and 30 seconds is necessary if breathing air.
Another inconvenience of heliox mixtures is that helium has a more elevated conductivity than nitrogen. As a result, the respiratory heat loss under heliox is six times faster than in air.
Another problem of heliox mixes is the cost of helium, which is a rare gas that cannot be fabricated. Reclaim systems can be installed to recover and recycle it. However, they have the inconvenience to be expensive, occupy a not neglected space, and to require a specific training of the personnel using them.
The tables published by competent bodies are designed to control the inconveniences of helium. These controls usually consist of limitations of the bottom times and pre-calculated mixes.
Also, some governments and professional associations limit the depth and the bottom times that can be applied. As an example, the French regulations restrict the use of surface supplied heliox diving procedures to depths less than 78 m. The United Kingdom "Approved Codes of Practices (ACOPs)" are more stringent and say that closed bell diving techniques should be used when diving deeper than 50 metres. ADCI limits the maximum depth to 300 fsw (91 msw), and IMCA and IOGP restrict it to 75 metres. IMCA also limits the bottom times of dives above 50 m to bottom times, calling for less than 100 minutes of in-water decompression, and the bottom times between 50 m and 75 m to 30 minutes, while IOGP restricts the bottom times to 30 minutes whatever the depth.
Again, for compatibility reasons with the most employed procedures, the recommendation of this handbook is to limit the depth to 75 m maximum and the bottom times to those promoted by IMCA.

2.1.4 - Trimixes

As suggested by their name, trimixes involve three different gasses. Incursion diving mixes are based on oxygen + nitrogen, + helium. The advantages and inconveniences of such mixes are between air and heliox mixtures, depending on the quantity of helium in the mix.
Note that there is currently no commercial diving table from well-known competent bodies based on such mixtures. However, they have been used by militaries and are employed by high-level sportive divers, so they may be used for commercial diving in the future. Also, the French labour ministry published a trimix table for coral fishers that can be downloaded through this link: http://diving-rov-specialists.com/index_htm_files/docs-2-tables-trimix-corail-mt95.pdf.
These technics are not described in this handbook as MT92/2019 procedures do not use such mixtures.

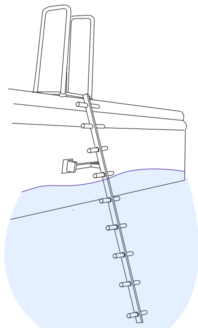
2.1.5 - Oxygen

Pure oxygen is used to speedup the decompression by replacing the nitrogen or the helium with oxygen during the stops at 6 m (20 fsw), 9 m (30 fsw), and 12 m (40 fsw). The inhalation of pure oxygen creates a washout which removes the nitrogen more efficiently. It has been demonstrated that systematic use of oxygen during the stops reduces the risk of decompression sickness.
The conditions for using pure oxygen are those of nitrox. However, although tables such as the US navy and DCIEM authorize the breathing of pure oxygen in the water at 30 fsw (9 msw), MT92/2019 limits it to 6 m to provide a safety margin and authorize its use at 12 m and 9 m in a wet bell. Note that NOAA (US-National Oceanic and Atmospheric Administration) also limits the oxygen in-water stops to 6 msw (20 fsw). Also, DCIEM provides an in-water decompression table with oxygen breathing at 6 m. For consistency, the in-water oxygen stops are limited to 6 msw, and deeper oxygen stops are performed in a wet bell in all our handbooks.

2.2 - Limitations linked to the deployment systems

Four means of deployment are employed for surface supplied operations. Their condition of use and limitations are decided by the statutory instruments of the countries and the professional organizations.

2.2.1 - Ladders



Ladders are the most simple means of deployment. Their advantage is that they can be installed on small boats. For this reason, they are often used for surface-orientated diving.
In case in-water decompression is to be performed a stop line is installed at its direct proximity.
However, the use of ladders is limited by the problems below:

- Depending on the height of the launching station above the surface of the water, they may oblige the diver to make efforts to ascent to the deck at the end of the dive, which can trigger decompression accidents. Thus, limiting this height to 2 m is recommended.
- They are not considered suitable for performing "surface decompression", which is a method of decompression that consists of partially decompressing the diver by completing

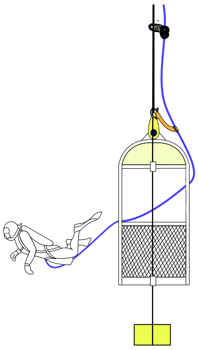
to complete the decompression in it. The main reasons for this incompatibility are that ladders do not allow for a controlled ascent as with a basket, in addition to the fact that the diver must climb the ladder and thus make efforts while he is decompressing. As a result, the surface transfer to the chamber may not be under control and, therefore, trigger a decompression accident.

- Diving using a ladder does not offer the possibility to restrict the diver's umbilical as precisely as using a basket because it is not enclosed in the deployment device. Suppose that a diver deployed from a Dynamic Positioning (DP) vessel is suddenly returned toward the surface for any reason. In that case, the umbilical length deployed during the descent or at depth is too long to prevent him from being drawn toward the active propellers and thrusters of the surface support, resulting in a high probability of fatality. Based on these considerations, all commercial diving organizations state that using ladders for diving from Dynamic Positioning (DP) vessels is highly hazardous and must be strictly forbidden.
- Because they are deployed in the splash zone of the vessel or the facility, they do not provide any protection against the waves and sudden movements of the ship that may prevent the divers from grabbing them and may cause injuries.

Note that the guidelines from NORSOK U 100 do not speak of ladders.
In addition, some clients limit the use of ladders to no-decompression dives only and thus consider that a system using a ladder is a "scuba replacement". "Scuba replacements" are portable systems that are, at the simplest, composed of three cylinders of breathing air mounted in a frame with a small control panel to which at least two divers umbilicals (Diver + standby diver) are connected. Dives with these systems are usually limited to 35 m with IMCA and 30 m with IOGP. Nevertheless, exceptions can be made to go to 50 m in special circumstances.

The procedures promoted in this handbook allow for ladders as primary means of deployment for no-decompression and decompression dives in waters where the weather and underwater conditions are continuously favorable, and only for operations are not performed in areas where the abandonment of the worksite may be necessary due to dangers linked to the facility's activity. Note that if one of these conditions is not fulfilled, the use of a ladder as primary means of deployment should be limited to no-decompression dives only.

2.2.2 - Open baskets

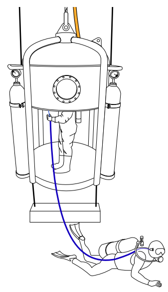


Open baskets are cages used to deploy the divers to the bottom and recover them to the deck in a controlled manner. They allow for deployments at roughest weather conditions than ladders and provide extra gas reserves to the divers (cylinders + Mouthpieces and neck dam hoses). Also, they allow restricting the divers' distance horizontally,
Open baskets are the most used deployment systems in the industry, although they are not considered the safest ones.
Note that baskets are usually designed to carry at least two divers (many models are designed for three persons) and provide divers' protections using top, lateral, and bottom grids. The divers usually enter the basket through the gate. When at depth, they go to the job site through the window on the opposite side of the gate, so the umbilicals are enclosed in it. Another means for securing the umbilicals to the basket is installing specific guide rings where the umbilicals are enclosed before starting the dive.
Even though gas reserves are provided in baskets, these deployment devices are not considered refuges where the divers can stay a long time. Also, the diver is confronted with the narcotic effect of nitrogen that increases with the depth. For these reasons, most European laws limit their use to 50 m. It is the limit also selected in this handbook.

2.2.3 - Baskets equipped with a dome

Such baskets are similar to those described above, except that the top of the device is closed by a dome that can be filled with air or heliox from its onboard gas reserves. It allows removing a helmet if necessary and thus provides a refuge that can be used for short periods.
These systems, which are between baskets and real wet bells, are less common than open baskets. It must be said that although they provide refuge and can be considered safer than open baskets, such systems are not considered by the statutory instruments of countries and professional organizations. Also, they are not regarded as wet bells because they are not supplied with gas and controlled from the surface.
For these reasons, they are considered baskets, so they are thus limited to the range allowed with such deployment devices by most national and professional organizations national and professional organizations.

2.2.4 - Wet bells



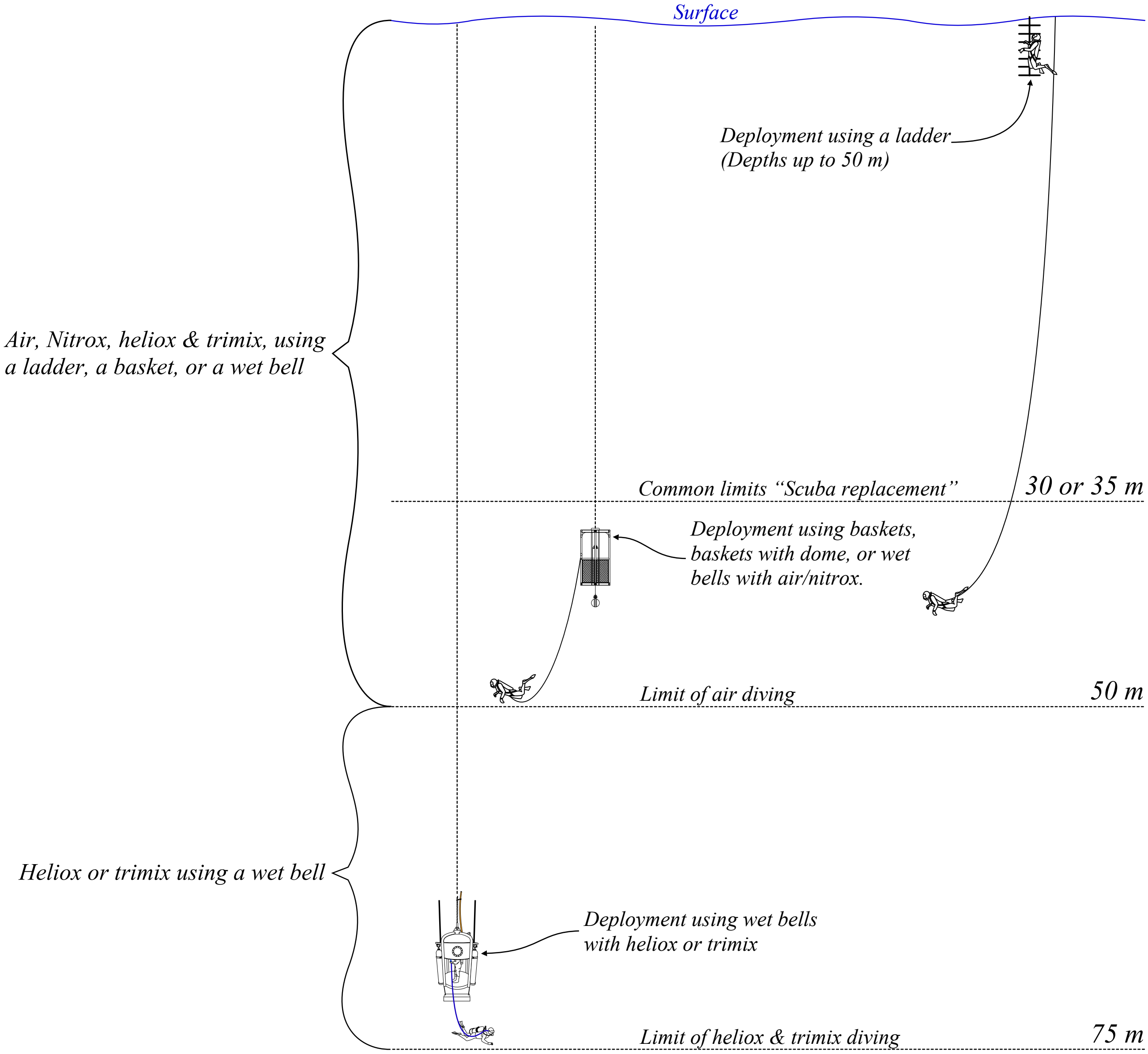
A wet bell consists of a dome sufficiently wide to accommodate two or three divers, designed to have the body parts above the belt outside the water when standing up in it or are sitting on the seats. It is supplied from the surface by the main umbilical that also carries communications, lights, video, gas analysis, depth reading systems, and hot water if necessary. The bell is provided with onboard gas reserves that must be sufficient to complete the longest decompression from the maximum depth the bell is designed for. An onboard panel allows controlling the gas to the divers and the dome. Also, an intercom allows discussion from the dome to the surface and vice versa.
Some recent bells are not provided with oxygen decompression systems. However, such methods are promoted in this handbook as they allow speeding up the decompression. For this reason, the procedures described are based on those previously recommended by COMEX.

Note that wet bells are mandatory for dives below the air dive limit up to the surface supplied heliox limits indicated before. Thus, the limits promoted in this handbook are 50 m for air diving and 75 m for heliox diving, which conforms with IMCA procedures.

2.3 - Summary of the limitations promoted in this handbook

The depth limitations selected in this handbook conform with those of IMCA that are the most implemented, even by companies not members of this association. They are less stringent than those in force in countries such as Norway. However, they are more balanced, and nothing forbids the reader from reinforcing them if necessary. Also, most people reading this document will never have access to these waters.

- Air or Nitrox diving using a ladder is limited to no-decompression dives for operations in places where the weather conditions can suddenly become unfavorable or where the abandonment of the worksite in an emergency may be necessary due to the facility's activity hazards. However, ladders can be used for decompression dives that will not be interrupted by suddenly degraded weather conditions or the urgent abandonment of the area for safety reasons. Thus, all surface-supplied operations up to to 50 m, where surface decompression is unnecessary.
- Diving with baskets is limited to 50 m, whatever is the bottom mix used. Note that if a ladder is used to launch the standby diver, the weather conditions for starting the dive are those of this means of deployment.
- Diving with a wet bell is limited to 50 m if the gas breathed is air or nitrox and 75 m if heliox and trimixes are used. Also, dives with heliox or trimix are limited to 50 m if the standby diver is deployed in a basket.



The bottom time limits are those suggested by doctors Shields and Lee in the report “The incidence of decompression sickness arising from commercial offshore air-diving operations in the UK sector of the North sea during 1982/83” issued in December 1997, and adopted by the UK Health and Safety Executive (HSE), and The International Association of Oil & Gas Producers (IOGP). The reason is that this report is based on a scientific process, and that these limits are today the most employed.

The oxygen partial pressure limit at work is 1.4 bar. It is selected according to the scientific studies indicated in the

chapter "adverse effects of hyperbaric oxygen" of Book #1, "Description and prevention of diving accidents".
This limit is also selected by NOAA (National Oceanic and Atmospheric Administration - USA). This limit of 1.4 bar replaces the previous limit of 1.6 bar, considered suitable during the eighties and nineties.

3 - The MT 92/2019 diving tables

3.1 - What MT92 Stands for?

The French government officially published MT92 tables on 15th May 1992 in replacement of the MT74 tables. They are part of a series of decrees that rule the underwater works in French waters. "MT" is the abbreviation of "Ministere du Travail", which means "Ministry of Labour", and "92" is the year of publication.
Note that the publication of these tables through decrees resulted in them being parts of the laws. Their implementation was thus mandatory when working within French territories. Thus, not only inland and in the territorial waters, but, as indicated in point #2 of chapter “B”, "Parts of the sea under the authority of states" on the bottom of the "exclusive economic zone" and structures built in these parts of the sea. However, note that since May 1992, the French ministry of labour has emitted two other decrees modifying some of the initial procedures: The decree of 13th December 2012 and the decree of 14th May 2019 that has made more flexible the conditions of use of another table. Nevertheless, that must be done according to a strict process indicated in Article #8 of Chapter 3 of this latest decree, which says the following:

1. *The reference decompression tables are those annexed to this decree.*
   When situations or methods of intervention are not provided in the tables or the physiological parameters retained for these tables do not correspond to those of the intervention, the employer uses any national or international table presenting the same guarantees for the operator intervening in a hyperbaric environment.
2. *The employer cannot modify or extrapolate the decompression tables.*
3. *When the employer implements another decompression table than the one included in this decree, he logs the following in the hyperbaric safety manual provided for in article R. 4461-7 of the labour code:*
   - *The specific conditions of use he previously established with the support of the hyperbaric advisor, mentioned in article R. 4461-4 of the Labour Code;*
   - *The elements allowing him to select the particular decompression table.*

Operators intervening in a hyperbaric environment use the reference decompression tables or any other table defined in this article and corresponding to the dive to perform or a computerized system implementing decompression algorithms that conform with these tables.

It must be noted that even though the last decree of 14th May 2019 modified some operating procedures and certification processes of the previous editions, tables MT92 remained untouched since their 1st publication, which means that their efficiency is still considered highly satisfactory.
For convenience and to indicate that the French administration follows these tables, we name them MT92/2019. However, MT92 and MT92/2019 stand for the same set of tables which provides air, nitrox, and heliox decompression procedures for surface-supplied diving, saturation diving, tunneling operations, and hyperbaric medical treatments.
Note that, as usual, these documents are available in the database of the website “Diving and ROV Specialists”.:

- An English translation of the decree of 15th May 1992 is in the section “Historical diving” and can be downloaded through this link: history-3-french-legislation-1992
- The decree of 30 October 2012, related to hyperbaric works, is also available in the section “Historical diving” and can be downloaded through this link: history-27-french-decree-30-october-2012
- The tables associated with the decree of 30 October 2012, published 13 December 2012, also available in “historical diving”, can be downloaded through this link: /history-28-annex-french-decree-of-30-october-2012
- The decree of 14 May 2019, related to hyperbaric works, is available in the section “Diving and ROV procedures” and can be downloaded through this link: docs-61-arrete-14-mai-travaux-hyperbares
- The tables associated to the decree of 14 May 2019, published 24 May 2019, also available in “Diving and ROV procedures”, can be downloaded through this link: docs-16-tables-mt2019

3.2 - The decompression model

The decompression theory of Tables MT92/2012 is not explained in the French ministry of labour decrees. Nevertheless, the document *“A method for introducing new decompression procedures”*, published by Jean Pierre Imbert and Michel Bontoux, who led the study of these tables, explains their creation process. It is integrally displayed on the next page, before a quick comparison with the Norwegian and DCIEM tables.

Two complementary documents are also available on the website “Diving and ROV Specialists.com” that can be downloaded by clicking on their titles:

- *“Safety analysis of French tables 1974 air decompression tables”*, also written by Jean Pierre Imbert and Michel Bontoux, describes the process of evaluations of the MT74 tables made prior to starting the study of the MT92.
- “*Decompression safety*”, published by Jean Pierre Imbert, explains the creation of a decompression model and the use of a database. This paper takes the study process of the MT92 tables in reference.

Note that MT92 and DCIEM tables (See our handbook *“Surface supplied diving using DCIEM tables”*) were published roughly simultaneously. Their no-stop limits are similar and more stringent than those of the US Navy table. Also, the comparison of their decompression times, displayed in the following pages of this chapter, shows that they are pretty identical. However, despite these similitudes, MT92 and DCIEM are built on two different decompression models.

A METHOD FOR INTRODUCING NEW DECOMPRESSION PROCEDURES

Jean-Pierre IMBERT and Michel BORTOUX

UMS Workshop on Validation of Decompression Schedules
Bethesda, Maryland, 13-14 February 1987

In France, in 1984, Comex was awarded a 3 years contract from the F.S.H. (Fonds de Soutien aux Hydrocarbures) to improve the safety performances of the French 1974 official air decompression tables.

Because a large number of parameters are involved in the safety performances of decompression tables, it was clear from the beginning that no :
- mathematical model,
- animal model,
- onshore laboratory manned study,

could be used to test the procedures and that the only way to validate the new tables was to dive with them in actual worksite conditions.

It was also apparent that decompression sickness (DCS) incidence of the air tables presently used for commmercial diving are still relatively low (around 1%-2% overall DCS incidence) and that a large number of man exposures would be required to statistically document any improvement of the new tables over the old ones.

The Comex programme was thus organized into 5 steps (Figure n° 1) :
- evaluation of the existing tables,
- calculation of new tables,
- test of the new tables on selected worksites,
- modifications if required,
- presentation of the proposed procedures to French authorities for integration into the new diving regulations.

This paper presents this original method used to introduce the decompression procedures.

METHOD

Decompression tables

The starting point of the development of the new tables was a study carried out on the safety performances of the French 1974 decompression tables based on a computer processing of worksites dive reports (2). As a complement, Doppler bubble detections were also carried out onshore on a set of selected tables (11, 12).

The conclusions, which apply to the in-water decompression technique only, were that :

- dives of moderate hyperbaric exposure, corresponding approximatively to the permitted bottom times of DOE memo no 7/86, were associated to very safe decompressions (0.1 % DCS incidence).
- deep and/or long dive exposures, corresponding to dives beyond the DOEn border line, were associated to a higher rate of DCS incidence (1 to 2% DCS incidence).
- divers using a safety margin in the selection of the table time had performed significant safer decompression when diving in the critical depth and time range.

These foundings were the basis of the calculation of the new tables which were designed to :

- remain identical to the original French 1974 tables in the range where safe results have been demonstrated,
- become equivalent to longer bottom times of the French 1974 tables elsewhere.

Effectively, the tables displayed deeper and/or longer decompression stops in the critical range. It was therefore possible to claim that the new tables were at any moment more conservative than the former ones, because :

- most decompression theories and models consider that deeper and longer decompression stops yield safer decompression,
- it is current practice among diving supervisors to use longer table times as a safety precaution in case of difficult dive conditions. This procedure is clearly described in the US Navy manual which states that "if the diver was exceptionally cold, or if his work load was relatively strenuous, the next longer decompression schedule than the one he would normally follow should be selected".

With references such as the famous US Navy diving manual, this statment became the corner stone of our approach to decompression tables validation. It provides :

- an ethical basis to the problem of sending new decompression procedures to worksites,
- a simple explanation for applying to government authorities for the permission to use the modified decompression procedures.

Instructions

Practically, the new tables were presented in a small manual edited as special instructions by the company methods department. The instructions were said to be designed for worksites associated with difficult dive conditions, i.e. cold, hard work, current, intensive diving operations, etc...

This procedure was aiming at avoiding questions of divers being exposed to different decompression instructions on different worksites.

Worksites

For obvious reasons, the new decompression procedures were sent only to pilot worksites. The following criteria were used for selection :

- favourable legal environment and good relations with the client permitting the introduction of special instructions without arduous discussions,
- proximity of the worksite or specially well organized operation base allowing a good feed back of information,
- high standard of professionalism among the LST's, diving supervisors and diving superintendents insuring that the new procedures were correctly understood and strictly followed,
- intense diving operations in the depths and times related to the new tables, providing a large volume of dive records.

As far as possible, the operational personnel (diving supervisor, LST's,..) were briefed prior being sent on the barges and interviewed upon their return onshore. Weekly contacts were made by telephone or radio. However, the main source of information was the dive reports.

Dive reports

The dive reports are part of the Comex internal reporting system and include three sorts of document :

- the diving report which contains the basic information on the dive parameters. It is primarily a working document used to keep a good record of all operations. It is also a contractual document between the diving contractor and the client, that serves to control the work performed. It is finally a legal requirement, the report being used as the only reference in case of emergency or accident.
- the chamber log which is filled in whenever a deck chamber is operated. It contains all the information relevant to ambient parameters control, during normal dives, but also all the details of the treatment in case of DCS.
- the accident report which is filled in for DCS cases.

The Comex Data Bank

Whenever a dive is carried out on Comex worksites, a copy of the dive report is sent to the method department in Marseille (the reports have carbon copying sheets which are used for the dispatch, one for the worksite, one for the base and one for method department).

All the dive reports received are fed into a computer. This computer system is called the Comex data bank.

When typing the reports in, the computer runs automatic tests on the consistency of the data. Tests include, for instance, comparison of actual dive depth and time with table depth and time, check of the actual decompression time against correct decompression time, correspondance of dive depth with diving method and breathing gas, etc.. The reports are typed in by operational personnel , who are qualified to check any abnormalities eventually detected.

In addition to the above precautions, the validity of the data is checked at worksite level. The local trends are compared to the general results to identify systematic errors of procedures or simply missing reports that would bias the statistics.

Objectives

Safety was the primary concern of the study.

Safety of the decompression tables was measured in term of number of DCS recorded. Any accident / incident / near misses not directly related to decompression procedures were rejected.

The accident reports were checked by the safety officer, the medical department and the method department. Complementary information was eventually obtained by inquiry, interview, post accident medical examination, etc...

Efficiency was a second objective. A special effort was made to produce a manual with clear and simple instructions. Back up procedures were detailed for decompression emergencies such as exceeding the planned bottom time, impossibility to carry out the 3m stop due to worsening sea conditions, oxygen supply failure during oxygen stops, etc. Efficiency was measured from the comments of the project managers, diving superintendents and supervisors who learned to use the possibilities of the tables and reported on their practical and commercial consequences.

RESULTS

Operations

The validation of the new procedures took place from 1985 to 1986.
The instructions were sent to selected worksites around the world : shallow long tables were tested in the Persian Gulf during welding operations not exceeding 24 msw ; deep tables were implemented in Burundi, for the installation of fresh water lines for Bujumbura city ; surface decompression tables were used in North Sea inspection operations,...

Table below summarises the results obtained in january 1987. An estimated number of 1,000 additional diving reports are still waiting to be treated by the computer.

TABLE N° 1

Dives recorded after two years of offshore evaluation of the new French Air decompression tables

tables	number of men x dives	number of tables used
Air std Standard	124	4
Air/oxy at 6m	814	55
Air/oxy at 12m	573	40
Air Surf D	627	52
TOTAL	2138	

DISCUSSION

The method used to introduce the decompression tables is not new. Even if the process is reluctantly admitted and rarely published, it is the simplest approach to improvement of decompression tables. Most of the diving contractors have used this empirical method to develop their own procedures from the original US Navy manual tables. Even at the worksite level, diving supervisors have for long developed similar recepies for the improvement of decompression safety. However, it is the first time that the method has been used systematically and presented as the only reasonable and practical way of developing new decompression tables.

Potential of the method

The primary limitation of the method is that it only provides improvement over former decompression tables and that there is no room for drastic change or new idea. Using this method, we are bound to "Haldanian" decompression procedures for ever ! However, it must be recognized that the method allows for some innovation and that the work done for the new French tables has at least documented the fact that deeper stops are associated with safer decompression.

The second limitation is that the method tends to produce non optimal decompression schedules. As the basic assumption is to promote longer decompression, it is impossible to consider shortening decompression stops for schedules judged too conservative. In that case, information should be obtained from a complementary source.

In fact, the problem arose with the 1974 French tables for the no-stop decompression limit which was considered too restrictive. To slightly extend the no-stop limit, reference was made to the data published by the DOE on UK North Sea operations (2), which clearly documents that the US Navy no-stop decompressions are very safe.

In any case, these short comings are well counter-balanced by the capacity of the method to produce a large volume of data and to allow statistical analysis of the results.

Time required

As Comex has an international activity, the possibilities to use the new tables were numerous. However, it took two years before sufficient information was gathered. The difficulties did not arise from legal or commercial constraints but rather out of the criteria for selection of the worksites. The list of worksites operating in the "interesting range", providing good feed back of information and control of procedures, appeared relatively short. It must be admitted that even for a large diving company, the process is slow.

Divers acceptance

Divers acceptance was good. The reason being that they are used to such modifications in case of difficult dive conditions and that they merely considered them as "Jesus factors". They even treated our new tables, which we considered as "la crème de la crème", as modified US tables !

Quality of the information

The Comex system of computer processing of diving reports was set up in 1974. Similar systems are known to be run by the US Navy (5), the Canadian forces (6), and the University of Pennsylvania, but until 1983 it was the only example of a data bank covering commercial diving operations The only recent equivalent is the system presently commissioned by the DOE to Dr. SHIELDS for North Sea diving operations.

Besides the volume of the information, the nature of the operations (military,scientific or commercial), what really caracterizes a given data bank is the accuracy of its data. A lot of time and effort must be put in checking the quality of the information but the success depends on two conditions.

The first condition is to have the authority to impose the diving report system. Operational personnel just hate paper work and a lot of incentive is required to get good feed back of information. Governements have legal means of pressure, a diving company pays its personnel, but a university, for instance, seems helpless. At Comex, we used a combination of negative actions (angry notes to worksites, warnings, ...) and positive actions (personal listing of dive records, safety records,..) until the system was recognized as useful for everybody.

The second condition is a simple and efficient diving report form. The first diving reports designed by Comex looked like news papers and were far too complex to be efficient. In fact a lot of information judged irrelevant or time consuming on the worksite was just not filled in. Several modifications of the report were proposed until we came to an acceptable compromise between what we would like to get and what diving supervisors would accept to fill in.

Started in 1974, the Comex data bank has been considered as reliable and fully operational since 1976. Results published (2) have shown to be in good accordance with other published statistics (1, 4, 5) and we believe that the system is a good and reliable tool.

Statistical analysis of the results

A large number of parameters are involved in the final safety performances of a set of decompression tables. The currently accepted independent parameters are listed in table n° 2. Because it is impossible to control all these parameters during a given dive, the outcome of the decompression table has been considered as a probabilistic event. Validation of a new set of decompression procedures thus requires recording many dives, performed by many divers, on many different worksites. This for at least two reasons.

Firstly, considering present commercial diving practice, the list of controlled parameters reduces to :
- dive technique (in-water or surface decompression),
- breathing mix,
- pre-dive surface interval,
- dive depth and time.

This means that the decompression tables must fit all the divers, for all the dive conditions and all the worksites procedures. Good training, adequate equipment and sound procedures may reduce the influence of the other uncontrolled factors but not eliminate them. It is therefore expected that any variations of these uncontrolled factors will remain within the safety margin of the decompression tables.

Statistically, this assumption is equivalent to considering the uncontrolled factors as random events of low incidence. Then, the overall combination of all these secondary variables has a random effect on the final result. Such an assumption requires that the number of dives studied is large enough for the secondary variables to be considered as centered, normal variables of small standard deviation (7). This is not always the case and we can recall a diver who twice got a DCS with the new tables and who certainly introduced some bias in the evaluation of the new procedures.

Secondly, because of the random nature of DCS occurrence, it is necessary, when comparing the performances of different schedules, to implement statistical techniques (7, 8,9, 10).
However, DCS incidence in commercial diving is low. Present state of the art in air decompression procedures ranges from 0.5 % to 2 % DCS occurrence depending on dive exposure (1, 2, 4, 5) and the classic statistic tools appear very unefficient in separating tables performances. Using standard comparison technique for observed percentages, it requires about 100 dives without any accident to show any improvement over a former schedule which was used 25 times with 1 DCS occurrence ! It might be even more drastic if one DCS is recorded during the evaluation of the new table.

The practical implication is that, nowadays, the number of dives required to document any significant improvement of new tables over former ones is large.

Considering the 2,100 dive reports collected and the 1,000 dive reports waiting for processing, we can rely on an approximated of 3,100 dives for this study. It might appear small when compared to the 60,000 dives recorded with the French 1974 tables, but it must be noted that :

- exposures recorded are located in the critical depth and time range,

- a given worksite generally operated at constant depth for almost always the same bottom time and the dives recorded are concentrated on small number of decompression schedules.

However, even though the process of data acquisition has lasted for two years, we must admit that in 90 % of the cases, the information gathered was insufficient to allow conclusive comparison of table by table. As a consequence, when decompressions were insufficiently documented, the results of several schedules were grouped together into categories to allow statistical comparison.

CONCLUSION

Even if the method developed is relatively limited and very slow, it appears to be a reasonable way of introducing new decompression tables because today, lengthy and tedious dive logging is required to document any modifications of procedures.

Even though this study has represented an effort to implement statistical techniques, it is right to say that the exact tables performances will be only known in ten years from now, when tables will have been used as standard procedures and 100,000 dives will have been recorded !

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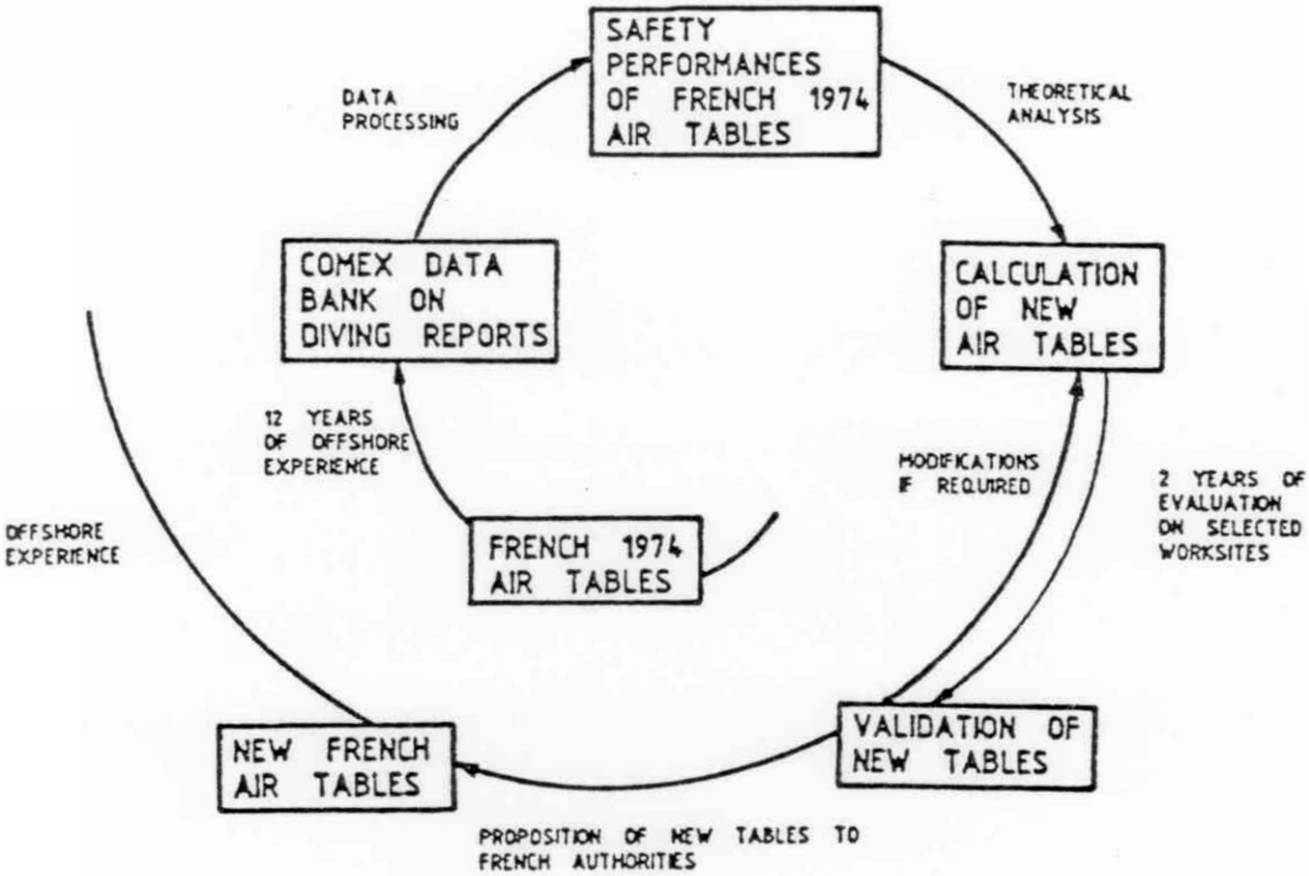
FIGURE N° 1



METHOD USED TO DEVELOP AND VALIDATE NEW AIR DECOMPRESSION PROCEDURES FOR THE FRENCH DIVING LEGISLATIONS.

TABLE Nº 2

LIST OF CURRENTLY RECOGNIZED FACTORS INFLUENCING THE PERFORMANCE OF A DECOMPRESSION

DIVE CONDITIONS	ERRORS OF PROCEDURE	INTER INDIVIDUAL VARIABILITY	INTRA INDIVIDUAL VARIABILITY
- Water or chamber temperature	- Poor control of depth (swell)	- Training, Experience	- Fatigue after travelling
- Wet suit, dry suit, or hot water suit	- Wrong calibration of gauges	- Adaptation to narcosis	- Fatigue after intense diving
	- Error in calculation of bottom time	- Physical fitness	- Hangover, Flue
- Light or heavy work at bottom	- Selection of wrong schedule	- Smoking, Drinking	- Anxiety, Stress
- Up and down depth variations	- Omitted decompression stop	- Weight, fat content	
- Swell	- Shortened decompression	- Age	
- Current	- Exceeding the surface interval	- Previous DCS history	
- Visibility	- Leakage on oro-nasal mask		
- Narcosis	- Wrong quality of oxygen		
- Dry/wet environment	- CO_2 in breathing gas		
	- Work/exercise after decompression		

3.3 - Comparison with DCIEM and Norwegian edition 5 tables

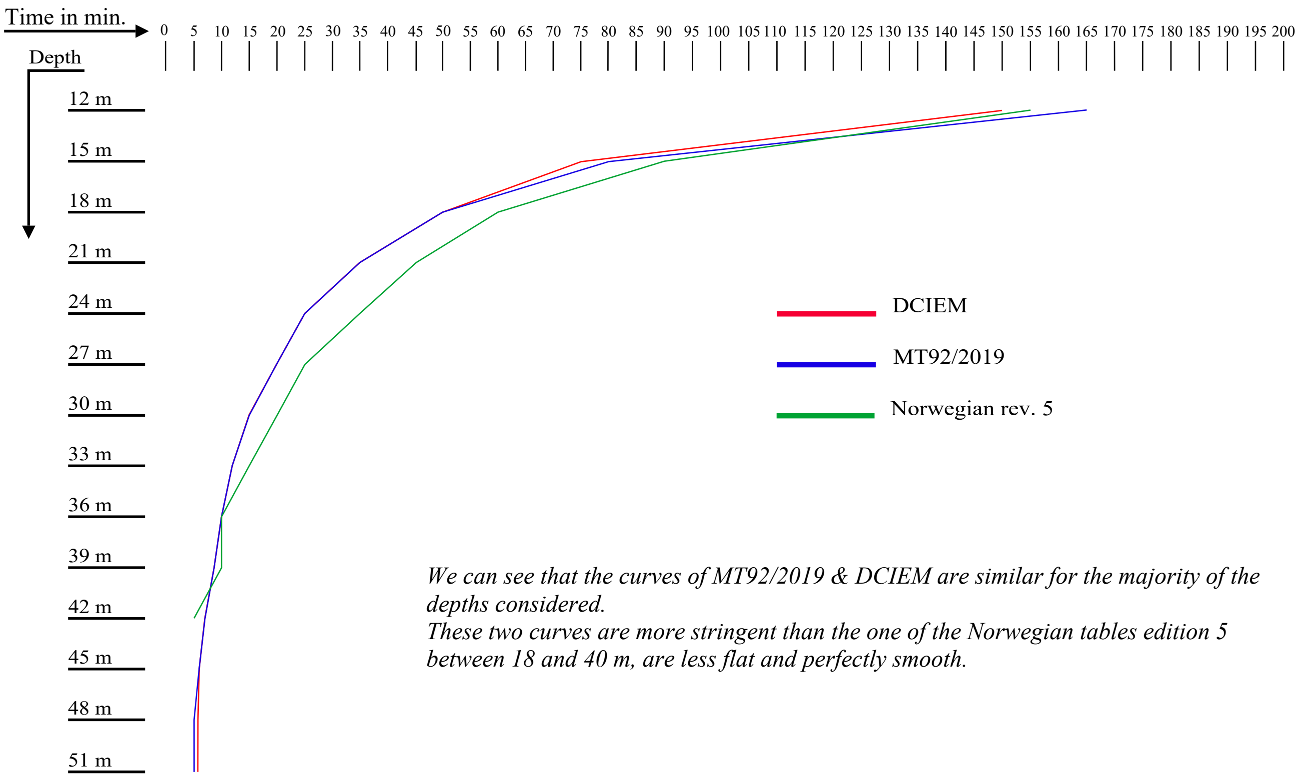
This section aims not to validate the MT92/2019 but to highlight their design and show that, with the DCIEM tables we also promote, they are still comparable and perhaps better than other tables currently used in the industry.

3.3.1 - Comparison of the no-decompression limits

“No-decompression limits curves” are commonly used to visualize whether the mathematic model has been modified, as abrupt direction changes of a curve often indicate a modification of the initial calculation. However, the visualization of the no-decompression limits should be completed by other elements, such as the decompression times for each depth and bottom time, incident reports from databases, and many others. Note that it happens that the authors of a set of tables reinforce the decompression times of some depth to solve weaknesses without touching the initial mathematic model. The fifth edition of the Norwegian tables, published in 2019, is used as a reference with DCIEM to compare MT92/1919 with other decompression models currently used in the diving industry.

Comparison no decompression limits MT92/2019, DCIEM, and Norwegian edition #5

Depth	*MT92/2019*	*DCIEM*	*Norwegian*	*Most stringent*
12 m	*165*	*150*	*160*	*DCIEM*
15 m	*80*	*75*	*90*	*DCIEM*
18 m	*50*	*50*	*60*	*MT92/2019 & DCIEM*
21 m	*35*	*35*	*45*	*MT92/2019 & DCIEM*
24 m	*25*	*25*	*35*	*MT92/2019 & DCIEM*
27 m	*20*	*20*	*25*	*MT92/2019 & DCIEM*
30 m	*15*	*15*	*20*	*MT92/2019 & DCIEM*
33 m	*12*	*12*	*15*	*MT92/2019 & DCIEM*
36 m	*10*	*10*	*10*	–
39 m	*8*	*8*	*10*	*MT92/2019 & DCIEM*
42 m	*7*	*7*	*5*	*Norwegian*
45 m	*6*	*7*	–	*Norwegian*
48 m	*5*	*6*	–	*Norwegian*
51 m	*5*	*6*	–	*Norwegian*



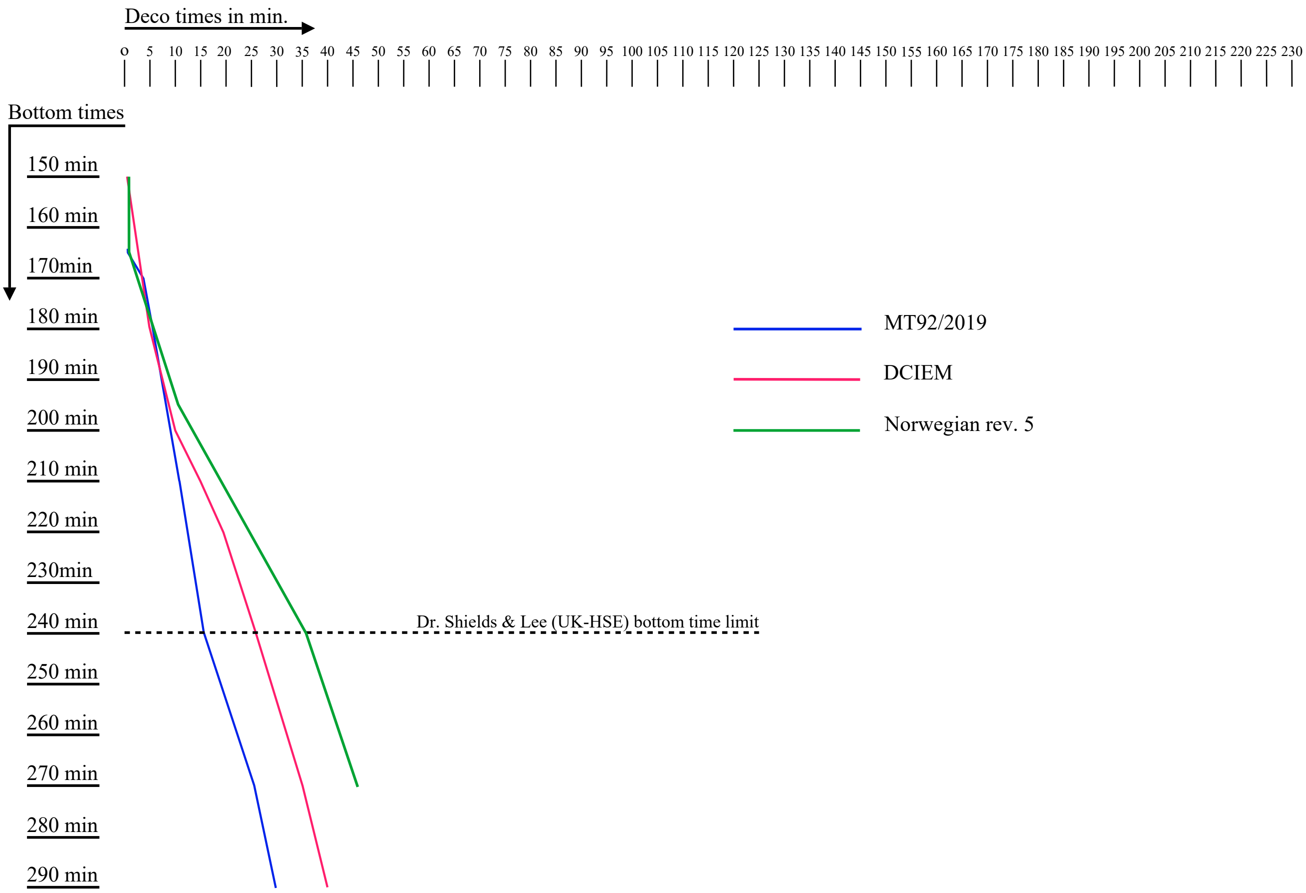
We can see that the curves of MT92/2019 & DCIEM are similar for the majority of the depths considered.
These two curves are more stringent than the one of the Norwegian tables edition 5 between 18 and 40 m, are less flat and perfectly smooth.

3.3.2 - Comparison of the air in-water decompression stops with those of DCIEM and Norwegian fifth edition

The tables and graphs below compare decompression curves for each depth considered in the MT92/2019 tables with those of the DCIEM and the Norwegian tables. Note that a table with longer decompression times is not automatically the safest, as many elements, such as the ascent rates, the organization of the stops, incidents logs databases, etc., are to be considered to evaluate this point. Nevertheless, these curves allow us to visualize some adjustments of the decompression times, whether the scientists who studied the tables obtained similar answers, and whether another set of tables in use in the commercial diving industry, such as the Norwegian edition #5, provide different or similar results.

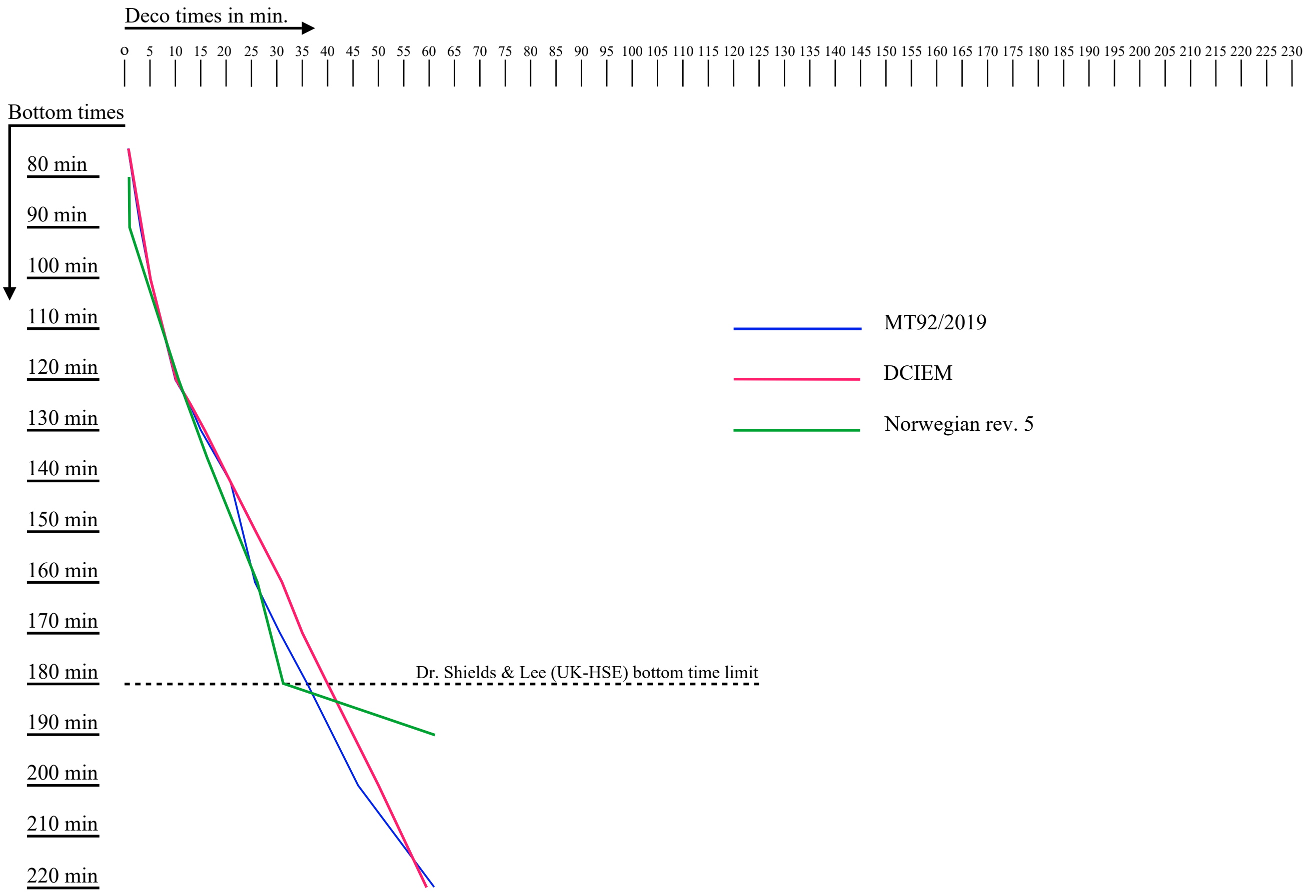
Comparison ascent times MT92/2019, DCIEM, Norwegian edition 5, for a dive at 12 m (in minutes)

Bottom time	*Ascent time MT92*	*Ascent time DCIEM*	*Ascent time Norwegian*
150	*1:00*	*1:00*	*1:12*
165	*1:00*	*(Stop not indicated)*	*1:12*
170	*3:45*	*(Stop not indicated)*	*(Stop not indicated)*
180	*5:45*	*5:00*	*(Stop not indicated)*
195	*(Stop not indicated)*	*(Stop not indicated)*	*11:12*
200	*(Stop not indicated)*	*10:00*	*(Stop not indicated)*
210	*10:45*	*15:00*	*(Stop not indicated)*
220	*(Stop not indicated)*	*19:00*	*(Stop not indicated)*
240	*15:45*	*26:00*	*36:12*
Operational limits UK-HSE			
270	*25:45*	*35:00*	*46:12*
300	*30:45*	*44:00*	–
330	*35:45*	*53:00*	–



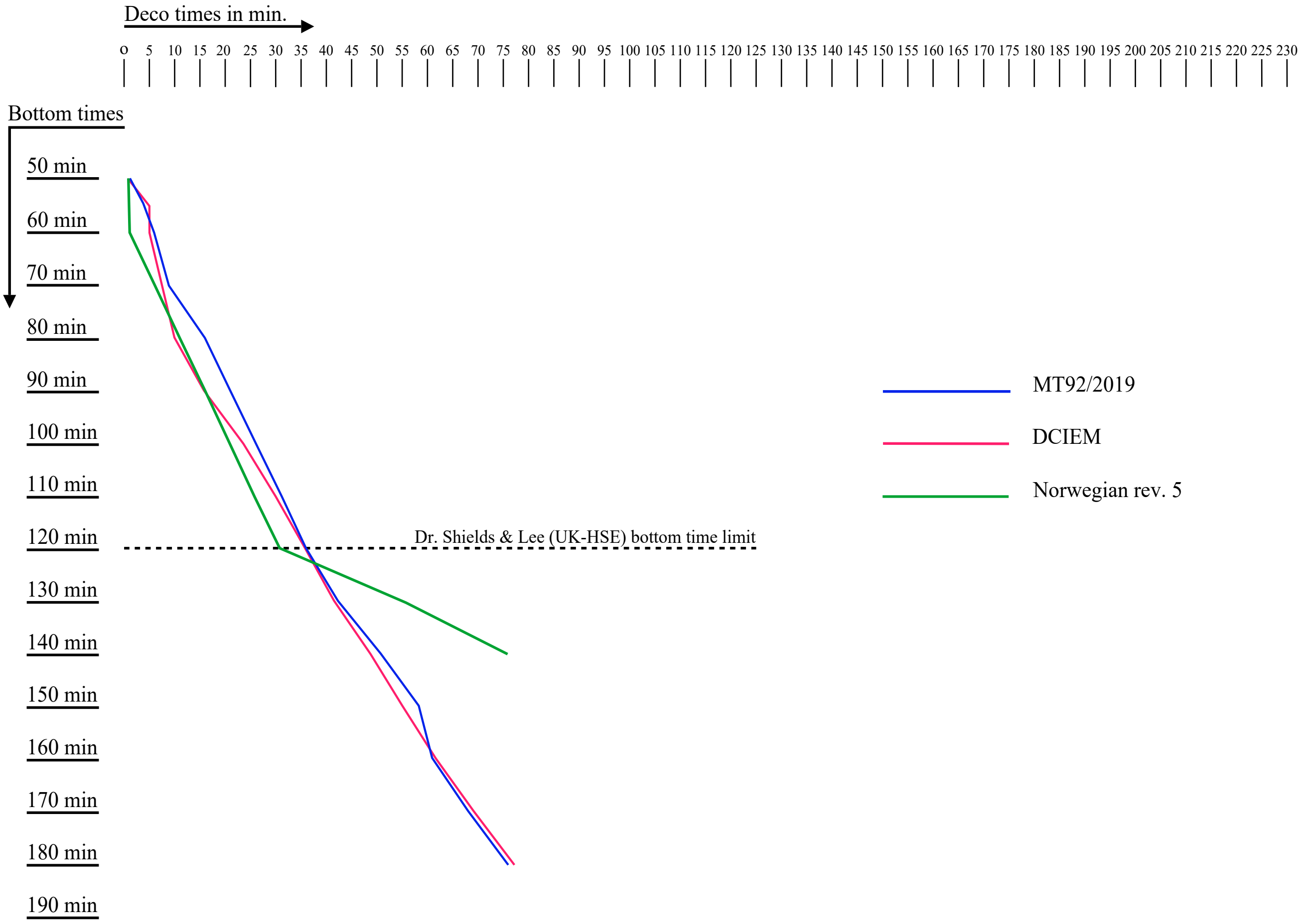
Comparison ascent times MT92/2019, DCIEM, and Norwegian, for a dive at 15 m (minutes)

Bottom time	Ascent time MT92	Ascent time DCIEM	Ascent time Norwegian
60	1:00	1:00	1:30
75	1:00	1:00	1:30
90	3:00	(Stop not indicated)	1:30
100	5:00	5:00	(Stop not indicated)
120	10:00	10:00	11:30
125	13:00	13:00	(Stop not indicated)
130	15:00	16:00	(Stop not indicated)
135	(Stop not indicated)	(Stop not indicated)	16:30
140	21:00	21:00	(Stop not indicated)
150	(Stop not indicated)	26:00	(Stop not indicated)
160	26:00	31:00	26:30
170	31:00	35:00	(Stop not indicated)
180	36:00	40:00	31:30
Operational limits UK-HSE			
200	46:00	50:00	
220	61:00	59:00	
240	71:00	70:00	



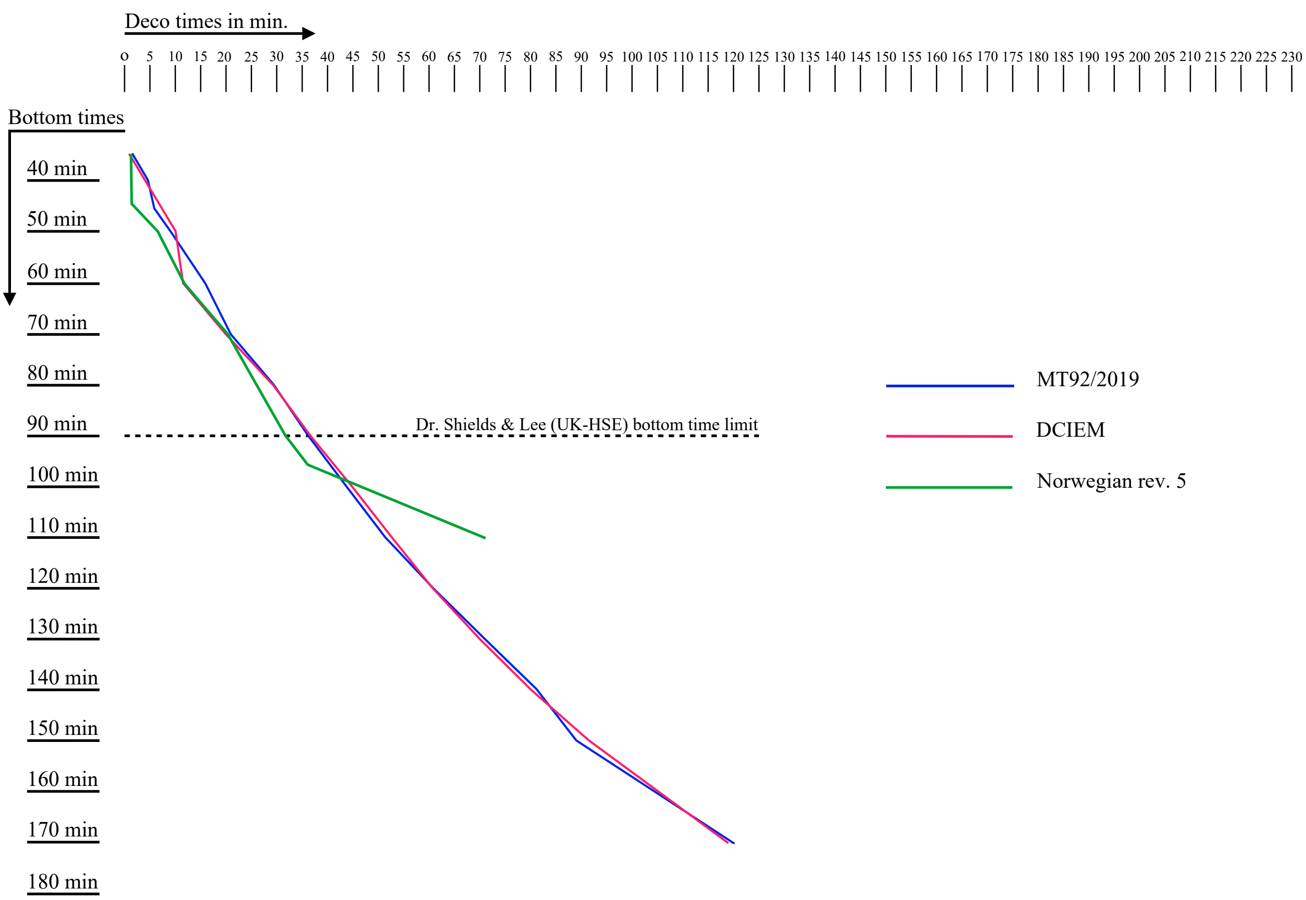
Comparison ascent times MT92/2019, DCIEM, and Norwegian rev. 5, for a dive at 18 m

Bottom time	Ascent time MT92	Ascent time DCIEM	Ascent time Norwegian
50	1:30	1:00	1:48
55	4:15	5:00	1:48
60	6:15	5:00	1:48
70	8:15	(Stop not indicated)	6:48
80	16:15	10:00	11:30
90	21:15	16:00	16:30
100	26:15	24:00	16:30
110	31:15	30:00	26:30
120	36:15	36:00	31:30
Operational limits UK-HSE			
130	44:00	42:00	61:30
140	51:00	48:00	76:12
150	58:00	55:00	(Stop not indicated)
160	61:00	62:00	(Stop not indicated)
170	68:00	69:00	(Stop not indicated)
180	76:00	77:00	(Stop not indicated)



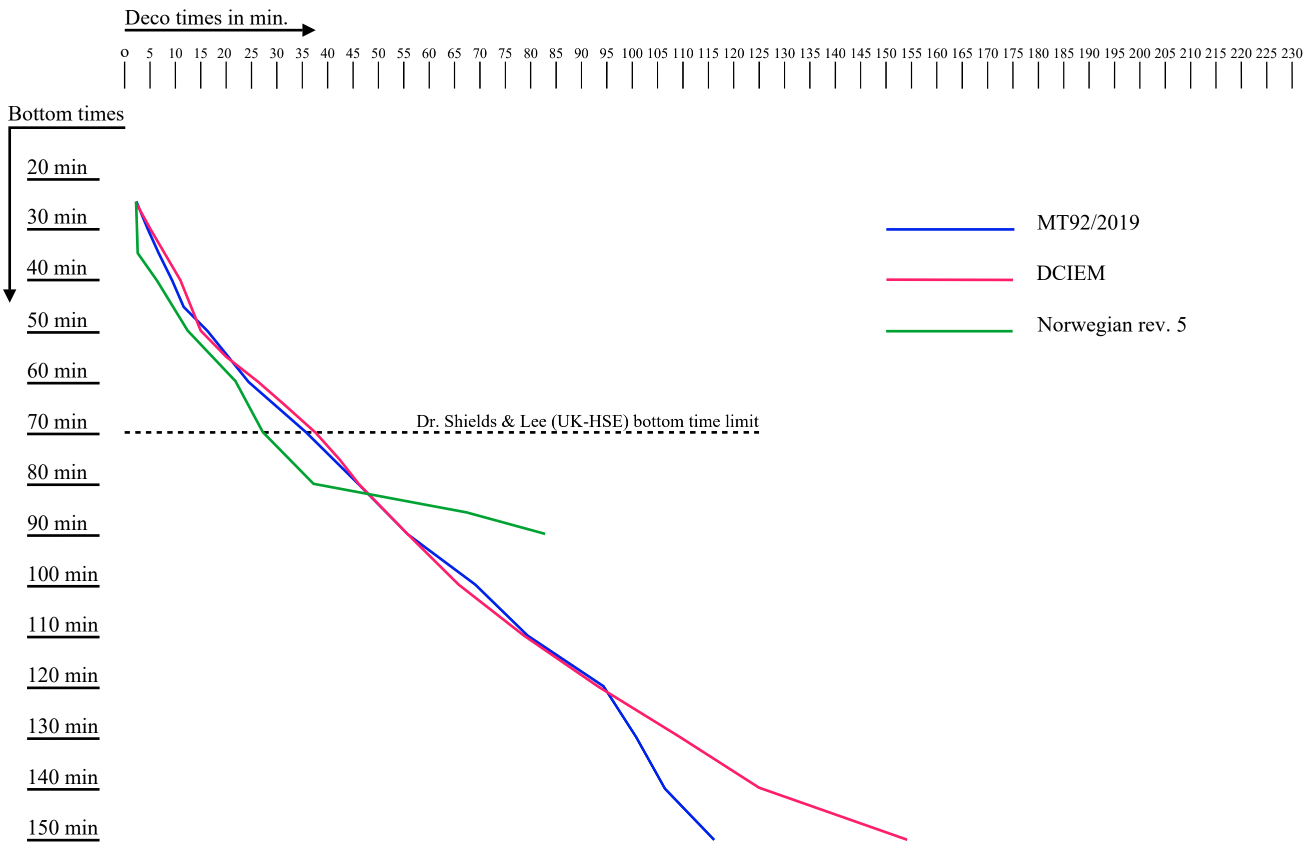
Comparison ascent times MT92/2019, DCIEM, and Norwegian rev. 5, for a dive at 21 m

Bottom time	Ascent time MT92	Ascent time DCIEM	Ascent time Norwegian
35	1:45	1:00	2:06
40	4:30	5:00	2:06
45	6:30	Stop not indicated	2:06
50	8:30	10:00	7:06
60	16:30	12:00	11:48
70	21:30	20:00	16:48
80	29:15	29:00	Stop not indicated
90	36:15	37:00	31:48
Operational limits UK-HSE			
100	43:15	45:00	Stop not indicated
110	51:15	53:00	71:48
120	61:15	61:00	Stop not indicated
130	71:15	70:00	Stop not indicated
140	81:15	80:00	Stop not indicated
150	89:00	92:00	Stop not indicated
160	Stop not indicated	105:00	Stop not indicated
170	121:00	118:00	Stop not indicated



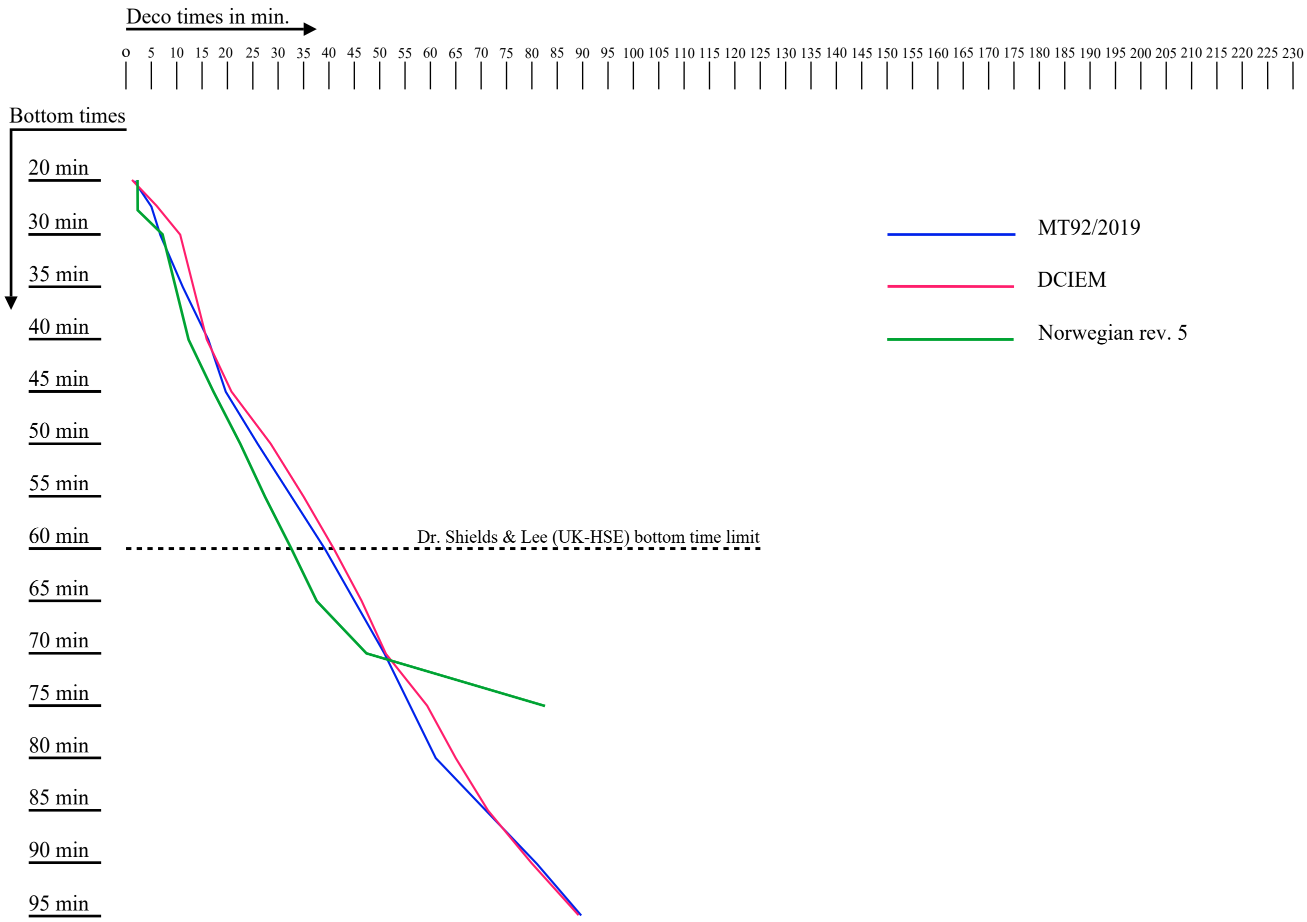
Comparison ascent times MT92/2019, DCIEM, and Norwegian rev. 5, for a dive at 24 m

Bottom time	***Ascent time MT92***	***Ascent time DCIEM***	***Ascent time Norwegian***
25	2:00	2:00	2:24
30	4:45	5:00	2:24
35	6:45	11:00	2:24
40	8:45	11:00	7:24
45	11:45	Stop not indicated	Stop not indicated
50	16:45	15:00	12:06
55	Stop not indicated	20:00	17:06
60	24:30	27:00	22:06
65	36:30	32:00	Stop not indicated
70	36:30	37:00	27:06
Operational limits UK-HSE			
75	Stop not indicated	42:00	Stop not indicated
80	46:30	46:00	42:06
85	Stop not indicated	51:00	67:06
90	56:30	56:00	87:06
95	Stop not indicated	61:00	Stop not indicated
100	69:15	66:00	Stop not indicated
110	79:15	78:00	Stop not indicated
120	94:15	93:00	Stop not indicated



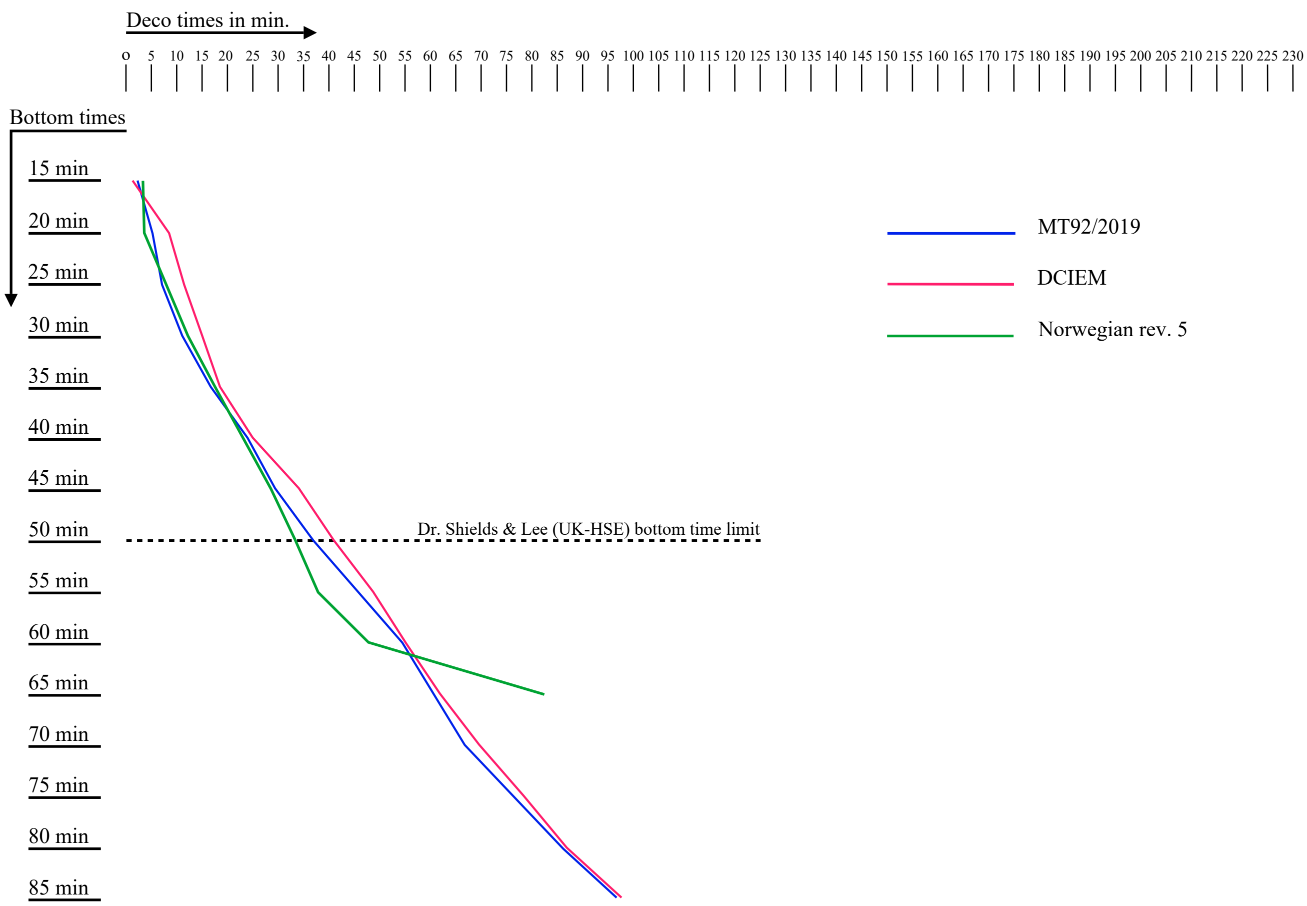
Comparison ascent times MT92/2019, DCIEM, and Norwegian rev. 5, for a dive at 27 m

Bottom time	*Ascent time MT92*	*Ascent time DCIEM*	*Ascent time Norwegian*
20	*2:15*	*2:00*	*2:42*
25	*5:00*	*7:00*	*2:42*
30	*7:00*	*11:00*	*7:42*
35	*12:00*	*Stop not indicated*	*Stop not indicated*
40	*16:45*	*16:00*	*12:24*
45	*19:45*	*21:00*	*17:24*
50	*26:45*	*28:00*	*22:24*
55	*Stop not indicated*	*35:00*	*27:24*
60	*38:45*	*41:00*	*32:06*
Operational limits UK-HSE			
65	*Stop not indicated*	*47:00*	*37:06*
70	*51:45*	*52:00*	*47:06*
75	*Stop not indicated*	*59:00*	*82:06*
80	*61:30*	*65:00*	*Stop not indicated*
85	*Stop not indicated*	*71:00*	*Stop not indicated*
90	*81:30*	*79:00*	*Stop not indicated*
95	*Stop not indicated*	*87:00*	*Stop not indicated*



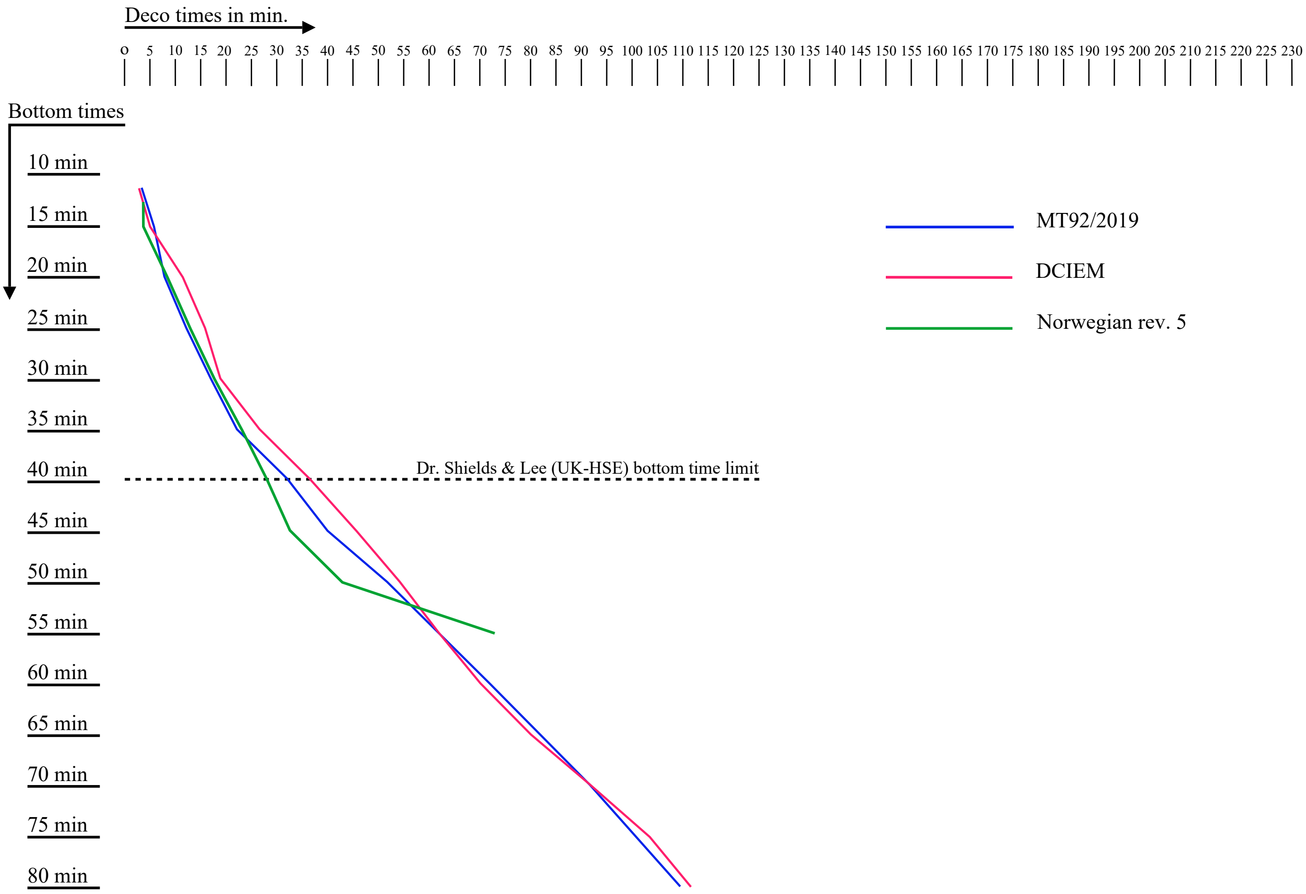
Comparison ascent times MT92/2019, DCIEM, and Norwegian rev. 5, for a dive at 30 m (minutes)

Bottom time	*Ascent time MT92*	*Ascent time DCIEM*	*Ascent time Norwegian*
15	2:30	2:00	3:00
20	5:15	8:00	3:00
25	7:15	12:00	8:00
30	12:15	15:00	12:42
35	17:00	18:00	17:42
40	24:00	25:00	22:42
45	29:00	34:00	27:42
50	37:00	41:00	32:24
Operational limits UK-HSE			
55	Stop not indicated	48:00	37:42
60	54:45	55:00	47:42
65	Stop not indicated	62:00	82:42
70	66:45	69:00	Stop not indicated
75	Stop not indicated	78:00	Stop not indicated
80	86:45	87:00	Stop not indicated
85	Stop not indicated	97:00	Stop not indicated



Comparison ascent times MT92/2019, DCIEM, and Norwegian rev. 5, for a dive at 33 m (minutes)

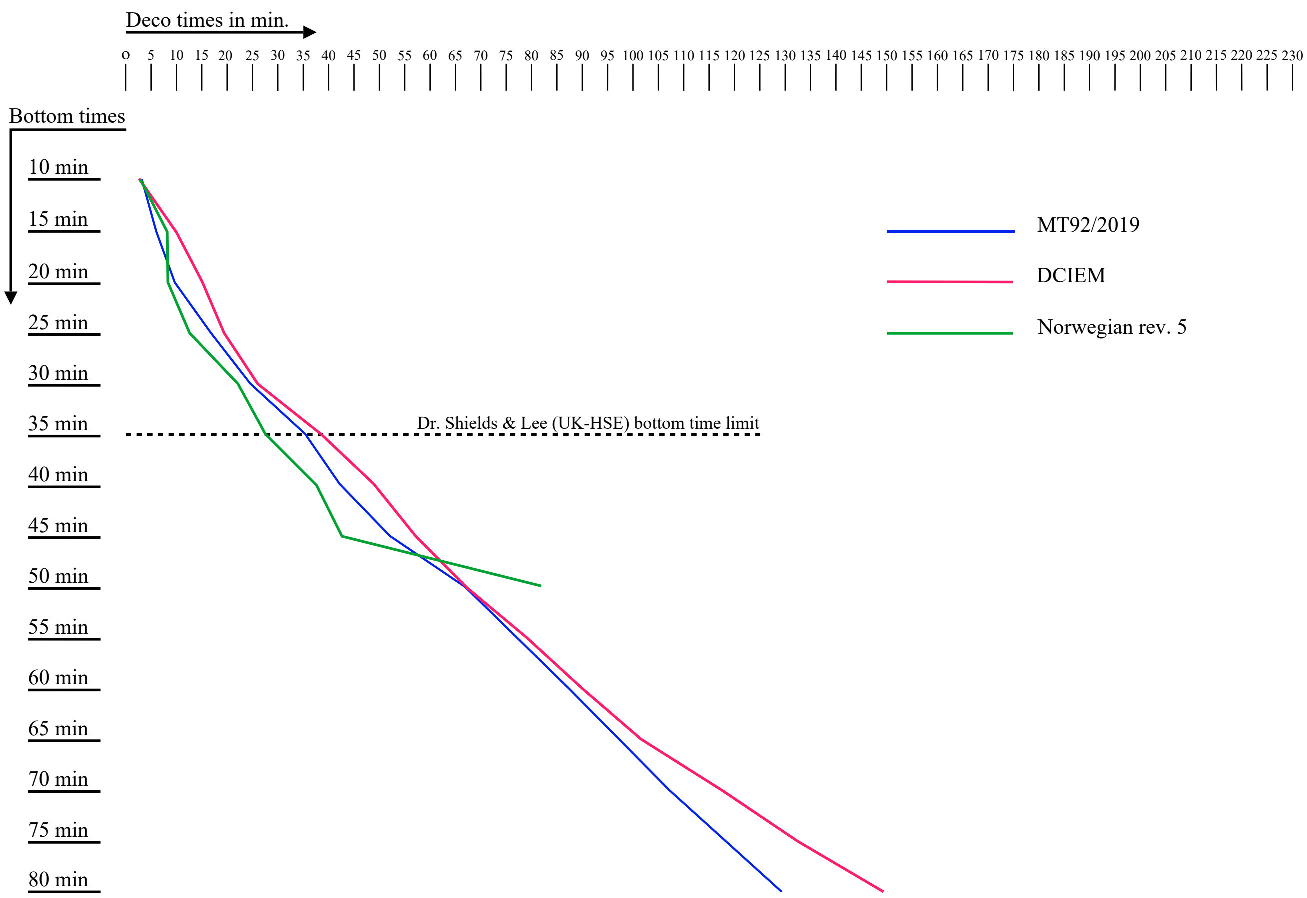
Bottom time	*Ascent time MT92*	*Ascent time DCIEM*	*Ascent time Norwegian*
12	*2:45*	*2:00*	
15	*5:30*	*5*	*3:18*
20	*7:30*	*12*	*8:18*
25	*12:15*	*16*	*13:00*
30	*17:15*	*19*	*18:00*
35	*22:15*	*27*	*23:00*
40	*32:00*	*37*	*28:00*
Operational limits UK-HSE			
45	*40*	*46*	*32:42*
50	*52:00*	*54*	*42:42*
55	*Stop not indicated*	*62*	*72:42*
60	*72:00*	*70*	*Stop not indicated*
65	*Stop not indicated*	*80*	*Stop not indicated*
70	*91:45*	*92*	*Stop not indicated*
75	*Stop not indicated*	*103*	*Stop not indicated*
80	*109:45*	*116*	*Stop not indicated*



Hyperlink Tables of contents

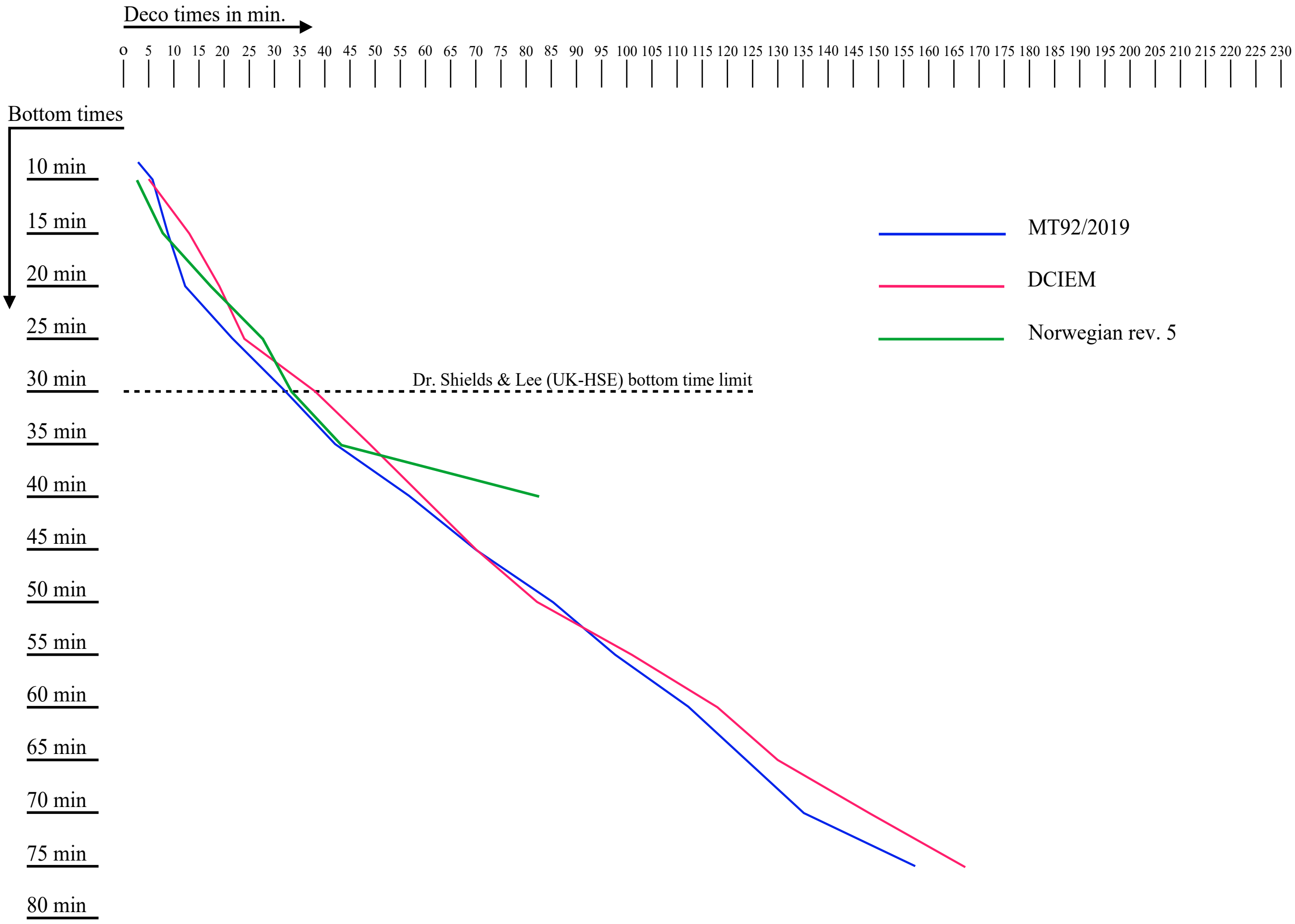
Comparison ascent times MT92/2019, DCIEM, and Norwegian rev. 5, for a dive at 36 m (minutes)

Bottom time	*Ascent time MT92*	*Ascent time DCIEM*	*Ascent time Norwegian*
10	*3:00*	*2:00*	*3:36*
15	*5:45*	*10:00*	*8:36*
20	*9:45*	*15:00*	*8:18*
25	*17:30*	*19:00*	*13:18*
30	*24:30*	*26:00*	*23:18*
35	*35:15*	*38:00*	*28:00*
Operational limits UK-HSE			
40	*42:15*	*48:00*	*38:00*
45	*52:15*	*57:00*	*43:00*
50	*67:00*	*67:00*	*82:42*
55	*Stop not indicated*	*78:00*	*Stop not indicated*
60	*87:00*	*90:00*	*Stop not indicated*
65	*Stop not indicated*	*102:00*	*Stop not indicated*
70	*107:00*	*117:00*	*Stop not indicated*
75	*Stop not indicated*	*133:00*	*Stop not indicated*
80	*129:00*	*149:00*	*Stop not indicated*



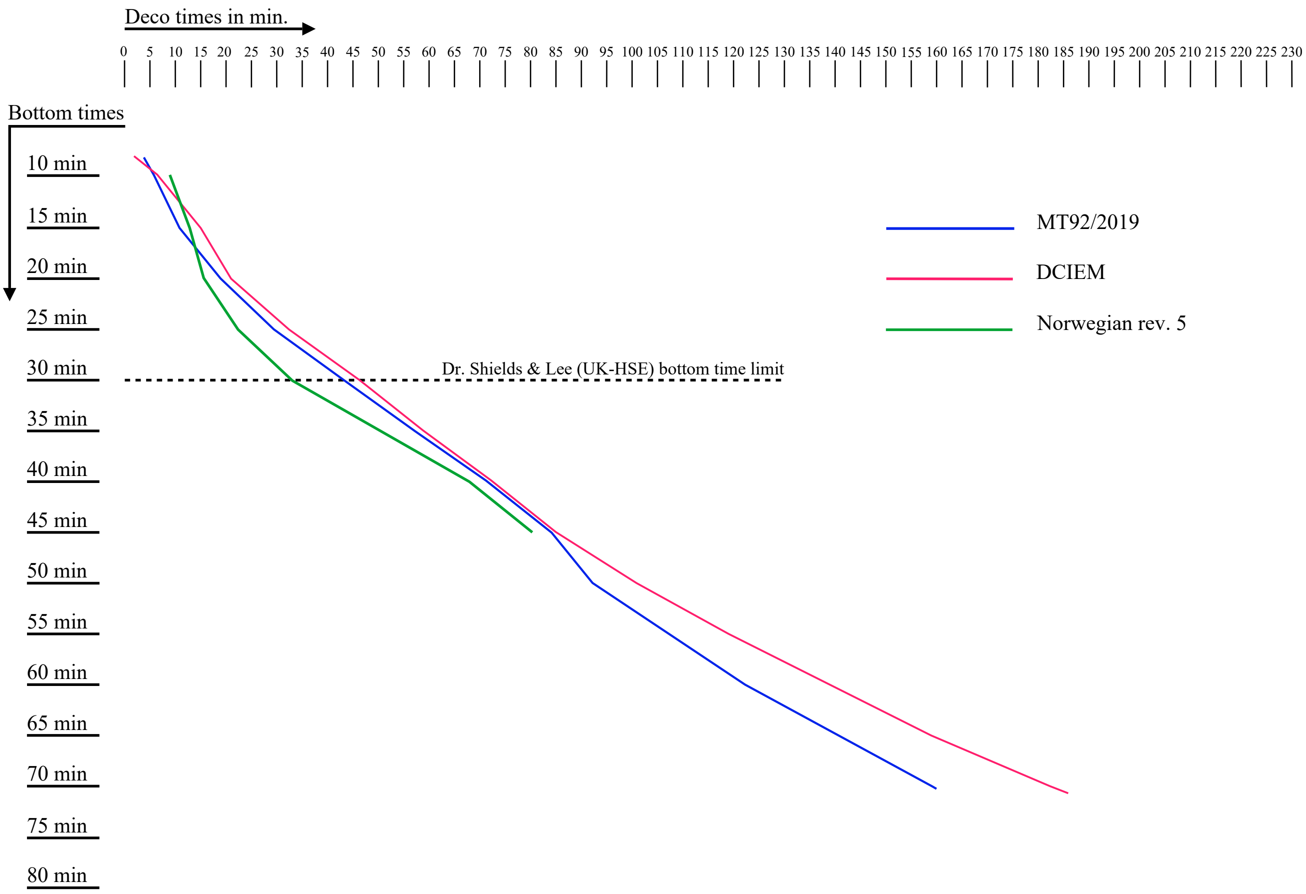
Comparison ascent times MT92/2019, DCIEM, and Norwegian rev. 5, for a dive at 39 m (minutes)

Bottom time	*Ascent time MT92*	*Ascent time DCIEM*	*Ascent time Norwegian*
8	3:15	2:00	3:54
10	6:00	5:00	3:54
15	8:00	12:00	8:54
20	12:45	18:00	18:36
25	22:45	23:00	28:36
30	32:30	37:00	33:36
Operational limits UK-HSE			
35	42:30	48:00	33:18
40	57:15	59:00	43:18
45	70:15	70:00	83
50	85:15	82:00	Stop not indicated
55	Stop not indicated	97:00	Stop not indicated
60	107:15	112:00	Stop not indicated
65	Stop not indicated	130:00	Stop not indicated
70	135:00	148:00	Stop not indicated
75	157:00	167:00	Stop not indicated



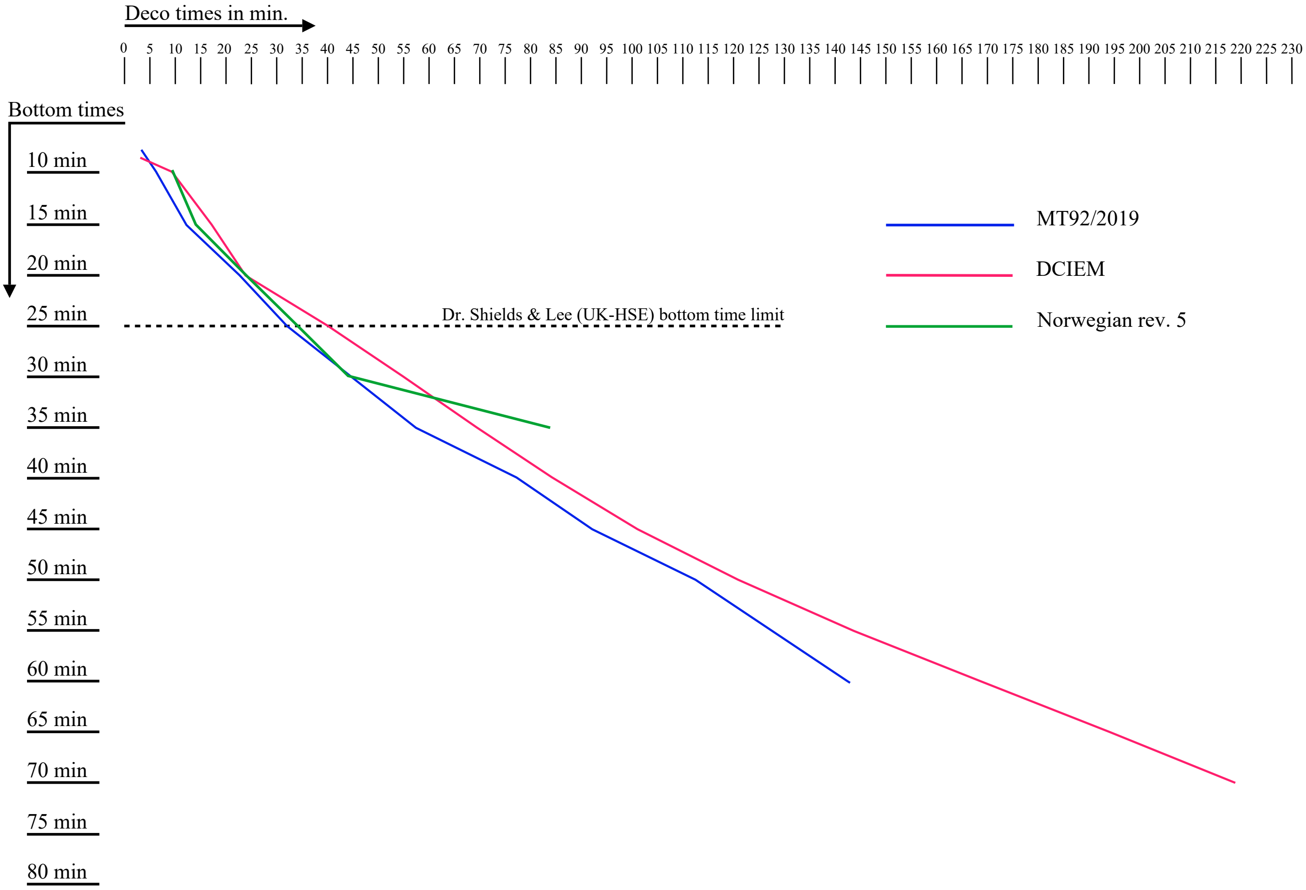
Comparison ascent times MT92/2019, DCIEM, and Norwegian rev. 5, for a dive at 42 m (minutes)

Bottom time	***Ascent time MT92***	***Ascent time DCIEM***	***Ascent time Norwegian***
7	*3:30*	*2:00*	
10	*6:15*	*7:00*	*9:30*
15	*11:00*	*15:00*	*13:54*
20	*18:00*	*21:00*	*15:54*
25	*29:45*	*32:00*	*23:54*
30	*42:45*	*46:00*	*33:36*
Operational limits UK-HSE			
35	*57:30*	*58:00*	*68:18*
40	*70:30*	*70:00*	*80:18*
45	*84:30*	*85:00*	*Stop not indicated*
50	*92:30*	*101:00*	*Stop not indicated*
55	*Stop not indicated*	*119:00*	*Stop not indicated*
60	*122:15*	*139:00*	*Stop not indicated*
65	*Stop not indicated*	*159:00*	*Stop not indicated*
70	*159:15*	*182:00*	*Stop not indicated*



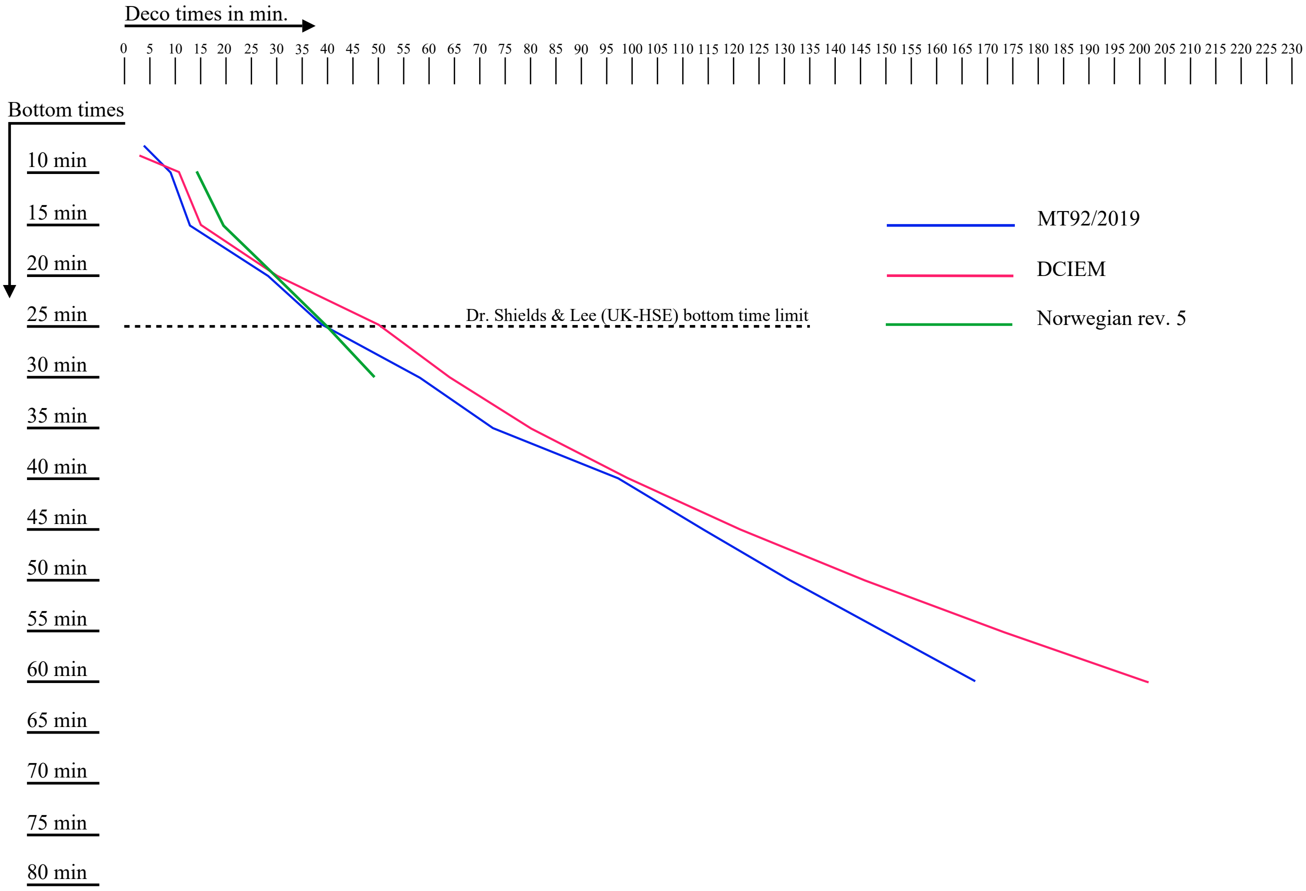
Comparison ascent times MT92/2019, DCIEM, and Norwegian rev. 5, for a dive at 45 m (minutes)

Bottom time	***Ascent time MT92***	***Ascent time DCIEM***	***Ascent time Norwegian***
6	*3:45*	*3:00*	*Stop not indicated*
7	*Stop not indicated*	*3:00*	*Stop not indicated*
10	*6:30*	*9:00*	*9:30*
15	*13:15*	*17:00*	*14:12*
20	*23:00*	*24:00*	*24:12*
25	*33:00*	*40:00*	*33:54*
Operational limits UK-HSE			
30	*Stop not indicated*	*55:00*	*43:54*
35	*57:45*	*69:00*	*83:36*
40	*77:45*	*84:00*	*Stop not indicated*
45	*92:30*	*101:00*	*Stop not indicated*
50	*112:30*	*121:00*	*Stop not indicated*
55	*Stop not indicated*	*144:00*	*Stop not indicated*
60	*142:15*	*168:00*	*Stop not indicated*



Comparison ascent times MT92/2019, DCIEM, and Norwegian rev. 5, for a dive at 48 m (minutes)

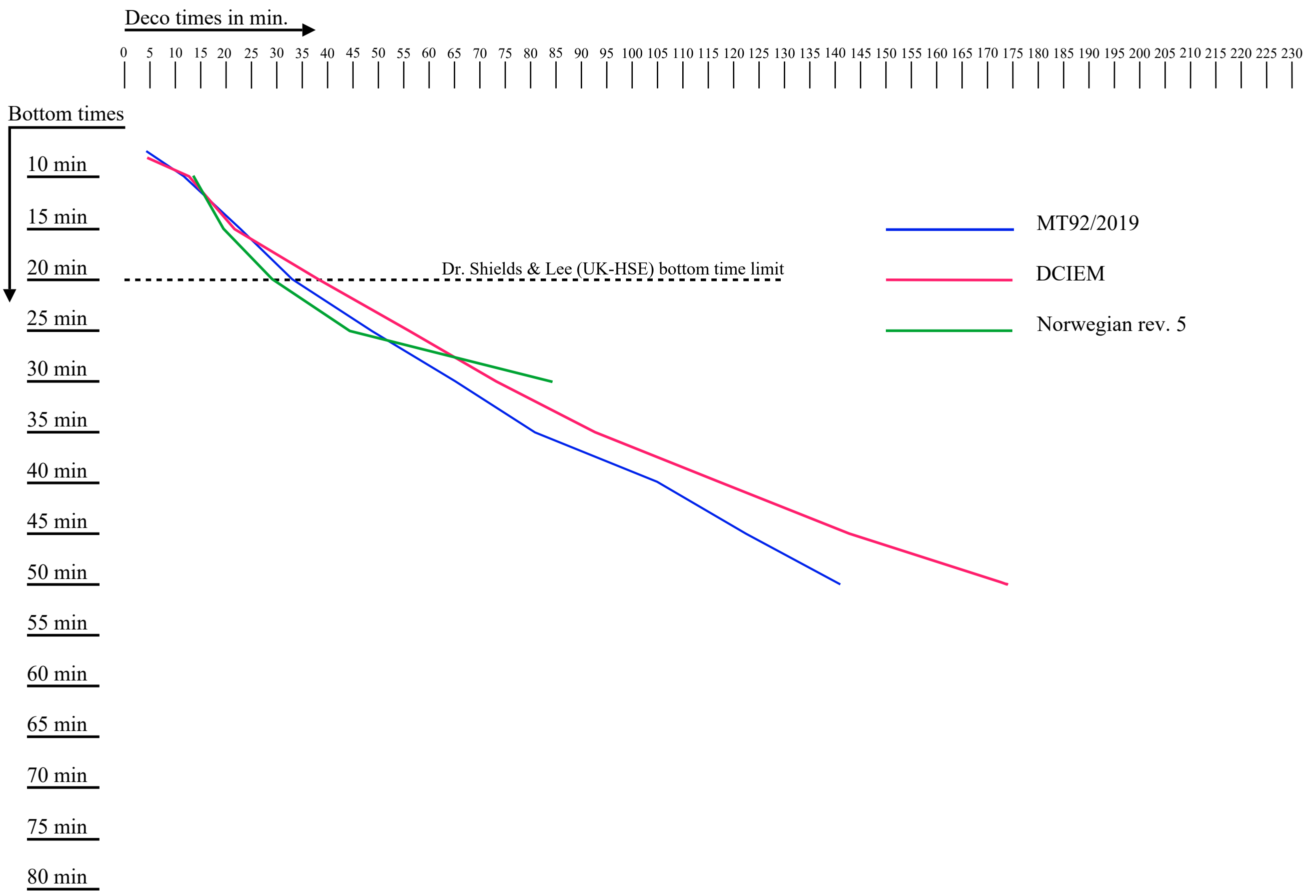
Bottom time	***Ascent time MT92***	***Ascent time DCIEM***	***Ascent time Norwegian***
5	*4:00*	*3:00*	*Stop not indicated*
6	*Stop not indicated*	*3:00*	*Stop not indicated*
10	*8:45*	*11:00*	*14:30*
15	*13:30*	*20:00*	*19:30*
20	*28:15*	*30:00*	*29:12*
25	*38:15*	*49:00*	*39:12*
Operational limits UK-HSE			
30	*58:00*	*64:00*	*48:54*
35	*73:00*	*80:00*	*Stop not indicated*
40	*97:45*	*99:00*	*Stop not indicated*
45	*114:45*	*121:00*	*Stop not indicated*
50	*130:30*	*146:00*	*Stop not indicated*
55	*Stop not indicated*	*173:00*	*Stop not indicated*
60	*167:30*	*201:00*	*Stop not indicated*



Hyperlink Tables of contents

Comparison ascent times MT92/2019, DCIEM, and Norwegian rev. 5, for a dive at 51 m (minutes)

Bottom time	*Ascent time MT92*	*Ascent time DCIEM*	*Ascent time Norwegian*
5	*4:15*	*3:00*	*Stop not indicated*
6	*Stop not indicated*	*3:00*	*Stop not indicated*
10	*11:45*	*13:00*	*14:48*
15	*23:30*	*22:00*	*19:48*
20	*32:30*	*38:00*	*29:30*
Operational limits UK-HSE			
25	*48:15*	*56:00*	*44:30*
30	*65:15*	*73:00*	*88:54*
35	*81:00*	*94:00*	*Stop not indicated*
40	*105:00*	*117:00*	*Stop not indicated*
45	*122:45*	*143:00*	*Stop not indicated*
50	*144:45*	*174:00*	*Stop not indicated*



To conclude this point:

The decompression curves of MT92/2019, DCIEM, and Norwegian ed. #5 are pretty similar, except for the depth of 12 metres, where they slightly differ past 200 minutes of bottom time. Also, note that the curve of Norwegian edition #5 often radically changes direction below the doctor Shield & Lee limit (UK HSE limit), which is surprising and not logical if we consider the other parts of the curves.
We can conclude that, as discussed previously, MT92/2019 and DCIEM have similar decompression times as the Norwegian tables, which are currently used for commercial diving in Norwegian waters and other parts of the world.

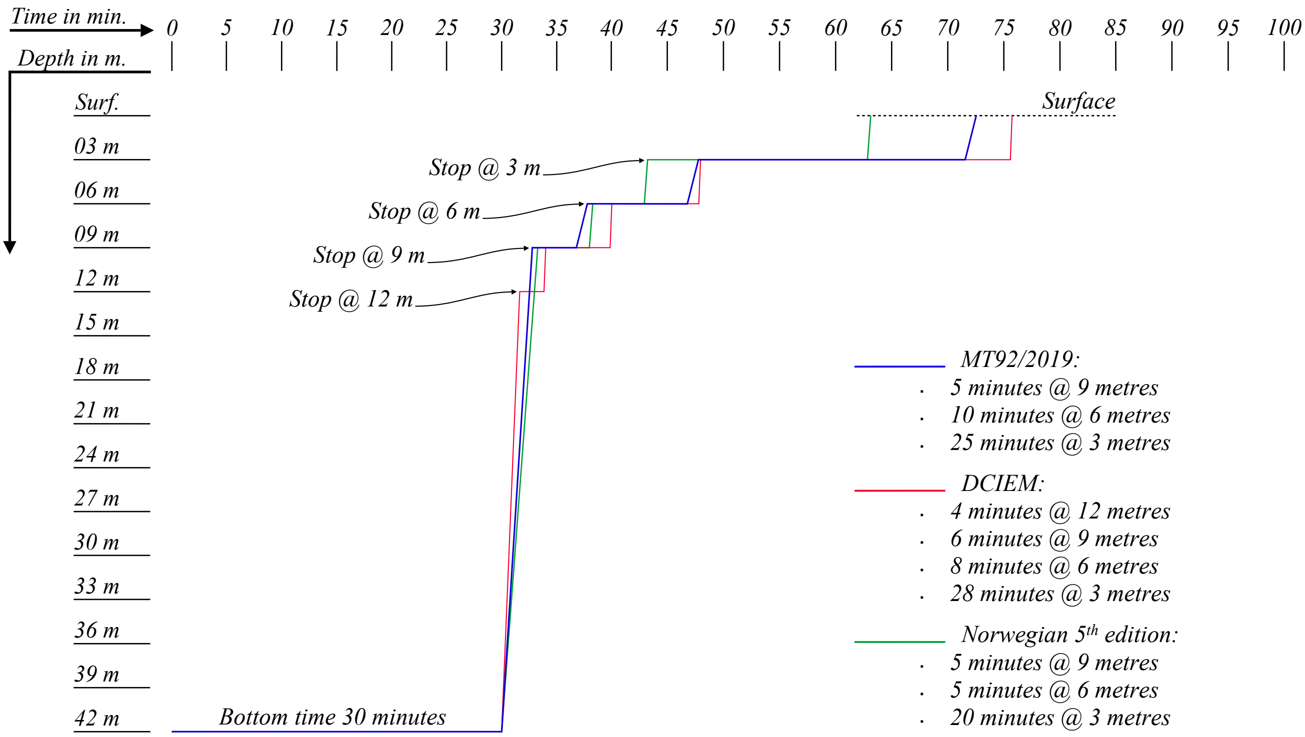
3.3.3 - Other elements to consider

As previously said, these three set of tables are based on different decompression models, so even though their decompression times are pretty similar, they are not organized in the same manner.

Among the elements that influence the decompression time, note the ascent rate, which is part of the decompression process and thus impacts the depths and duration of the stops.

- DCIEM tables are designed with an ascent rate of 18 m per minute, and the ascent time from the bottom to the 1st stop is part of this stop. This rate is also used to ascent between stops, but included in the stop time.
  This ascent speed is the fastest of the three decompression models considered, and the stops of this set of tables are usually organized to start deeper than those of MT92/2019 and Norwegian edition 5 tables. As an example, for a dive of 30 minutes at 42 metres, the first stop is at 12 m, whereas the tables MT92/2019 and Norwegian have their 1st stop at 9 m. Also, DCIEM tables usually provide slightly longer decompression times than MT92/2019 and Norwegian ed. 5 tables.
  It must be considered that a lot of tables initially designed during the eighties and still in use have an ascent rate comparable to the one of DCIEM. For example, the French Navy tables MN90 are designed with an ascent rate of 17 m/min. It is justified in a report published by the CEPISMER (*Commission Pratique d'Intervention Sous la Mer = Practical committee for intervention under the sea*), issued in January 1990, where doctor Meliet explains that the team who studied this table finally preferred this speed instead of a slower one to avoid having accidents due to too fast ascents because most navy divers were used to it with the previous tables. Also note that 60 ft/min (18 m/min) was the US Navy ascent rate during the seventies and the beginning of eighties, and that the decompression model of DCIEM tables (Kidd-Stubbs), is a reinforcement of the initial US Navy one.
- The Norwegian tables edition 5 have an ascent rate of 10 m/min, which is similar to the ascent speed of many recent decompression models. The 1st stops are organized shallower than with DCIEM. Using the example above of a dive of 30 minutes at 42 metres, the first stop is at 9 m instead of 12 m with DCIEM. The ascent time to the 1st stop is not included in the stop time. 10 m/min is also the ascent rate between the stops and is included in the stop times. Note that these air decompression tables, issued for the first time in 1980 (NUI-report 30-80), and revised in 1991, 2001, 2008, 2017, and 2019, are initially based on the Royal Navy's Tables 11.
- The tables MT92/2019 provide the most flexible ascent rate of the three proposals, as it can vary between 9 m/min and 15 m/min, depending on the choice of the diving supervisor. Note that the tables published by the French Ministry of labour are based on an ascent rate of 12 m/min, which corresponds to the mid speed between the slowest and the fastest. 12 m/min is also often preferred by many supervisors as it is easy to monitor on a traditional watch display (divided by 12). The ascent rate is not included in 1st stop. Also, the last minute of each stop is used to ascend to the next one. As with the Norwegian tables, the 1st stops of MT92 are organized shallower than with DCIEM. Thus, using the previous example of a dive of 30 minutes at 42 metres, the first stop is at 9 m instead of 12 m with DCIEM.

The scheme below superposes the decompression graphs of the three models for a dive of 30 minutes at 42 metres.



Note regarding the US Navy tables:

In Book #2 of our handbook *"Surface supplied diving using DCIEM tables"*, available on our website, the comparison between US Navy and DCIEM tables shows that the latest modification of the US Navy tables algorithm has resulted in very long decompression stops for some depths and bottom times, some being widely longer than those of the DCIEM tables, which is questionable if we consider that the three tables above are reputed to provide safe decompressions.

Another aspect of a diving tables set is its facility of use and the types of dives it allows to perform.
Regarding this point, and not considering heliox diving, MT 92/2019 provides the following in metric:

- Air table for decompression without stops (Table #1)
- Simplified air standard tables (Table #2)
- Air standard tables with in-water decompression (Table #3)
- Air oxy-6 m tables - In-water & in-bell decompression (Table #4)
- Air oxy 12 m tables - In-bell decompression (Table #5)
- Air/surface decompression tables (Table #6)
- Nitrox equivalent depth table (Table #7)
- Multi level diving table (Table #8)
- Equivalent depth table for diving at altitude (Table #9)
- Correction table for mud diving (Table #10)
- Repetitive diving calculation table (Table #11)

DCIEM provides the following in metric and imperial:

- Standard air decompression (Table #1)
- Short Standard Air Decompression (Table #1S)
- Equivalent air depth for nitrox diving (Table #1N)
- Recommended Bottom Time Limits (Table #2N)
- In-Water Oxygen Decompression at 9 m (Table #2) - Not used for in water stops with this handbook
- Short in-water oxygen decompression (Table #2S)
- Modified In-Water Oxygen Decompression (Table 2M)
- Surface Decompression with Oxygen (Table #3)
- Repetitive Diving Procedures (Tables #4)
  - 4A - Repetitive Factors / Surface intervals Table
  - 4B - No-Decompression Repetitive Diving
- Depth Corrections for Diving at Altitude (Table #5)
- Multi-Level Diving calculation procedure

Norwegian tables edition 5 provide the following in metric

- Standard Air decompression table
- Residual timetable for repetitive dives
- Correction for dive site altitude table
- Correction for depth of decompression stops
- EAD-table for open-circuit nitrox with 32 % O2
- EAD-table for open-circuit nitrox with 36 % O 2
- EAD-table for open-circuit nitrox with 40 % O 2
- Surface Decompression Table Using Oxygen

Opposite to some recent presentations such as the one of the US Navy revision 7, where the air in water decompression, air oxygen decompression, and surface oxygen decompression tables are grouped on a single chart. These tables are presented on separate documents, which in my opinion, avoids misreading errors. MT92/2019 air standard tables provide following elements for controlling the decompression of the diver:

- Bottom times
- Ascent to time the 1st stop
- Duration of each stop, including the ascent to the next stop or the surface, and the breathing gas
- Total decompression time
- Whether a repetitive dive is possible or not.

Depth 12 metres

Bottom time	Ascent to stop min :sec	Air 18 m	Air 15 m	Air 12 m	Air 9 m	Air 6 m	Air 3 m	Total decompression min :sec	Repetitive dive
165	1 :00	-	-	-	-	-	-	1 :00	Possible
170	0 :45	-	-	-	-	-	3	3 :45	Possible
180	0 :45	-	-	-	-	-	5	5 :45	Possible
210	0 :45	-	-	-	-	-	10	10 :45	No
240	0 :45	-	-	-	-	-	15	15 :45	No
270	0 :45	-	-	-	-	-	25	25 :45	No
300	0 :45	-	-	-	-	-	30	30 :45	No
330	0 :45	-	-	-	-	-	35	35 :45	No
360	0 :45	-	-	-	-	-	40	40 :45	No

The presentation of the DCIEM tables is similar, except the ascent to the 1st stop is not indicated as it is part of this stop. The presentation of the Norwegian tables is similar, except that the ascent time to the 1st stop is not indicated and that the total decompression time does not include the ascent times to the 1st stop and from the last stop to the surface.
Opposite to MT92/2019 tables, the DCIEM and Norwegian tables use repetitive groups to calculate the successive (repetitive) dive, which obliges using at least two tables, whereas the MT92/2019 procedure considers that the reference tissues are saturated to their maximum acceptable level, which results that only one table is necessary to calculate the penalty to be applied, which is safer and limits the sources of calculation errors (See below).

Repetitive Dive Depth (m)	Surface interval included between :									
	0h00 0h29	0h30 0h44	0h45 0h59	1h00 1h29	1h30 1h59	2h00 2h59	3h00 3h59	4h00 4h59	5h00 5h59	6h00 11h59
12-15	110	90	80	70	60	50	40	30	20	15
15-18	85	70	60	55	50	40	30	20	10	10
18-20	65	55	50	45	40	30	25	15	10	10
21-23	55	45	45	40	35	25	20	15	10	10
24-26	50	40	35	35	25	25	15	15	10	5
27-29	45	35	35	30	25	20	15	10	10	5
30-32	40	30	30	25	25	20	15	10	10	5
33-35	35	30	25	25	20	20	15	10	5	5
36-38	30	25	25	25	20	15	15	10	5	5
39-41	30	25	25	20	20	15	10	10	5	5
42-44	25	25	20	20	15	15	10	10	5	5
45-47	25	20	20	20	15	15	10	10	5	5
48-50	25	20	20	15	15	15	10	10	5	5
51	25	20	20	15	15	10	10	5	5	5
	Penalty to add to the real time									

The procedures below for nitrox, and altitude diving of tables MT92/2019 are also among the most simple, whereas those of the two other tables taken as references are more complex, particularly those of the Norwegian tables.

PROCEDURE FOR NITROX DIVING
EQUIVALENT DEPTH METHOD

Real Depth (m)	Nitrox Mix					
	25/75 (m)	30/70 (m)	35/65 (m)	40/60 (m)	45/55 (m)	50/50 (m)
9	9	9	6	6	6	3
10	9	9	9	6	6	3
11	12	9	9	6	6	6
12	12	12	9	9	6	6
13	12	12	9	9	9	6
14	15	12	12	9	9	6
15	15	15	12	9	9	6
16	15	15	12	12	9	9
17	18	15	15	12	9	9
18	18	15	15	12	12	9
19	18	18	15	15	12	9
20	21	18	15	15	12	9
21	21	18	18	15	12	12

TABLE N°9
PROCEDURE FOR ALTITUDE DIVING
EQUIVALENT DEPTH METHOD

Real Depth (m)	Altitude / Atmospheric pressure					
	300-500m 950mbar	500-1000m 900mbar	1000-1500m 850mbar	1500-2000m 800mbar	2000-2500m 750mbar	2500-3000m 700mbar
5	9	9	9	9	12	12
6	9	9	9	12	12	15
7	9	9	12	12	15	15
8	9	12	12	15	15	18
9	12	12	15	15	18	18
10	12	15	15	15	18	21
11	15	15	15	18	18	21
12	15	15	18	18	21	24
13	15	18	18	21	21	24
14	18	18	21	21	24	27
15	18	18	21	24	24	27
16	18	21	21	24	27	30
17	21	21	24	24	27	30
18	21	24	24	27	30	30

Note that the surface decompression procedures MT92/2019 are among the most stringent, with an interval surface limited to less than 3 minutes instead of 7 minutes for the DCIEM and 5 minutes for the Norwegian tables. Also, the last in-water stop of the Norwegian tables is at 12 m instead of 9 m with the MT92/2019 and that its 1st in-chamber stop is at 15 m instead of 12 m with the MT92/2019. As for the in-water decompression tables, the surface decompression tables MT92/2019 provide all the necessary information (see below). In contrast, the Norwegian tables do not give the ascent time to the 1st stop and the interval surface.
As the system of calculation of penalties for successive (repetitive) dives of MT92/2019 is different from those of the DCIEM and the Norwegian tables, the interval before starting another dive is indicated in hours instead of a repetitive group. Again, this system, in addition to a perfect display, limits the sources of mistakes.

Depth 36 metres

Minimum depth time min	Ascent to stop min :sec	In water			Surface Interval Inferior to	In Chamber		Total decompression min :sec	Interval after dive
		Air 15 m	Air 12 m	Air 9 m		Oxy 12 m	Oxy 12-0		
15	3 :00	-	-	-	3	10	6	22 :00	12h00
20	3 :00	-	-	-	3	10	6	22 :00	12h00
25	3 :00	-	-	-	3	15	6	27 :00	12h00
30	3 :00	-	-	-	3	20	6	32 :00	12h00
35	2 :15	-	-	3	3	25	6	39 :15	12h00
40	2 :15	-	-	3	3	30	6	44 :15	12h00
45	2 :15	-	-	5	3	35	6	51 :15	12h00
50	2 :00	-	3	7	3	40	6	61 :15	12h00

In addition to providing one of the best, or perhaps the best ergonomic, of the tables used in the industry, the MT 92/2019 tables offer more functions than the DCIEM and Norwegian tables. For example, the Norwegian tables do not provide in-water oxygen procedures. Also, the tables MT92/2019 are the only set providing tables for diving in the mud, which is useful when pouring concrete, operations in bentonite mixes, or merely diving operations in areas where liquid mud is present near the bottom, which happens in some estuaries, and result in a higher water density as normal fresh or salt water (See below).

DEPTH (m)	Mud Density			
	1.1 (m)	1.2 (m)	1.3 (m)	1.4 (m)
5	6	6	9	9
6	9	9	9	9
7	9	9	12	12
8	9	12	12	12
9	12	12	12	15
10	12	15	15	15
11	15	15	15	18
12	15	15	18	18
13	15	18	18	21
14	18	18	21	21
15	18	18	21	21
16	18	21	21	24
17	21	21	24	24
18	21	21	24	27
19	21	24	27	27
20	24	24	27	30

To conclude this presentation, the MT92/2019 tables are considered safe by the French ministry of labour and the labour ministries of many countries. They have similar decompression curves as the two tables taken in reference, which are also commonly used in the industry , and reputed safe. Their ergonomics are among the best, making them easy to use with fewer risks of human errors due to miscalculation or misreading than many other tables.

3.4 - Reinforcement of the original procedures

3.4.1 - Purpose

The MT92/2019 tables have been published at the beginning of the nineties, and their study shows that some contingency procedures today in force were not considered during this period and have to be introduced.
The purpose of a diving manual is to make sure that the diving team will not have to face adverse situations without clear guidelines. For this reason, missing procedures have been covered by procedures that are:

- Compatible
- Agreed by at least another competent body
- Already in use in the diving community
- Simple to apply
- Easy to remember

In addition, reinforcements have been added to some existing procedures. Most of them consist of the use of the chamber that is not indicated in the original procedures, except for violated surface intervals in the surface O2 decompression procedure. The use of a chamber as a precaution in the case of an incident is today a standard procedure in the offshore diving industry. Nevertheless, note that reinforcements must be done in respect to the way these tables have been originally designed, so there that there is no modification of the decompression model and the original procedures.
As already said in the presentation, no modification of the original procedure published in 1992 have been made in 2012 and 2019. The decrees of October 2012 and May 2019 focusing only on the classification of the divers, the limitation of the maximum depth that is today compliant with what is performed in the offshore industry, and the conditions of application of this table within the French territories. As a result the table remains as it was published by COMEX and adopted by the French ministry of labour in 1992.
The main reason is that theses revisions have not been made by people unfamiliar with the practices today in force in the offshore diving industry.
One of the essential rules today in force for surface supplied diving is that when a method of decompression is selected a backup procedure must be ready to recover safely the diver if the main method becomes inapplicable. As an example, the backup procedure of “In-water decompression procedure” is the “surface oxygen decompression procedure”. Also, in addition to the uncovered contingencies, the following elements needed some attention:

- Heliox surface decompression procedure is not provided. As a consequence there is no backup decompression procedure available. Note that heliox diving is not discussed in this document.
- The air surface O_2 decompression procedure offers fewer bottom times and depths than the in-water air decompression table. For this reason, before launching an in-water decompression dive, the supervisor must make sure that the decompression selected can be performed using the surface oxygen decompression table. To reinforce this point, a warning showing the missing bottom times and depths has been written *(see “Bottom times and depths of in-water and surface O2 decompression tables”)*. Also, additional warnings are in place in the tables to make sure that the supervisor will not organize a dive beyond the limits offered by the surface decompression tables.
- In-water O2 decompression procedure at 6 m offer more bottom times than the standard air decompression procedure. However this point is covered by the implementation of the bottom time limits from doctor Shields and Lee (UK-HSE limits)

  The table for Equivalent Air Depth calculation (Table 7) has been designed for a maximum PPO2 of 1.6 bar. To comply with the latest recommendations from scientists explained in Book #1 *(See in “Adverse effect of hyperbaric oxygen”)*, the maximum PPO2 is reduced to 1.4 bar, and the corresponding table has been updated to this maximum limit.

The reinforcements applied to the table are explained in the next pages as follows:

- Summary of contingencies procedures selected for air in-water & surface decompression tables MT92/2019
- Bottom times and depths of in-water and surface O2 decompression tables
- Reinforcement of the medical tables
- DMAC 7 in place of the original procedure
- UK-HSE (Doctors Shields & Lee) maximum operational limits
- Bottom times reinforcement (Jesus procedure)
- Predive conditioning

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3.4.3 - Summary of contingencies procedures selected for air in-water & surface decompression tables MT 92/2019

3.4.1.1 - Standard air in-water decompression

No	*Contingency*	*Procedures MT92*	*Procedure reinforced*	*Comments*
1	Ascent to 1st stop too slow	No procedure indicated	Delay added to the bottom time and decompress in accordance with the new bottom time.	*Source: MN 90* This is a classical procedure easy to remember and that most divers know. It is also in force with the US Navy procedures
2	Ascent to 1st stop too fast:	The diver returns to the half depth within less than three minutes and carries out a five minute stop. Decompression is renewed, based on the total diving time, including re-descent and the five minute stop at half depth.	The diver returns to the half depth within less than three minutes and carries out a five minute stop. Decompression is renewed, based on the total diving time, including re-descent and the five minute stop at half depth. The diver must perform 2 min stop at 3 metres if no stop is scheduled.	*Source: MN 90* It is a “standard procedure” and many divers can testify that it works fine. MN 90 proposes the same procedure than MT92/2012, but it is indicated that the diver must perform a 2 min stop at 3 metres if no stop is scheduled
3	Omitted decompression (Not a blow up)	No procedure indicated in the decree. Nevertheless, the COMEX medical book manual (in chapter 4) recommends this rule for the selection of the recompression table: - For dives above 9 m treat with Cx12 - For dives below 9 m treat with Cx 18	*1) Recompression in chamber not possible in less than 3 minutes:* • <u>If only one stop is omitted:</u> - Return the diver to the stop where the omission occurred in less than 3 minutes, perform this stop from the beginning and continue the decompression using the original schedule. • <u>If more than one stop is omitted:</u> - Return the diver to the deeper omitted stop in less than 3 minutes. - Perform all the omitted stops from the beginning and complete the total schedule. Upon the arrival of the diver on deck, put the diver under 100% O_2 and transfer him to the Deck Decompression Chamber . - Observe for signs of decompression sickness and pulmonary barotrauma and contact the Diving Medical Specialist (DMS). Treat using COMEX procedure if the DMS cannot be contacted: - For dives above 9 m treat with Cx12 - For dives below 9 m treat with Cx 18. *2) Recompression in chamber possible in less than 3 minutes:* • <u>If only one stop is omitted:</u> - Return the diver to the stop where the omission occurred in less than 3 minutes, perform this stop from the beginning and continue the decompression using the original schedule. Observe closely the diver for signs of decompression sickness upon his arrival on deck. • <u>If more than one stop is omitted:</u> - If the stop 9 m is completed and no previous decompression omitted, or the stops below 6 m not scheduled, recompress the diver at 12 m in the chamber in less than 3 min and decompress him using the surface O2. decompression table. - If the stops at 9 m and below are omitted, return the diver to the deeper omitted stop in less than 3 minutes. Perform all the omitted stops from the beginning and	Note that Omitted decompression is not a blow-up (The ascent is made at the normal speed) *Source: MN 90* Return at the interrupted stop in less than 3 minutes and re-start the interrupted stop from the beginning. Then, complete the decompression. Procedure MN 90 is very simple to remember. Nevertheless, we have a chamber and it must be used for prevention . One stop omitted is a situation where the diver misses a stop or is stopped slightly above. It may happen if the reference marks of the winch are incorrect or due to a mistake from the supervisor or the winch man. Generally, the correction is made within a few seconds. Two stop omitted is more undesirable. For this reason, a reinforcement has been introduced. The method for selecting the treatment table if the Diving Medical Specialist is not reachable is from COMEX medical book (chapter 4): - For dives above 9 m treat with Cx12 - For dives below 9 m treat with Cx 18

No	Contingency	Procedures MT 92	Procedure reinforced	Comments
	Omitted decompression (Continuation from the previous page)		complete the total schedule. Then, transfer him to the DDC as soon as possible	
4	Blowup	- If the decompression chamber is not at direct proximity: If the condition of the diver allows it, return to half depth in less than 3 minutes, carry out 5 minutes stop. Decompression is renewed, based on the total diving time, including re-descent and the five minute stop at half depth.	• If the decompression chamber is not at direct proximity: At the surface give 100% O2 to the diver, and transfer him to the chamber. In the chamber, treat: - For dives above 9 m treat with Cx12 - For dives below 9 m treat with Cx 18 • If the decompression chamber is at direct proximity: Transfer to the chamber in less than 3 min and treat: - For dives above 9 m treat with Cx12 - For dives below 9 m treat with Cx 18	*Sources MT92 & COMEX medical book*
5	Delays in leaving a stop or between decompression stops	No procedure	- Remember that the last minute of the stop is used to ascent to the next stop. - When the delay happens at and shallower than 12 m: Ignore the delay, and complete the decompression normally. - When the delay happens deeper than 12 m: Recalculate the required decompression using the multilevel table (Table #8)	*Sources: MT92 multi level diving & US Navy* The US Navy manual says that the decompression must be recalculated for stops at and below 15 m. However, MT92/2019 is provided with a multilevel diving table that can be used to verify the decompression schedule. This rule is mainly given for information because if the operational limit UK-HSE is applied as it should be, there is no stop below 9 m. Nevertheless, this procedure highlights the fact that longer stop times at depth can trigger re-saturation. This information is more useful in the case of heliox dives which call for deep stops. Most diving teams tend to apply longer stops than scheduled in the table. This time is often lost because the teams are afraid to burn stops and ascent too fast.
6	Travel rate between decompression stops too fast	No procedure	- If the rate of ascent is faster than 3 m/min, stop the ascent, allow the chronometer to catch up, and then continue the ascent. - Consider an early arrival at the next stop as an omitted decompression.	The 1st procedure is commonly used by scuba and surface supplied divers. For the 2nd procedure: MT 92 considers that the ascent is part of the decompression of the stop that has been left. For this reason, we can consider an early arrival at the next stop as an omitted decompression.
7	Difficulty in performing the 3 metre stop	- Perform the 3 m air stop at 6 m - Or, switch to surface decompression table	- Perform the 3 m air stop at 6 m - Or, switch to surface decompression table *(No reinforcement)*	
8	Exceeding the planned bottom time	Use either the next bottom time, or the last bottom time that should be used only as a backup.	Use either the next bottom time, or the last bottom time that should be used only as a backup. *(No reinforcement)*	Note that the surface decompression table offers fewer bottom times than the corresponding depth of the in-water decompression table. A warning is in place with a comparison of the bottom times. Warnings are also in place in the tables to alert the supervisor.
9	Exceeding the planned depth	Select the next depth	Select the next depth *(No reinforcement)*	Note that the maximum depth of the surface decompression table is 51 m instead of 60 m for the in water table

3.4.1.2 - Air surface oxygen decompression

No	*Contingency*	*Procedures MT 92*	*Procedure reinforced*	*Comments*
1	Ascent to 1st stop too slow	No procedure indicated	Delay added to the bottom time and decompress in accordance with the new bottom time.	*Source: MN 90* This is a classical procedure easy to remember and that all the divers know.
2	Ascent to 1st stop too fast:	The diver returns to the half depth within less than three minutes and carries out a five minute stop. Decompression is renewed, based on the total diving time, including re-descent and the five minutes stop at half depth.	The diver returns to the half depth within less than three minutes and carries out a five minute stop. Decompression is renewed, based on the total diving time, including re-descent and the five minute stop at half depth. The diver must perform 2 min stop at 3m if no stop is scheduled	*Source: MN 90* It is a "standard procedure" and many divers can testify that it works fine.
3	Omitted decompression (not associated to a blowup)	No procedure	• <u>If only one stop is omitted:</u> Return the diver to the stop where the omission occurred in less than 3 minutes, perform this stop from the beginning and continue the decompression using the original schedule. Observe closely the diver for signs of decompression sickness upon his arrival on deck.. • <u>If more than one stop is omitted:</u> - If the stop 9 m is completed and no previous decompression omitted, or the stops below 6 m not scheduled, recompress the diver at 12 m in the chamber in less than 3 min and decompress him using the surface O2. decompression table. - If the stops at 9 m and below are omitted, return the diver to the deeper omitted stop in less than 3 minutes. Perform all the omitted stops from the beginning and complete the total schedule. Then, transfer him to the DDC and apply Cx18	Procedure also explained in standard air *Sources: MN 90 & COMEX medical book*
4	Blowup	No procedure indicated for in-chamber deco, but procedure for air standard exist. Also the treatment is indicated in COMEX medical book	Transfer to the chamber as soon as possible and treat: - Use Cx12 if the depth of the dive is above 9m - use Cx 18 if the depth of the dive is below 9m	*Source: COMEX medical book*
5	Decompression stress during the surface interval	No procedure	The diver should be treated for decompression sickness if the signs and symptoms of the surface interval stress have not been completely resolved when he is confirmed on oxygen at 12 m in the chamber. In this case, the chamber must be compressed to 18 m and the treatment table Cx 18 Comex, or table 6 USN initiated.	*Sources: DCIEM & COMEX medical book*
6	Interval from in water stop 9 m to in-chamber stop 12 m exceeding four minutes	- If the surface interval exceeds four minutes but does not exceed five minutes, switch to the next longer table time. - If the surface interval exceeds five minutes, consider the dive as a shortened deco and apply the procedure for decompression accident type 1	If the surface interval exceeds four minutes but does not exceed five minutes, switch to the next longer table time. If the surface interval exceeds five minutes, consider the dive as a shortened decompression, and apply the procedure for decompression accident type 1 *(No reinforcement)*	

No	Contingency	Procedures MT 92	Procedure reinforced	Comments
7	Delays in leaving a stop or between decompression stops	No procedure	- When the delay happens at and shallower than 12 m: Ignore the delay, and complete the decompression normally. - When the delay happens deeper than 12 m: Recalculate the required decompression using the multilevel table (Table #8)	*Source: MT92 & US Navy* The US Navy manual says that the decompression must be recalculated for stops at and below 15 m. However, MT92/2019 is provided with a multilevel diving table that can be used to verify the decompression schedule. This rule is mainly given for information because if the operational limit UK-HSE is applied as it should be, there is no stop below 9 m.
8	Travel rate between decompression stops too fast	No procedure	- If the rate of ascent is faster than 3 m/min, stop the ascent, allow the chronometer to catch up, and then continue the ascent. - Consider an early arrival at the next stop as an omitted decompression.	The 1st procedure is commonly used by scuba and surface supplied divers. MT 92 considers that the ascent is part of the decompression of the stop that has been left. For this reason, we can consider an early arrival at the next stop as an omitted decompression.
9	Delay when travelling from the in-water stop 9 m to the surface	No procedure	- Ignore the delay and continue the ascent at the normal rate. DO NOT try to recover the delay. When at the surface, transfer to the the chamber in less than 4 minutes after leaving the 9 m stop. - If the surface interval is more than 4 minutes, apply the procedures for internal surface exceeding the planned time.	This is a classical procedure. If the winch- man try to recover the lost time, we have a fast ascent: The time can be recovered at the surface if the team is well organised.
10	Travel rate between from the in-water stop 9 m to the surface too fast	No procedure	If the rate of ascent is faster than 9 m/min, stop the ascent, allow the chronometer to catch up, and then continue the ascent.	*Source: Diving community*
11	Diver unable to reach the 12 m stop in chamber	No procedure	Two procedures can be used to solve this problem: - The procedure US Navy indicated in the US Navy manual revision 6.1 - The procedure US Navy “reinforced” from Dr Massimelli (DMAC) which is the original procedure USN with additional O2 stops at 3m (10 ft).	*Sources USN & Dr Massimelli (DMAC)* Such incident may happen during surface decompression and must be quickly solved. The “safe way out procedure” had been published by USN in 2006 and is the only existing procedure to solve such problem. This procedure is applicable to any surface decompression table.
12	Oxygen supply breakdown	If the loss of the oxygen supply is permanent: MT-92/2012 says: Decompress the divers on air using the standard air table for the same depth. Use the maximum bottom time available for safety.	For temporary loss of oxygen supply. The divers breathe chamber air. Return the divers to oxygen breathing when the supply is reestablished. Consider any time spent on air as dead time (The valid decompression is the time spent on O2). If oxygen cannot be reestablished, Decompress the divers on air using the standard air table for the same depth. Use the maximum bottom time available for safety.	*Common procedures:*
13	Acute oxygen poisoning during the decompression	No procedure	Remove the O2 mask, breathe air for 15 minutes, then resume the decompression at the point interruption. Generally the crisis will not happen again but the incident must be reported to the diving medical specialist. In the case that a 2nd crisis starts, the decompression will have to be completed on air. (Continue on the next page)	Acute oxygen poisoning is explained in the document “Diving Accidents”. Additional procedure is classical and explained in many diving medical docs Also, explained in diver medic courses

No	Contingency	Procedures MT 92	Procedure reinforced	Comments
	Acute oxygen poisoning during the decompression (Continuation from the previous page)		In case of convulsions, the attendant must prevent the casualty from injuring himself, check the airways and makes sure that the tongue will not be swallowed (A padded mouth piece may be gently placed between the teeth to protect the tongue). After the convulsion, the patient may be unconscious for a short time. Important: DO NOT attempt to decompress a diver during a convulsion: The casualty will be unable to exhale with the high risk to create a pulmonary barotrauma. The ascent to the next stop must begin only after full recovery and the patient is relaxed. If the decompression has to be completed on air use the procedure indicated previously: Decompress the diver on air using the standard air table for the same depth of dive. Use the maximum table time available for safety.	*Sources:* *Refer to Book #1 / Adverse effects of hyperbaric oxygen.*
14	Exceeding the planned bottom time	Use either the next bottom time, or the last bottom time that should be used only as a backup.	- Use either the next bottom time, or the last bottom time that should be used only as a backup. - If there is no bottom time available, switch to in-water decompression table and complete the decompression in the water. - If the in-water stops are not possible due to adverse weather conditions, and there is no in chamber stop corresponding to the bottom time, perform the in-water stops until 9 m, then, transfer the diver to the chamber in less than 4 minutes. In the chamber treat using the Cx 18 (procedure COMEX omitted decompression)	Use the in-water air in the case that no surface deco procedure is available is acceptable if the weather is fine. Nevertheless, accumulation of mistakes may lead to a problem if the diver is in the water and the decompression is impossible. In this case he must be decompressed using a medical table as no table is available. Based on the fact that the decompression profile of the in-water decompression table and in-chamber decompression table is normally the same until the 9 m stop, the 9 m stop is performed to allow a safe transfer (in less than 4 minutes) to the chamber. A warning is included in the procedure to prevent the supervisor from considering it a standard practice.
15	Exceeding the planned depth	Select the next depth, or the last depth that should be used only as a backup	Select the next depth, or the last depth that should be used only as a backup. If there is no depth available, switch to in-water decompression table, select the depth attained by the diver and complete the decompression in the water. If the in-water stops are not possible due to adverse weather conditions, perform the in-water stops until 9 m then transfer the diver to the chamber in less than 4 minutes. In the chamber treat using CX18	This is a similar procedure than the previous one . As indicated the surface decompression table offers fewer bottom times and depths than the in-water air decompression table. - Procedure must be in place to make sure that the divers will work within the UK-HSE limits. - Procedures must be in place to recover safely the diver in the case that the diver is outside the limits given by the table.

3.4.1.3 - Nitrox procedures

No	*Contingency*	*Procedures MT92*	*Procedure reinforced*	*Comments*
1	Acute oxygen poisoning during the decompression	No procedure	• Minor symptoms during the dive - The nitrox supply must be stopped, and the helmet flushed with air. - The divers ascent to the basket which should be stored above him (that should reduce the partial pressure of O2) . - The stand by diver must be sent to assist the diver. - The decompression table to apply is the air decompression table for the actual depth of the diver, if the diver has been passed on air when at depth. - If the diver has been passed on air when the "equivalent air dive" level has been reached or passed, the decompression to apply is the one corresponding to the equivalent air dive level. • Serious symptoms during the dive - If the symptoms are too severe, but the epileptic crisis not yet started, the diver must be passed on air, removed from water and surface decompression procedure should be applied. Surface decompression must be considered even for trivial cases, and must be organized for all cases that could become more serious. The advantage of decompression in chamber is that the casualty can be easily controlled, which is not the case if the casualty is wearing his helmet and underwater. - The selection of the decompression table is to be done according to what is explained in the point 8.1. - If the epileptic crisis is started in the water, the diver cannot be ascended as he is not able to exhale. If the ascent is undertaken, it can trigger a pulmonary barotrauma. In this case, the solution is to wait the end of the crisis and ascend later on. But during such crisis, the diver can swallow his tongue or vomit in his helmet. Suffocation or vomit swallowed by the lungs can be the result. In both cases the final result could be death. For these reasons, an epileptic crisis at depth must be avoided. The diver must inform the diving supervisor of any symptom/bad feeling. Prudence must be the rule!	*Sources:* *Refer to Book #1 / Adverse effects of hyperbaric oxygen.*
14	Calculation Equivalent Air Depth (EAD)	Maximum partial pressure limited to 1.6 bar in table 7	Modification Table 7: To comply with the latest scientific research, the maximum partial pressure has been adjusted to 1.4 bar. As a result, the depths where the PPO2 were above 1.4 bar have been erased.	*Sources:* *Refer to Book #1 / Adverse effects of hyperbaric oxygen.*

3.4.3 - Bottom times and depths of in-water and surface O2 decompression tables

As explained before, when starting a diving operation using in-water decompression, the corresponding surface oxygen decompression table must be ready.
The study of MT 92/2012 tables shows that the surface decompression table offers fewer bottom times and depths than the in-water air decompression table. For this reason, warnings have been introduced and highlighted to make sure that the decompression selected can be performed using the surface oxygen decompression table.

The table below shows a comparison of the bottom times of in-water and surface O2 decompression tables. It can be found in each diving document. In addition similar warnings are in the tables.

Depth	***Bottom times Standard air table***	***Bottom times Surface Oxygen deco. table***	***UK-HSE bottom time limits***	***Comments***
12 m	165 to 360 min	180 to 360 min	240 min	
15 m	80 to 270 min	90 to 180 min	180 min	The surface O2 deco table is limited to 180 min that is also the UK-HSE bottom time limit. Manage to have at least 1 recovery table. Nevertheless 2 recovery tables is better. Also, take this problem into consideration if the safety procedure selected is one additional bottom time.
18 m	50 to 210 min	60 to 150 min	120 min	4 bottom times are missing in the surface deco. table. Nevertheless there are 3 bottom times after the IOGP bottom time limit.
21 m	35 to 180 min	40 to 120 min	90 min	4 bottom times are missing in the surface deco. table. Nevertheless there is 3 bottom times after the IOGP bottom time limit.
24 m	25 to 150 min	30 to 90 min	70 min	6 bottom times are missing in the surface deco. table. Only 2 bottom times after the UK-HSE bottom time limit. Take this into consideration if the safety procedure selected is one additional bottom time.
27 m	20 to 130 min	25 to 70 min	60 min	6 bottom times are missing in the surface deco. Table. Only 1 bottom time after the UK-HSE bottom time limit. Take this into consideration if the safety procedure selected is one additional bottom time.
30 m	15 to 110 min	20 to 60 min	50 min	5 bottom times are missing in the surface deco. table. Only 1 bottom time after the UK-HSE bottom time limit. Take this problem into consideration if the safety procedure selected is one additional bottom time.
33 m	12 to 100 min	15 to 60 min	40 min	4 bottom times are missing in the surface deco. table.
36 m	10 to 90 min	15 to 50 min	35 min	4 bottom times are missing in the surface deco. table.
39 m	8 to 80 min	10 to 40 min	30 min	5 bottom times are missing in the surface deco. table. Only 2 bottom times after the UK-HSE bottom time limit.
42 m	7 to 70 min	10 to 40 min	30 min	4 bottom times are missing in the surface deco. able. Only 2 bottom times after the UK-HSE bottom time limit.
45 m	6 to 60 min	10 to 30 min	25 min	4 bottom times are missing in the surface deco. table. Only 1 bottom time after the UK-HSE bottom time limit. Take this into consideration if the safety procedure selected is one additional bottom time.
48 m	5 to 60 min	10 to 30 min	25 min	5 bottom times are missing in the surface deco. table. Only 1 bottom time after the UK-HSE bottom time limit. Take this into consideration if the safety procedure selected is one additional bottom time.
51 m	5 to 50 min	10 to 30 min	20 min	4 bottom times are missing in the surface deco. table. Only 2 bottom times after the UK-HSE bottom time limit. There is no surface decompression table below this level: Limit the depth to have at least 2 recovery tables. Take this into consideration if the safety procedure selected is one additional bottom time.
54 m	5 to 45 min	No table	Beyond the limit	No surface O2 decompression table.
57 m	5 to 40 min	No table	Beyond the limit	No surface O2 decompression table.
60 m	5 to 35 min	No table	Beyond the limit	No surface O2 decompression table.

3.4.4 - Reinforcement of the medical tables

MT92 initially proposed only COMEX tables Cx12 (Table 1) and Cx30 (Table 2), so one table for treatment of type 1 decompression accidents (CX12) and the 2nd table (CX30) for treatment of type 2 decompression accidents based on the use of heliox. The latest revision has provided the CX18 for treatments at 18 m

This handbook proposes the full collection of COMEX tables as it is considered that the selection of a treatment table is a medical act that is normally under the responsibility of the diving medical specialist. That is why for every action where a medical table has to be used for prevention or to solve a problem it is said *"Contact the diving medical specialist and follow his instructions"*. Nevertheless, the diving medical specialist is not on board, and for this reason, the diving team must have all the tables the diving medical specialist may decide to use.
Also, the team must have guidance for solving a decompression sickness or and arterial gas embolism in case the communication with the diving medical specialist cannot be established. Limit the selection of tables to only three tables is not realistic for the following reasons:

- It gives the divers a false feeling of safety, which results that many of them think that applying a Cx12 (table 1), Cx18 (table 2), or Cx30 (table 3) will automatically solve all the decompression sickness and Arterial Gas Embolism problems they can be confronted with. Every chamber operator who has been confronted with real cases knows that it is not true and that treatments using Cx30 may have to be continued with "Cx30 saturation" that is not indicated in the latest decree of May 2019. For this reason, it has been integrated in this handbook.
- The treatment tables published in MT92/2019 do not cover all possible scenarios. As an example, the procedure for selecting the preventive treatment tables is not indicated in MT92/2019. Nevertheless the procedure is available in the COMEX medical book *(chapter 4)* edited in 1986. This procedure should be used in case the diving medical specialist cannot be contacted on time. This procedure considers two possible cases:
  - Depth of the dive less than 9 m: Treat using Cx 12
  - Depth of the dive more than 9 m: Treat using Cx 18
- A lot of hyperbaric doctors consider suitable and efficient to have a full set of medical tables available instead to only a few of them. Many of them also prefer having several sets of tables where they can select the most suitable procedure for the situation encountered.

US Navy Treatment Tables are the most commonly used by hyperbaric doctors, in Asia and Americas. It is the reason, they are published in this manual in addition to what is said in the text above.

- Some people believe that because the treatment tables published in the decree of May 2019 are table 1 (Cx12), table 2 (Cx18), and table 3 (Cx30), only these tables have to be applied to solve decompression illness or Arterial Gas Embolism. This is false, as the use of a treatment table is a medical act under the sole responsibility of the diving medical specialist who is a doctor, and is the most competent person to solve medical cases linked to diving.
  Note that the diving medical specialist should be selected according to the guidelines from states, and other competent medical organizations, and be recognized as a diving doctor. Lists of recognized doctors are provided in Logistics/Diving doctors & clinics on the website Diving and ROV Specialists.com.

  The purpose of treatment tables is to save or preserve a compromised life. As a simple rule, decompression tables are designed to protect divers from decompression sickness. They are calculated according to a bottom time at a certain depth for a particular activity. Treatment tables are designed to solve a situation where a diver is beyond the operational limit of the decompression table that has been selected or is already suffering from decompression sickness or arterial gas embolism. Treatment tables are applied according to symptoms and possible development of an illness and not according to a bottom time at a certain depth. The doctor will check the dive profile of the diver, but it is to have a clear idea of what happened and refine his strategy.
  A lot of doctors are used to USN medical tables because they have been taught with them. So they will tend to apply these tables in priority.
  Some other doctors do not hesitate to use tables from different origins. As an example, Cx30 with 50/50 heliox is commonly used if heliox is available onboard. For this reason, the full sets of US Navy and COMEX treatment tables are in this handbook. Note that the diving medical specialist must indicate the preferred set of medical tables before starting the diving operations.

To conclude on this point:

The handbooks published by diving and ROV specialists propose the full sets of US Navy and COMEX treatment tables whatever is the decompression table used (DCIEM or MT92/2019). The reason is that these medical sets of tables are the most used in the offshore industry. That gives the advantage to propose many options and not limit the diving medical specialist and the diving team to only 2 tables.
Other treatment tables exist, and the Diving Medical Specialist may decide to use another table than those proposed in these manuals. Nevertheless, it has been considered that too many options could be difficult to manage, and should double the size of document "Diving accidents" that is already more than 300 pages.

3.4.5 - DMAC 7 in place of the original procedure for flying after diving

DMAC 7 "Flying after diving: Recommendations" is a guidance that was 1st published by the Diving Medical Advisory Committee (DMAC) in 1982 and was then regularly reviewed. The current version (Revision #2), published in November 2017 provides some reinforcement of the previous ones
It must be remembered that this guidance is based on COMEX procedures, and was also initially part of MT92 tables. That can be verified by comparing the two tables below that were published in 1992 (MT/92) and in 2001 (DMAC 7)

Diving procedure used	Variation in pressure or altitude	
	Greater than 500 m (Approx 50 hPa)	Greater than 2600 m or a flight in a commercial aircraft (Approx 250 hPa
No stop air diving	*2 hours*	*4 hours*
Air or heliox diving with stops	*12 hours*	*12 hours*
Heliox saturation	*12 hours*	*12 hours*
Emergency recompression	*24 hours*	*48 hours*

MT 92 - May 1992

Diving without Decompression Illness (DCI) problems	Minimum times before flying at cabin altitude	
	2000' (600 m)	All other flights
No-stop dives Total time under pressure less than 60 minutes within previous 12 hours	*2 hours*	*8 hours (24 hours)**
All other air and nitrox diving, heliox and mixed gas bounce diving (less than 4 hours under pressure)	*12 hours*	*24 hours*
Heliox saturation (more than 4 hours under pressure)		
Air, Nitrox or Trimix saturation (more than 4 hours under pressure)	*24 hours*	*48 hours*

**8 hours applies to short flights. For longer flights, as for example intercontinental flights, the time is extended to 24 hours*

Table #1 of DMAC 07 - Rev. 1 - March 2001

We can see that the initial document was the same. However, there were already some differences with revision #1 from the DMAC, published nine years later: Flying after diving was reinforced. Note that the altitude of 500 m (1640 ft) was raised to 600 m (1968 ft) by the DMAC. Another point is that this guidance DMAC 7 introduced the recommendation below regarding flying following therapy for DCI, which was not part of the MT92 tables.

	Minimum times before flying at cabin altitude	
	2000' (600 m)	All other flights
Immediate and complete resolution of symptoms on first recompression	*24 hours*	*48 hours*
Cases without immediate response or with residual symptoms must be decided on an individual basis by a diving medical specialist. Generally wait as long as possible.	*Consult a diving medical specialist*	

Table #2 of DMAC 07 - Rev. 1 - March 2001

As indicated in the introduction, no reinforcement of the original procedure published in 1992 has been made in 2012 and 2019. Also, the recommendations for flying after diving were removed from the decree of 30 November 2012 and then returned in the decree of 14 May 2019 as it was initially published in 1992, except that it was added that flying after heliox saturation is not permitted before 12 hours inland and 48 hours offshore, which is illogical as inland or offshore saturation result in the same problem of decompression. This illogical procedure is not from the creators of the table.

For the reasons above, and also because most offshore teams are today familiar with the guidance DMAC 7. It is advisable to adopt revision #2 of DMAC 7, published in 2017, in place of the original procedure, which should be considered obsolete. Note that this latest update of DMAC 7 results that the standby period before flying after a no decompression dive is now 18 and 24 hours instead of 4 hours with the original procedure MT92 and that the standby period before flying after a DCI is now 72 hours instead of 48 hours with the previous revision of DMAC 7 *(Remember that this table #2 was not part of MT92 procedures)*.

1 - Diving without Decompression Illness problems or any symptoms	***Minimum times before flying at cabin altitude***	
	2000' (600 m)	***All other flights***
No-stop dives Total time under pressure less than 60 minutes within previous 12 hours	*2 hours*	*18 hours (24 hours)**
All other air and nitrox diving, heliox and mixed gas bounce diving (less than 4 hours under pressure)	*12 hours*	*24 hours*
Heliox saturation (more than 4 hours under pressure)		
Air, Nitrox or Trimix saturation (more than 4 hours under pressure)	*24 hours*	*48 hours*

** 18 hour time applies to short flights (less than 3 hours). For longer flights the time is extended to 24 hours*

2 - Following therapy for DCI, advice must be sought from a diving medical specialist	***Minimum times before flying at cabin altitude***	
	2000' (600 m)	***All other flights***
Immediate and complete resolution of symptoms on first recompression	*24 hours*	*72 hours*
Cases without immediate response or with residual symptoms must be decided on an individual basis by a diving medical specialist. Generally wait as long as possible.	*Consult a diving medical specialist*	

Residual risks will be reduced by giving 100% oxygen during the flight. Following landing the diver should be assessed by a diving medical specialist.

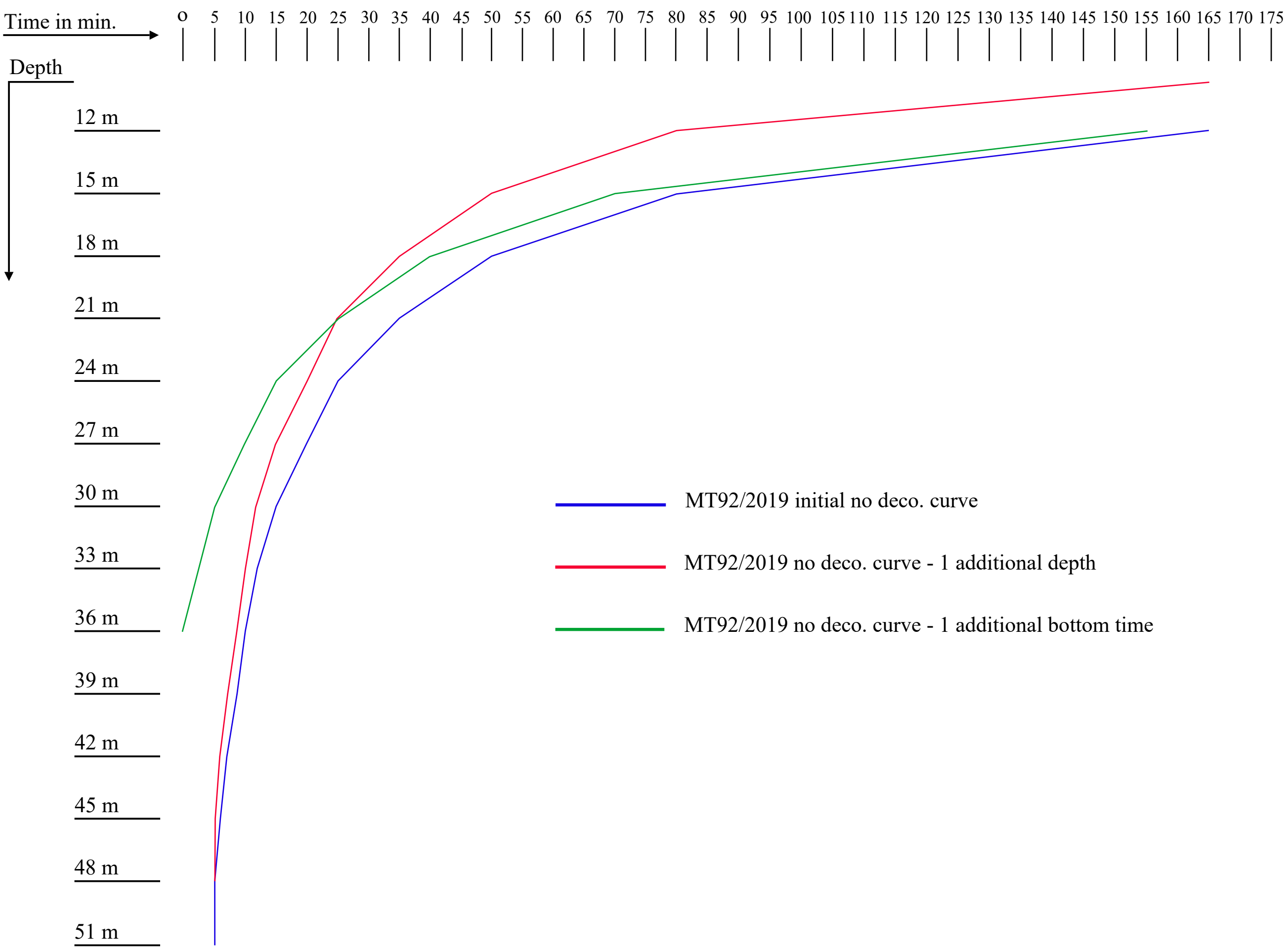
3.4.6 - Decompression safety procedure

The “Decompression safety procedure”, previously called “Jesus factor”, is an old concept based on the fact that a table is developed for a determined population of divers, which does not always correspond to the divers operating on the job site. This procedure was initially implemented because most tables used during the 60s and 70s were initially designed for military divers which resulted in numerous decompression accidents. This “Jesus factor” is described in detail in the document *“The incidence of decompression sickness arising from commercial offshore air-diving operations in the UK sector of the North sea during 1982/83”* issued in December 1997 by doctors Shields and Lee.

Even though the tables currently used, such as MT 92 or DCIEM, have provided considerable improvements, this procedure that consists in adding bottom time or switching to the next deeper depth continues to be applied by numerous supervisors and is mandatory with some companies because databases have demonstrated that the tables need to be sometimes reinforced according to the tasks performed, the environmental conditions, and the age of the diver.
In addition to preserving the divers' health, many companies ensure that no decompression sickness happens because such an undesirable event results in incident reports that may damage their reputation. This point is not the most glorious, but it must be taken into account.

Safety procedures are officially introduced in the MT 92/2019 tables, where it indicated the following: *“When diving or working conditions are difficult, the risk of a decompression accident is higher. It is an established fact that poor physical condition, nervous tension, poor visibility, cold and accumulated fatigue after weeks of intensive diving, predispose a diver to decompression sickness. Similarly, a current, uncertain depth control and poor sea conditions make decompression procedures difficult to follow and thus increase the risk of a decompression accident. All these factors must be taken into consideration when a decompression table is chosen. In the case where diving conditions are such that they may adversely affect decompression safety, the next longest time on the bottom in the table should be used in order to give the divers an additional margin of safety”*.
It is also the case of the Norwegian tables where it is said in chapter “prevention for decompression illness”: *”If there are circumstances increasing the risk for decompression illness, the decompression should be more conservative than prescribed by the tables. Especially this is true if multiple risk increasing factors are present and for dives with bottom times bordering the maximum allowed bottom time. In such cases the standard air decompression tables should be used more conservatively by decompressing according to a table time one or two steps longer than otherwise”*.

This concept has also been adopted by manufacturers of diving computers designed for scuba diving that provide the possibility to reinforce the basic decompression profile. These reinforcements usually consist of shifting the decompression curve and do not modify the mathematic model *(see the scheme below)*.
This handbook recommends applying at minimum an additional bottom time or depth, except for dives with perfect sea and underwater conditions for performing light works and using short bottom times.



3.4.7 - Predive conditioning procedures

Current diving tables control the risks linked to Decompression Sickness (DCS) by managing factors such as the dive duration, the depth, the ascent rate, and the duration of the stops. However, in the paper *"Preconditioning Methods and Mechanisms for Preventing the Risk of Decompression Sickness in Scuba Divers: A Review"*, doctors Emmanuel Gemp & Jean-Eric Blatteau say that clinical data supporting the importance and the role of each factor on Decompression Sickness (DCS) development are lacking due in part to the great inter/intra-variability between individuals regarding susceptibility to DCS. They also say that based on their clinical experience and Divers Alert Network (DAN) statistics, most injured divers presenting neurological DCS (75%–90%) followed their dive profile and did not performed inadequate decompression schedules, which puts forward the notion that conservative dive profiles are no guarantor of protection against DCS and that novel means are required for DCS prevention.

The fact that diving time and nitrogen pressure are not the only determinants of Vascular Gas Embolisms (VGE) formation and that factors such as the variation between individuals and other not fully clarified phenomenons is taken into account by many other scientists. For example, doctors Peter Germonpré & Costantino Balestra confirm these points in their study *"Preconditioning to reduce decompression stress in scuba divers"*. For these reasons, new concepts still under evaluation have been developed to explain the production of Vascular Gas Embolisms (VGE), such as the generally admitted assumption that bubbles form from already present gaseous nuclei, and that these initially unstable nuclei may be trapped in intercellular hydrophobic crevices on the endothelial surface or be coated by surface-active molecules like surfactant, platelets, or proteins and thus stabilized by these processes before being released into the bloodstream. These mechanisms of nuclei formation are still debated by scientists with also the role of body substances such as Nitric Oxide (NO), an omnipresent intercellular messenger, modulating blood flow and neural activity, which is thus responsible for vasodilatation. That opens to studies on chemical reactions and drugs that may be used to interfere in these phenomenon and be used to control the production of Vascular Gas Embolisms (VGE).

In the paper called *"Static Metabolic Bubbles as Precursors of Vascular Gas Emboli During Divers' Decompression: A Hypothesis Explaining Bubbling Variability"* Jean-Pierre Imbert, Salih Murat Egi, Peter Germonpré, and Costantino Balestra make a status of the research ongoing and propose solutions that will probably result in new decompression tables in the near future.

As there is, for the moment, no table integrating these new concepts in a public release for commercial diving, we continue to use tables such as DCIEM or MT 92/2019 that, although they are not integrating these new concepts, have proved to be and continue to be efficient means of control. However, some elements from the studies mentioned above can be implemented to improve these procedures. Among the solutions investigated to improve decompression, the authors of this document insist on the benefits of "pre-dive conditioning", which refers to experimental studies made to demonstrate that exercises, oxygen, or substances uptake before the immersion have beneficial effects on decompression. These beneficial effects are assumed to result from eliminating nuclei by physical processes or/and chemical reactions.

To highlight the advantage of the pre-dive conditioning, we can refer to a paragraph of this study where the authors remember experiments made by doctors Gennser & al. that concluded that five weeks of bed-rest significantly increased bubble grades after decompression. The reasons given to explain these results are the following:

- Bedrest conditions are associated to minimal activity and therefore to a minimal metabolism. The consequence is that the initial Static Metabolic Bubbles (SMB) volume in the divers prior to the dive was maximal.
- The lack of exercise reduces vibrations and it is likely that most of the available Active Hydrophobic Spots (AHS) were populated by SMB.
- After a bedrest, the divers started the dive with a high density of SMB with a maximal volume that favored higher grades of detected VGE.

Scientists have successfully tested the pre-dive conditioning solutions listed below on humans.

- Endurance exercise:
  This process consists of exercises requiring 70 to 90% of maximum heart rate performed before the dive. Note that the maximum heart rate is often calculated with the formula "220 minus the age of the person tested".
- Hydration:
  This concept is based on the fact that it has long been suggested that dehydration may increase the risk of Decompression Sickness (DCS) and that experiments have been made on animals that correlate it.
- Heat exposure:
  This concept leans on papers that demonstrated that moderate dehydration resulting in stroke volume reduction induced by a predive exercise could decrease venous circulating bubbles in divers.
- Oxygenation:
  These procedures are based on the assumption that oxygen breathing before diving eliminates pre-existing gas micronuclei before they can grow into bubbles. The proposed mechanism is based on the ability of oxygen to replace nitrogen in the nucleus by diffusion. The reduction of oxygen pressure after switching from oxygen to air could enhance the consumption of oxygen from the nucleus, thus eliminating it completely.
- Vibration:
  This procedure consists of submitting the diver to sessions on vibrating mattresses sold to all public. The effects expected are similar to those obtained with predive exercise except that more efficiency is looked for.
- Jumping:
  This technique aims to provoke blood displacement and muscular contractions to dislodge VGE nuclei. The method selected to obtain the expected result consists of jumping on a mini trampoline.

- Specific substances uptake:
  This terminology refers to drugs or food that can be used to control chemical reactions linked to decompression, such as nitric oxide (NO) production.

The processes of these experiments are described in papers available on the "Diving and ROV Specialists.com" website and through recognized scientific article publishers.
We, nevertheless, need to take into account the fact that these reinforcement processes are experimental and that, despite the positive results obtained, they may not apply to commercial diving operations due to implementation issues and the fact that the procedures described have been tested with military and sportive SCUBA divers, so initially thought in the function of the concept to be tested and according to methods practiced for this type of diving instead of the intensive operations we commonly organize in commercial diving. For these reasons, it is reasonable to be conservative regarding these new procedures, so only to apply what has been tested and not go outside these limits, even though we may feel that some variations of the solutions described may work.

- Regarding endurance exercise and hydration, doctors Gempp & Blatteau conclude their article *"Preconditioning Methods and Mechanisms for Preventing the Risk of Decompression Sickness in Scuba Divers: A Review"* by saying *"Evidence suggests that, for a population of trained and military divers, endurance exercise (even in a warm environment) associated with oral hydration prior to the dive is beneficial in vascular bubble reduction"*.
- Normobaric pre-dive oxygen breathing is a procedure that is easy to implement with standard air diving, and is described in a paper called *"Pre-dive normobaric oxygen reduces bubble formation in scuba divers"*, published by doctors Olivier Castagna, Emmanuel Gempp, and Jean-Eric Blatteau. Because no tests have been made with nitrox and oxygen decompression stops, we must abstain from merging this concept with these procedures, even though there is no apparent conflict, and we feel that the two concepts used together may give excellent results. This is, of course, based on the idea of the conservative approach discussed previously.
- Whole body vibration results better than normobaric oxygen breathing and endurance exercise, and this concept can also be implemented for standard air diving.

However, in an article called "Pre-dive Whole-Body Vibration Better Reduces Decompression-Induced Vascular Gas Emboli than Oxygenation or a Combination of Both", doctors Costantino Balestra, Sigrid Theunissen, Virginie Papadopoulou, Cedric Le Mener, Peter Germonpré, François Guerrero, & Pierre Lafère say that pre-dive conditioning with only whole body vibration was more efficient during experiments than predive-conditioning with normobaric oxygen and body vibration performed together. They say that this absence of synergy could be explained by the fact that the two modes of preconditioning, mechanical or diffusion, could act on the same nuclei and thus be in direct competition. That demonstrates that procedures that have not been tested must not be implemented, so the idea of the conservative approach must always prevail.

3.4.8 - Operational limits UK-HSE

These recommended limits are those of the UK-HSE report *"The incidence of decompression sickness arising from commercial offshore air-diving operations in the UK sector of the North sea during 1982/83"* issued in December 1997 by doctors Shields and Lee. This report is available on our website and can also be found on the UK HSE website.

Depth		***Bottom times limits Surf. Deco. & In-water***
Metres	***Feet***	
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*
50	*164*	*20*

These recommendations have been adopted by numerous organizations and are commonly used offshore. We have integrated in them in the MT92/tables: A yellow bar where it is written "Maximum operational limitUK-HSE" is provided in each table.

Depth 24 metres

Bottom time	Ascent to Stop Min:sec	Air 18m	Air 15m	Air 12m	Air 9m	Air 6m	Air 3m	Total décomp. min:sec	Repetitive dive
25	2:00	-	-	-	-	-	-	2:00	Possible
30	1:45	-	-	-	-	-	3	4:45	Possible
35	1:45	-	-	-	-	-	5	6:45	Possible
40	1:45	-	-	-	-	-	7	8:45	Possible
45	1:45	-	-	-	-	-	10	11:45	Possible
50	1:45	-	-	-	-	-	15	16:45	Possible
60	1:30	-	-	-	-	3	20	24:30	Possible
70	1:30	-	-	-	-	5	30	36:30	Possible
Maximum operational limit UK-HSE									
80	1:30	-	-	-	-	10	35	46:30	Possible
90	1:30	-	-	-	-	15	40	56:30	Possible
100	1:15	-	-	-	3	20	45	69:15	Possible
110	1:15	-	-	-	3	25	50	79:15	Possible
120	1:15	-	-	-	3	30	60	94:15	Possible
130	1:15	-	-	-	5	30	65	101:15	Possible
140	1:15	-	-	-	10	35	70	116:15	No
150	1:15	-	-	-	10	40	75	126:15	No

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B - Elements for project preparation

1 - Organizations publishing rules and guidelines that influence diving operations.

1.1 - Purpose

Diving operations are risky activities as they consist of working in a surrounding that is not the one human body is initially designed for. Besides, since the development of industrial activities, the diver is also exposed to the dangers arising from these activities. As a result, the life of the diver depends on the performances and the reliability of the equipment he uses, the knowledge of the environment he is exposed to, and procedures to escape safely in case a problem happens. For these reasons, and in response to the numerous fatal accidents that have occurred during the early period, it has been necessary to publish guidelines and create training establishments where the divers are taught of the dangers they will be exposed to and how to control them. Also, to protect their citizen from abusive and unsafe working conditions, some counties' governments have published laws that indicate the minimum level of safety required when organizing such operations in waters under their jurisdiction. Some of these laws have been adopted by the United Nations and are in force throughout the globe. Also, in parallel with the laws emitted by States, companies involved in diving activities have issued their own rules that are based on the laws of the states and their experience. These rules are sometimes shared through structures such as professional associations or similar organizations that defend the interest of their profession.
As a consequence of the above, numerous organizations have been created that emit guidelines. Some of these guidelines can be considered useful for the protection of the divers, and some others have been published for the defense of the interests of some organizations, and are imposed on the companies and the divers operating on site. For this reason, they cannot and must not be ignored.
The organizations emitting such guidelines and rules that are described in the next point are those that are the most powerful. That does not mean that they are the sole organizations emitting their advice. Many other institutions and also some individuals have similar activities but not the same power to express and impose what they think. For this reason, we have to consider that every relevant advice can be useful whatever the size of the structure that issues it and that the reader must be sufficiently wise and smart not to fall into a monoculture. Note that monoculture is the opposite of progress.

1.2 - Organizations publishing guidelines, conventions, and standards

1.2.1 - IMO (International Maritime organization)

IMO (International Maritime Organization) is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships.

IMO publishes maritime and diving resolutions and codes that are used to establishes standards and design diving systems. As an example, the resolution A.692, provides "guidelines and specifications for hyperbaric evacuations systems". Note that the guidelines from this organization are the minimum to be in place everywhere in the world.

IMO also publishes international conventions such as MARPOL (International Convention for the Prevention of Pollution from Ships) and SOLAS (International Convention for the Safety of Life at Sea) that must be taken into account by the diving system manufacturers when designing the evacuation of used waters from the living chambers, or the firefighting system and the hyperbaric rescue units for abandoning the installation.

1.2.2 - NORSOK (Norsk Sokkels Konkuranseposisjon - Norway)

NORSOK is an organization created by the Norwegian petroleum industry that is involved in the offshore activities in Norway and emits specifications and recommendations. These specifications that are based on European (EN) and ISO standards are developed to ensure adequate safety, value-adding, and cost-effectiveness for the Norwegian petroleum industry developments and operations. They are intended to replace oil company specifications and serve as references in the regulations published by the authorities. So, they are to be applied in Norwegian waters.

NORSOK standards are among the most stringent, and are often taken as references by companies and safety organizations for this reason.
Among the documents published by this organization, NORSOK standards U100 and U101 are commonly used by the manufacturers for the conception of their system to be sure that they can be operated everywhere in the world.

1.2.3 - IMCA (International Marine Contractor association)

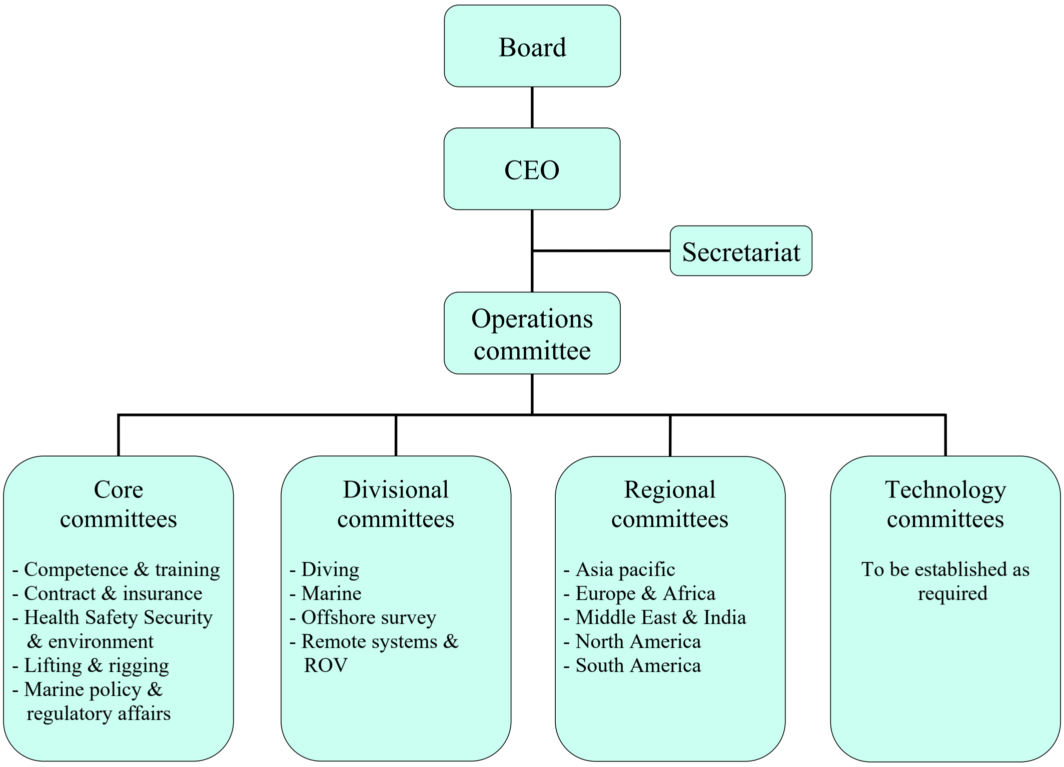
This association groups marine, diving, survey, & ROV contractors involved in offshore projects (outside the "territorial waters") or using techniques implemented offshore for the petroleum industry.
IMCA was formed in 1995 through the merger of the former Association of Offshore Diving Contractors (AODC,

established in 1972) and the Dynamically Positioned Vessel Owners Association (DPVOA, formed in 1989).
This organization, has published numerous safety guidelines that are taken as references by a lot of governmental standardization bodies and safety organizations.
In parallel to guidelines, the association has initiated formation and certification processes for divers, technicians, supervisors, ROV pilots, and other functions that are recognized internationally. So, we can say that the influence of IMCA in the diving industry is enormous.

IMCA is divided into four divisions:

- Diving
- Marine
- Offshore survey
- Remote systems & ROV

The current governance and corporate structure is composed of "the Board", "Operations Committee" and numerous "technical committees" and "workgroups".
Also, a secretariat manages the day-to-day business of the association.
This governance structure can be summarized as follows:



The working name of the International Marine Contractors Association is IMCA which, together with its logo, is trademarked. The legal entity of the Association to which members belong is IMCA Holdings Ltd, a company limited by guarantee and incorporated in England (this is the most common legal format of associations in the UK). The trading company, IMCA Trading Ltd, a company limited by shares, is a subsidiary of the holding company and conducts business on behalf of the Association. Thus, IMCA trading ltd is a commercial organization that has been recently created and did not existed at the origin of the association.
The published guidelines and reports can be found on the website of the association along, with safety alerts and other useful information. Among these documents, the "Diving Equipment Systems Inspection Guidance Notes" published this organization remains the most accurate guidance for the organization of audits.
Considering the new management system of this association, we must admit that it has become a commercial organization with nothing in common with the original one that emitted so many nice guidelines that were available free of charge and increased the industry's safety level.

1.2.4 - DMAC (Diving Medical Advisory Committee)

This independent body seeks to provide advice about medical and certain safety aspects of commercial diving.
The committee comprises doctors involved in the practice of diving medicine in Northern Europe *(currently France, The Netherlands, Norway and the United Kingdom)*, representatives of relevant health authorities *(the UK Health & Safety Executive and Norwegian Directorate of Public Health)*, medical representatives from relevant navies *(UK & The Netherlands)* and a diving safety officer nominated by IMCA *(the International Marine Contractors Association)*.
Members of the committee receive no payment for their time or contributions to committee proceedings; the work of the committee is entirely voluntary.
DMAC does not emit standards regarding the construction of diving systems. However its advice and guidelines lead to the creations of standards by the legal authorities and the modification of some equipment. For this reason, this organization is always taken into consideration by equipment manufacturers.

1.2.5 - ADCI (Association of Diving Contractors International)

ADCI (Association of Diving Contractors International) was originally a small group of American diving companies that created a nonprofit organization dedicated to commercial diving to establish safe practices throughout the world. Some of these guidelines have been adopted as standards by competent national bodies and other safety organizations and are today taken into account for the construction of diving systems.
This association, which is based in Houston (USA), represents today more than 600 members conducting safe underwater operations throughout the world.
Similarly to IMCA, this association has its formation and certification processes for divers, technicians, supervisors, and other functions.
The organization also share guidelines and point of views with other competent groups such as IMCA, NOAA (National Oceanic and Atmospheric Administrations), DMAC and others.

1.2.6 - IOGP (International Association of Oil and gas producers)

International Association of Oil and gas producers (IOGP) is an organization that defends the interest of some multinational petroleum companies such as Shell, Exxon, BP, Total, and others. This organization acts as a group of pressure to impose the point of view of its members to the contractors working for them and try to influence national and international safety organizations to establish its members in a dominant position.

1.2.7 - Dynamic Positioning Committee

The Dynamic Positioning Committee was founded in 1996 as a Professional Committee of the Marine Technology Society. This society promotes awareness, understanding, and the advancement and application of marine technology. Incorporated in 1963, the international society brings together businesses, institutions, professionals, academics, and students who are ocean engineers, technologists, policy makers, and educators.
The Dynamic Positioning Committee’s mission is to encourage exchange of information, discussion of technology, training and education, foster improvement of DP reliability, develop guidelines, and address any other issues pertinent to dynamic positioning that facilitate incident free execution of DP operations, and are consistent with the objectives of the Marine Technology Society.

1.2.8 - National safety organizations and ministries of labour

These national organizations and authorities are in charge of the protection of the citizens of their country. They may impose standards for the diving operations in the waters under their jurisdiction. As a result, some of the rules they publish may impact the design of the diving systems, and the way they are certified.

As examples of these numerous organizations note the UK Health and Safety Executive, the French Ministry of Labour, NOAA (National Oceanic and Atmospheric Administration - USA), etc.

1.2.9 - European Standards – European committee for standardization

European Committee for standardization (CEN) is an organization based at Brussels (Belgium) that groups the national industrial standards of the members of the European Union plus some external members such as members of the European Free Trade Association (EFTA).
European Standards (EN) are a component of the European market, and for this reason, they cover nearly the totality of industrial activities. They are designed and created by all interested parties through a consensual process.
The European Committee for Standardization governance is composed of the general assembly, the presidential committee and its advisory bodies, and the administrative board. Other bodies such as technical boards, committees, and working groups support the achievement of the scope of the organization.
These standards are commonly used for the fabrication of devices such as chambers, helmets, regulators, gas cylinders, etc. Tools built according to these standards are marked with the initials “CE”.
Note that these standards are distributed through the normalization bodies of the members. For this reason, the mention “EN” is usually preceded by the name of the normalization body of the country it is sold in. As an example, EN 1802 “Periodic inspection and testing of seamless aluminium alloy gas cylinders” is BS EN 1802 in the United Kingdom and NF EN 1802 in France. As a result, many authors of documents continue to refer to their national organization instead of the real emitter of these standards.

1.3.0 - ISO (International Organization for Standardization)

ISO (International Organization for Standardization) is an independent, non-governmental organization based in Geneva (Switzerland), the members of which are the standards organizations of the 168 member countries.
The organization provide standards that cover nearly the totality of industrial activities. It also provide certifications regarding quality management systems. The organization proposes three types of membership:

- Full members (or member bodies) influence ISO standards development and strategy by participating and voting in ISO technical and policy meetings. Full members sell and adopt ISO International Standards nationally.
- Correspondent members observe the development of ISO standards and strategy by attending ISO technical and policy meetings as observers. Correspondent members can sell and adopt ISO International Standards nationally.

- Subscriber members keep up to date on ISO's work but cannot participate in it. They do not sell or adopt ISO International Standards nationally.

The "council" is the governance body of the organization that reports to the "general assembly". It meets three times a year and is composed of twenty members. Council standing committees address matters related to finance, strategy and policy, nominations for governance positions, and oversight of the organization's governance practices. Membership to the council is open to all member bodies and rotates to make sure it is representative of the member community.
ISO standards are commonly used by manufacturers involved in the diving industry.

1.3.1 - ANSI (American National Standards Institute)

The American National Standards Institute (ANSI) is a private non-profit organization, based in Washington DC (USA) that oversees the development of standards for products, services, processes, systems, and personnel in the United States. ANSI does not write standards but accredits developers who are in charge of establishing consensus among qualified groups. Its guiding principles " consensus, due process, and openness " are followed by the 220 distinct entities currently accredited to develop and maintain the American National Standards (ANS).
The Institute's membership is composed of businesses and industrial organizations, standards-setting and conformity assessment bodies, trade associations, labour unions, professional societies, consumer groups, academia, and governmental organizations.
ANSI also promotes the use of United States standards internationally, and advocates United States policy and technical positions in standards organizations. It is the case with National Pipe Threads (NPT) standards that are promoted through this organization. Also, ANSI encourages the adoption of international standards as national standards where appropriate. Note that a lot of standards promoted by this organization are used in the diving industry.

1.3.2 - ASME (American Society of Mechanical Engineers)

ASME (American Society of Mechanical Engineers) is a professional association, which headquarters are in New York. It promotes art, science, and practice of multidisciplinary engineering and allied sciences around the world via education, training, codes and standards, research, conferences and publications, government relations, and other forms of outreach. This organization emit standards covering a lot of industrial activities such as pipelines, pressure vessels, and power plant systems. It is the reason these standards, that are developed by committees using a consensus process, are commonly used for the design of diving systems.
A lot of ASME standards are adopted by governmental agencies, and for this reason, the organization has three international offices in Beijing (China), Brussels (Belgium), and New Delhi (India).

1.3.3 - ASTM international

ASTM International, formerly known as the "American Society for Testing and Materials", is a nonprofit organization based in West Conshohocken (United States) that develops and publishes voluntary consensus technical standards covering procedures for testing and classification of materials. These standards are developed within committees, and new committees are formed as needed upon request of interested members.
Participation to committees is initiated at the member's request instead of by an appointment or invitation.
Membership in the organization is open to anyone with an interest in its activities. Members are classified as "users", "producers", "consumers", and "general interest". Also, to comply with American antitrust laws, "producers" must constitute less than 50% of every committee or subcommittee, and their votes are limited to one per producer company. Note that the organization report 30,000 members and says that its standards have been adopted in at least 140 countries. ASTM is also appointed for the United States Technical Advisory Group.

1.3.4 - ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers)

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) is an American professional association seeking to advance heating, ventilation, air conditioning and refrigeration systems design and construction. This organization has already published more than four thousand standards for the design and maintenance of indoor environments. Three types of standards are available: method of measurement or test, standard design, and standard practice. These standards are often used in the conception of the heating and refrigeration systems of the chambers,

2 - Parts of the sea under the authority of States

The laws and rules applicable to a diving project depend on whether it is performed in an area that is under the authority of a state or in international waters. For this reason, it is essential to define the notions of "territorial sea,"exclusive economic zone", and "continental shelf", that are given in the 1982 - 2012 United Nations Convention on the Law of the Sea that is published by the International Maritime Organization (IMO).
The texts below that explain how these zones are delimited and the rights and duties of each party inside these areas are extracts of this convention.

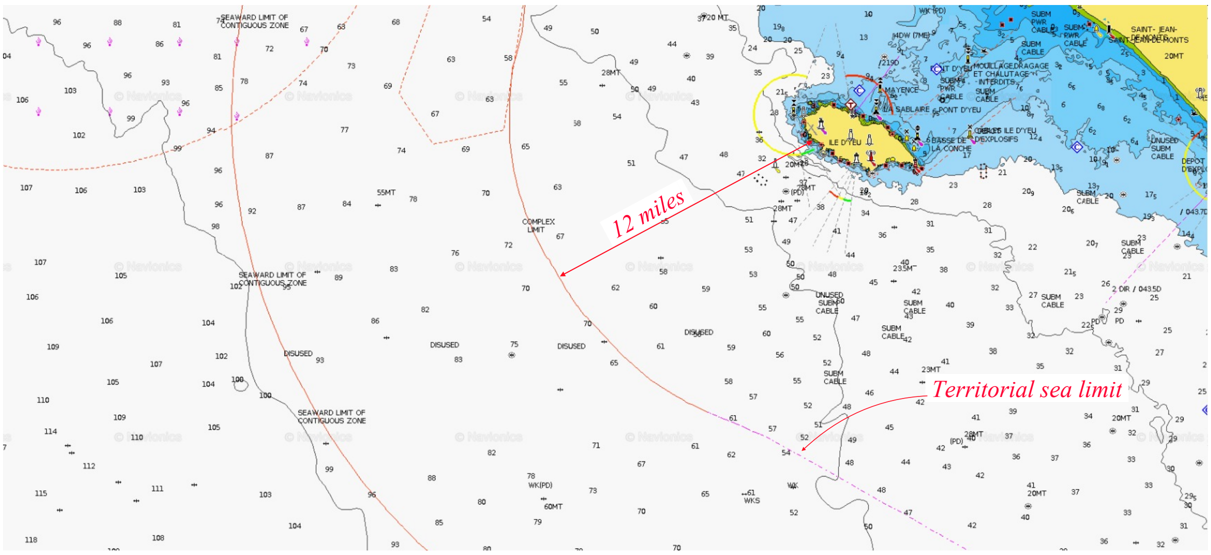
2.1 - Territorial sea & contiguous zone

2.1.1 - Legal status of the territorial sea, of the air space over the territorial sea and of its bed and subsoil

- The sovereignty of a coastal state extends beyond its land territory and internal waters to an adjacent belt of sea described as "the territorial sea".
- This sovereignty extends to the air space over the territorial sea as well as to its bed and subsoil.
- The sovereignty over the territorial sea is exercised subject to and to other rules of international law.

2.1.2 - Limits of the territorial sea

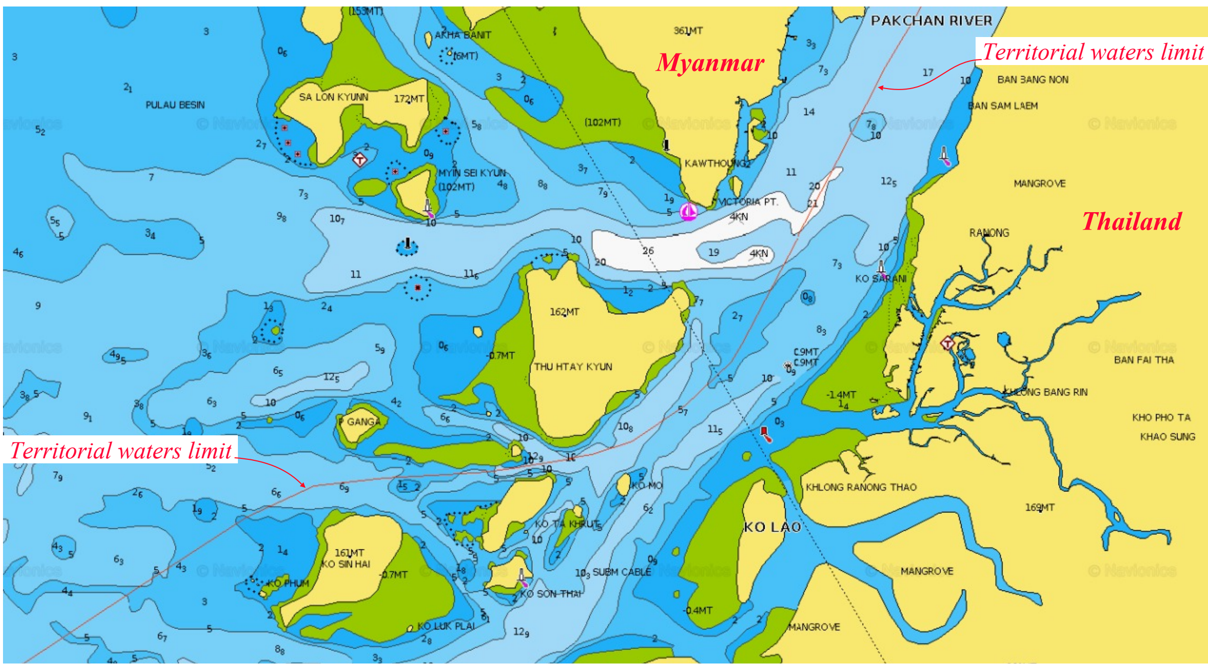
1. Every State has the right to establish the breadth of its territorial sea up to a limit not exceeding 12 nautical miles, measured from baselines determined in accordance with this convention.
2. The outer limit of the territorial sea is the line every point of which is at a distance from the nearest point of the baseline equal to the breadth of the territorial sea.
3. Except where otherwise provided in this Convention on the Law of the Sea, the normal baseline for measuring the breadth of the territorial sea is the low-water line along the coast as marked on large-scale charts officially recognized by the coastal state.
4. In the case of islands situated on atolls or of islands having fringing reefs, the baseline for measuring the breadth of the territorial sea is the seaward low-water line of the reef, as shown by the appropriate symbol on charts officially recognized by the coastal State.



5. Straight baselines:
   - In localities where the coastline is deeply indented and cut into, or if there is a fringe of islands along the coast in its immediate vicinity, the method of straight baselines joining appropriate points may be employed in drawing the baseline from which the breadth of the territorial sea is measured.
   - Where because of the presence of a delta and other natural conditions the coastline is highly unstable, the appropriate points may be selected along the furthest seaward extent of the low-water line and, notwithstanding subsequent regression of the low-water line, the straight baselines will remain effective until changed by the coastal state in accordance with this Convention on the Law of the Sea.
   - The drawing of straight baselines must not depart to any appreciable extent from the general direction of the coast, and the sea areas lying within the lines must be sufficiently closely linked to the land domain to be subject to the regime of internal waters.
   - Straight baselines are not drawn to and from low-tide elevations, unless lighthouses or similar installations which are permanently above sea level have been built on them or except in instances where the drawing of baselines to and from such elevations has received general international recognition.
   - Where the method of straight baselines is applicable, account may be taken, in determining particular

- economic interests peculiar to the region concerned, the reality and the importance of which are clearly evidenced by long usage.
- The system of straight baselines may not be applied by a State in such a manner as to cut off the territorial sea of another State from the high seas or an exclusive economic zone.

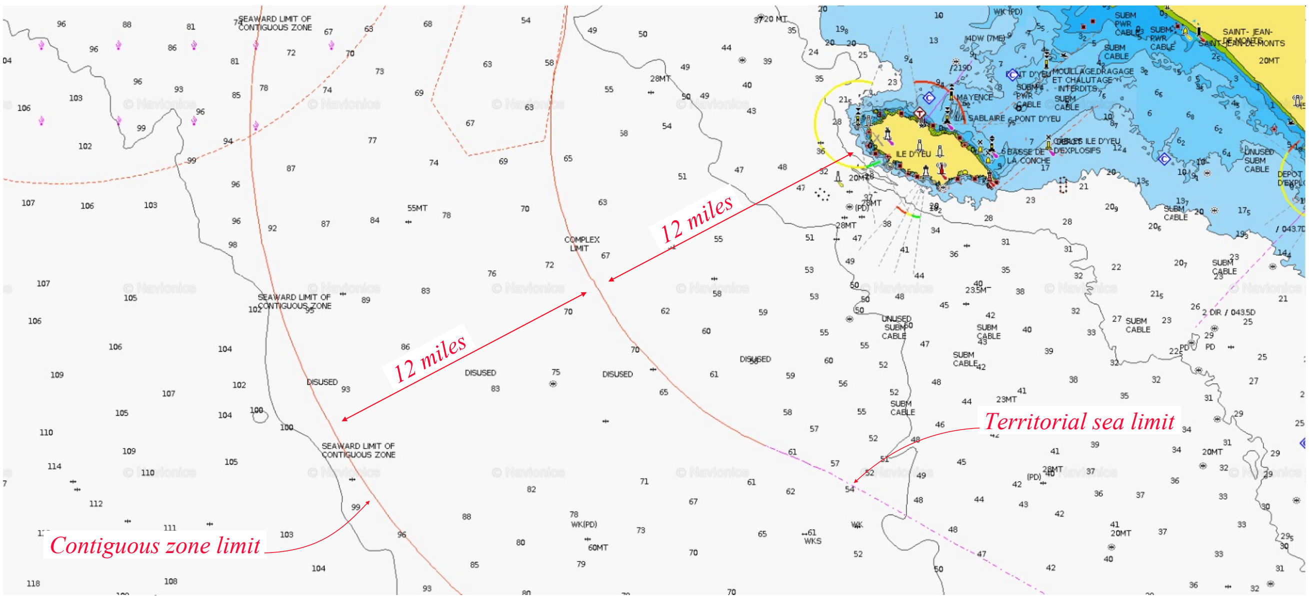
6. If a river flows directly into the sea, the baseline is to be a straight line across the mouth of the river between points on the low-water line of its banks.
7. Bays:
   - A bay is a well-marked indentation whose penetration is in such proportion to the width of its mouth as to contain land-locked waters and constitute more than a mere curvature of the coast. An indentation must not, however, be regarded as a bay unless its area is as large as, or larger than, that of the semi-circle whose diameter is a line drawn across the mouth of that indentation.
   - For the purpose of measurement, the area of an indentation is that lying between the low-water mark around the shore of the indentation and a line joining the low-water mark of its natural entrance points. Where, because of the presence of islands, an indentation has more than one mouth, the semi-circle is drawn on a line as long as the sum total of the lengths of the lines across the different mouths. Islands within an indentation are to be included as if they were part of the water area of the indentation.
   - If the distance between the low-water marks of the natural entrance points of a bay does not exceed 24 nautical miles, a closing line may be drawn between these two low-water marks, and the waters enclosed thereby are to be considered as internal waters.
   - Where the distance between the low-water marks of the natural entrance points of a bay exceeds 24 nautical miles, a straight baseline of 24 nautical miles is to be drawn within the bay in such a manner as to enclose the maximum area of water that is possible with a line of that length.
   - The foregoing provisions do not apply to so-called "historic" bays, or in any case where the system of straight baselines is applied.
8. For the purpose of delimiting the territorial sea, the outermost permanent harbour works which form an integral part of the harbour system are regarded as forming part of the coast. Offshore installations and artificial islands must not be considered as permanent harbour works.
9. Roadsteads which are normally used for the loading, unloading, and anchoring of ships, and which would otherwise be situated wholly or partly outside the outer limit of the territorial sea, are included in the territorial sea.
10. Low-tides elevations
    - A low-tide elevation is a naturally formed area of land which is surrounded by and above water at low tide but submerged at high tide. Where a low-tide elevation is situated wholly or partly at a distance not exceeding the breadth of the territorial sea from the mainland or an island, the low-water line on that elevation may be used as the baseline for measuring the breadth of the territorial sea.
    - Where a low-tide elevation is wholly situated at a distance exceeding the breadth of the territorial sea from the mainland or an island, it has no territorial sea of its own.
11. Where the coasts of two States are opposite or adjacent to each other, neither of the two States is entitled, failing agreement between them to the contrary, to extend its territorial sea beyond the median line every point of which is equidistant from the nearest points on the baselines from which the breadth of the territorial seas of each of the two States is measured. The above provision does not apply, however, where it is necessary by reason of historic title or other special circumstances to delimit the territorial seas of the two States in a way that is at variance therewith.



12. Archipelagic states:
An "archipelago" means a group of islands, including parts of islands, interconnecting waters and other natural features which are so closely interrelated that such islands, waters and other natural features form an intrinsic geographical, economic and political entity, or which historically have been regarded as such. An "archipelagic State" means a State constituted wholly by one or more archipelagos and may include other islands.
    - An archipelagic State may draw straight archipelagic baselines joining the outermost points of the outermost islands and drying reefs of the archipelago provided that within such baselines are included the main islands and an area in which the ratio of the area of the water to the area of the land, including atolls, is between 1 to 1 and 9 to 1.
    - The length of such baselines must not exceed 100 nautical miles, except that up to 3 percent of the total number of baselines enclosing any archipelago may exceed that length, up to a maximum length of 125 nautical miles. The drawing of such baselines must not depart to any appreciable extent from the general configuration of the archipelago.
    - Such baselines must not be drawn to and from low-tide elevations, unless lighthouses or similar installations which are permanently above sea level have been built on them or where a low-tide elevation is situated wholly or partly at a distance not exceeding the breadth of the territorial sea from the nearest island.
    - The system of such baselines shall not be applied by an archipelagic State in such a manner as to cut off from the high seas or the exclusive economic zone the territorial sea of another State.
    - If a part of the archipelagic waters of an archipelagic State lies between two parts of an immediately adjacent neighbouring State, existing rights and all other legitimate interests which the latter State has traditionally exercised in such waters and all rights stipulated by agreement between those States must continue and be respected.
    - Land areas may include waters lying within the fringing reefs of islands and atolls, including that part of a steep-sided oceanic plateau which is enclosed or nearly enclosed by a chain of limestone islands and drying reefs lying on the perimeter of the plateau.
13. Except for archipelagic States, waters on the landward side of the baseline of the territorial sea form part of the internal waters of the State. Also, where the establishment of a straight baseline has the effect of enclosing as internal waters areas which had not previously been considered as such, a right of “innocent passage” *(see the description below)* as provided in this Convention on the Law of the Sea must exist in those waters.
14. The baselines for measuring the breadth of the territorial sea should be shown on charts of a scale or scales adequate for ascertaining their position. Alternatively, a list of geographical coordinates of points, specifying the geodetic datum, may be substituted.
The coastal State must give due publicity to such charts or lists of geographical coordinates and depose a copy of each such chart or list with the Secretary-General of the United Nations.

2.1.3 - Contiguous zone

In a zone contiguous to its territorial sea, described as the contiguous zone, the coastal State may exercise the control necessary to prevent infringement of its customs, fiscal, immigration or sanitary laws and regulations within its territory or territorial sea, and punish infringement of the above laws and regulations committed within its territory or territorial sea.
The contiguous zone may not extend beyond 24 nautical miles from the baselines from which the breadth of the territorial sea is measured.



2.1.4 - Innocent passage in the territorial sea - Rules applicable to all ships

2.1.4.1 - Definitions

- Passage means navigation through the territorial sea for the purpose of traversing that sea without entering internal waters or calling at a roadstead or port facility outside internal waters, or proceeding to or from internal waters or a call at such roadstead or port facility.
- Passage must be continuous and expeditious. However, passage includes stopping and anchoring, but only in so far as the same are incidental to ordinary navigation or are rendered necessary by "force majeure" or distress or for the purpose of rendering assistance to persons, ships or aircraft in danger or distress.
- Passage is innocent so long as it is not prejudicial to the peace, good order or security of the coastal State. Such passage shall take place in conformity with the Convention on the Law of the Sea and with other rules of international law.
- Passage of a foreign ship is considered prejudicial to the peace, good order or security of the coastal State if in the territorial sea it engages in any of the following activities:
    - any threat or use of force against the sovereignty, territorial integrity or political independence of the coastal State, or in any other manner in violation of the principles of international law embodied in the Charter of the United Nations;
    - any exercise or practice with weapons of any kind;
    - any act aimed at collecting information to the prejudice of the defence or security of the coastal State;
    - any act of propaganda aimed at affecting the defence or security of the coastal State;
    - the launching, landing or taking on board of any aircraft;
    - the launching, landing or taking on board of any military device;
    - the loading or unloading of any commodity, currency or person contrary to the customs, fiscal, immigration or sanitary laws and regulations of the coastal State;
    - any act of wilful and serious pollution contrary to the Convention on the Law of the Sea;
    - any fishing activities;
    - the carrying out of research or survey activities;
    - any act aimed at interfering with any systems of communication or any other facilities or installations of the coastal State;
    - any other activity not having a direct bearing on passage.

2.1.4.2 - Laws and regulations of the coastal State relating to innocent passage

1. In the territorial sea, submarines and other underwater vehicles are required to navigate on the surface and to show their flag. Also, the coastal State may take the necessary steps in its territorial sea to prevent passage which is not innocent.
2. The coastal State may adopt laws and regulations, in conformity with the provisions of the Convention on the Law of the Sea, and other rules of international law, relating to innocent passage through the territorial sea, in respect of all or any of the following:
    - the safety of navigation and the regulation of maritime traffic;
    - the protection of navigational aids and facilities and other facilities or installations;
    - the protection of cables and pipelines;
    - the conservation of the living resources of the sea;
    - the prevention of infringement of the fisheries laws and regulations of the coastal State;
    - the preservation of the environment of the coastal State and the prevention, reduction and control of pollution thereof;
    - marine scientific research and hydrographic surveys;
    - the prevention of infringement of the customs, fiscal, immigration or sanitary laws and regulations of the coastal State.
3. The coastal State may, where necessary having regard to the safety of navigation, require foreign ships exercising the right of innocent passage through its territorial sea to use such sea lanes and traffic separation schemes as it may designate or prescribe for the regulation of the passage of ships.
   In particular, tankers, nuclear-powered ships and ships carrying nuclear or other inherently dangerous or noxious substances or materials may be required to confine their passage to such sea lanes.
4. In the designation of sea lanes and the prescription of traffic separation schemes under this article, the coastal State must take into account:
    - the recommendations of the competent international organization;
    - any channels customarily used for international navigation;
    - the special characteristics of particular ships and channels; and
    - the density of traffic
5. The coastal State must not hamper the innocent passage of foreign ships through the territorial sea except in accordance with this Convention. In particular, in the application of this Convention or of any laws or regulations adopted in conformity with the Convention on the Law of the Sea, the coastal State must not impose

requirements on foreign ships which have the practical effect of denying or impairing the right of innocent passage, or discriminate in form or in fact against the ships of any State or against ships carrying cargoes to, from, or on behalf of any State. Also, the coastal State shall give appropriate publicity to any danger to navigation, of which it has knowledge, within its territorial sea.

6. In the case of ships proceeding to internal waters or a call at a port facility outside internal waters, the coastal State also has the right to take the necessary steps to prevent any breach of the conditions to which admission of those ships to internal waters or such a call is subject.
7. The coastal State may, without discrimination in form or in fact among foreign ships, suspend temporarily in specified areas of its territorial sea the innocent passage of foreign ships if such suspension is essential for the protection of its security, including weapons exercises. Such suspension takes effect only after having been duly published.
8. No charge may be levied upon foreign ships by reason only of their passage through the territorial sea. Charges may be levied upon a foreign ship passing through the territorial sea as payment only for specific services rendered to the ship. These charges are to be levied without discrimination.
9. The criminal jurisdiction of the coastal State should not be exercised on board a foreign ship passing through the territorial sea to arrest any person or to conduct any investigation in connection with any crime committed on board the ship during its passage, save only in the following cases:
    - if the consequences of the crime extend to the coastal State;
    - if the crime is of a kind to disturb the peace of the country or the good order of the territorial sea;
    - if the assistance of the local authorities has been requested by the master of the ship or by a diplomatic agent or consular officer of the flag State; or
    - if such measures are necessary for the suppression of illicit traffic in narcotic drugs or psychotropic substances.

   The above provisions do not affect the right of the coastal State to take any steps authorized by its laws for the purpose of an arrest or investigation on board a foreign ship passing through the territorial sea after leaving internal waters.
   Regarding the points above, the coastal State must, if the master so requests, notify a diplomatic agent or consular officer of the flag State before taking any steps, and shall facilitate contact between such agent or officer and the ship's crew. In cases of emergency, this notification may be communicated while the measures are being taken.
   In considering whether or in what manner an arrest should be made, the local authorities must have due regard to the interests of navigation.
   Except as provided in this convention of the laws of the sea for the protection and preservations of the marine environment or with respect to violations of laws and regulations adopted in accordance with reclusive economic zones, the coastal State may not take any steps on board a foreign ship passing through the territorial sea to arrest any person or to conduct any investigation in connection with any crime committed before the ship entered the territorial sea, if the ship, proceeding from a foreign port, is only passing through the territorial sea without entering internal waters.
10. The coastal State should not stop or divert a foreign ship passing through the territorial sea for the purpose of exercising civil jurisdiction in relation to a person onboard the ship. Also, the coastal State may not levy execution against or arrest the ship for the purpose of any civil proceedings, save only in respect of obligations, or liabilities assumed or incurred by the ship itself in the course or for the purpose of its voyage through the waters of the coastal State.
    The paragraph above is without prejudice to the right of the coastal State, in accordance with its laws, to levy execution against or to arrest, for the purpose of any civil proceedings, a foreign ship lying in the territorial sea, or passing through the territorial sea after leaving internal waters.

2.2 - Exclusive economic zone

2.2.1 - Definition

The exclusive economic zone is an area adjacent to the territorial sea, that does not extend beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, and where the coastal state has the right of:

- exploring and exploiting the area;
- conserving and managing the natural resources, whether living or non-living, of the waters superjacent to the seabed and off the seabed and its subsoil, and concerning other activities for the economic exploitation and exploration of the zone, such as the production of energy from the water, currents, and winds;
- establishing and using artificial islands, installations, and structures;
- protecting and preserving the marine environment.

In exercising its rights and performing its duties, the coastal State must have due regard to the rights and obligations of other States and must act in a manner compatible with the provisions of the Convention on the Law of the Sea.
Also, the rights concerning the seabed and subsoil are to be exercised in accordance with those of the continental shelf that are discussed in the next topic.

In the exclusive economic zone, all States, whether coastal or land-locked, enjoy, subject to the relevant provisions of the Convention on the Law of the Sea, the freedoms of navigation and overflight and the laying of submarine cables and pipelines, and other internationally lawful uses of the sea related to these freedoms, such as those associated with the operation of ships, aircraft and submarine cables and pipelines and compatible with the other provisions of the Convention on the Law of the Sea.

Artificial islands, installations and structures do not possess the status of islands. They have no territorial sea of their own, and their presence does not affect the delimitation of the territorial sea, the exclusive economic zone or the continental shelf.

2.2.2 - Rights and duties of the State regarding artificial islands, installations and structures in the exclusive economic zone

In the exclusive economic zone, the coastal State has the exclusive right to construct and to authorize and regulate the construction, operation, and use of:

- artificial islands;
- installations and structures for the purposes indicated in point 2.2.1 and other economic purposes;
- installations and structures which may interfere with the exercise of the rights of the coastal State in the zone.

The coastal State has exclusive jurisdiction over such artificial islands, installations, and structures, including jurisdiction with regard to customs, fiscal, health, safety and immigration laws, and regulations.

Due notice must be given of the construction of such artificial islands, installations or structures, and permanent means for giving warning of their presence must be maintained.
Any installations or structures which are abandoned or disused must be removed to ensure the safety of navigation, taking into account any generally accepted international standards established in this regard by the competent international organization. Such removal must also have due regard to fishing, the protection of the marine environment, and the rights and duties of other States.
Appropriate publicity is to be given to the depth, position, and dimensions of any installations or structures not entirely removed.

The coastal State may, where necessary, establish reasonable safety zones around such artificial islands, installations, and structures in which it may take appropriate measures to ensure the safety both of navigation and of the artificial islands, installations, and structures.
The breadth of the safety zones is to be determined by the coastal State, taking into account applicable international standards. Such zones must be designed to ensure that they are reasonably related to the nature and function of the artificial islands, installations or structures, and must not exceed a distance of 500 metres around them, measured from each point of their outer edge, except as authorized by generally accepted international standards or as recommended by the competent international organization. Due notice must be given regarding the extent of the safety zones.
All ships must respect these safety zones and shall comply with generally accepted international standards regarding navigation in the vicinity of artificial islands, installations, structures, and safety zones.

Artificial islands, installations and structures, and the safety zones around them may not be established where interference may be caused to the use of recognized sea lanes essential to international navigation.
Artificial islands, installations and structures do not possess the status of islands. They have no territorial sea of their own, and their presence does not affect the delimitation of the territorial sea, the exclusive economic zone or the continental shelf.

2.3 - Continental shelf

2.3.1 - Definition

The continental shelf of a coastal State comprises the seabed and subsoil of the submarine areas that extend beyond its territorial sea throughout the natural prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines from which the breadth of the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance.
The continental margin comprises the submerged prolongation of the landmass of the coastal State and consists of the seabed and subsoil of the shelf, the slope, and the rise. It does not include the deep ocean floor with its oceanic ridges or the subsoil thereof.

The fixed points comprising the line of the outer limits of the continental shelf on the seabed must not exceed 350 nautical miles from the baselines from which the breadth of the territorial sea is measured or must not exceed 100 nautical miles from the 2,500-metres isobath, which is a line connecting the depth of 2,500 metres.
Notwithstanding the provisions of the above, on submarine ridges, the outer limit of the continental shelf shall not exceed 350 nautical miles from the baselines from which the breadth of the territorial sea is measured.
This paragraph does not apply to submarine elevations that are natural components of the continental margin, such as its plateaux, rises, caps, banks, and spurs.

The coastal State must delineate the outer limits of its continental shelf, where that shelf extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, by straight lines not exceeding 60 nautical miles in length, connecting fixed points, defined by coordinates of latitude and longitude.

Information on the limits of the continental shelf beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured must be submitted by the coastal State to the United Nations Commission on the Limits of the Continental Shelf on the basis of equitable geographical representation. This Commission makes recommendations to coastal States on matters related to the establishment of the outer limits of their continental shelf. The limits of the shelf established by a coastal State on the basis of these recommendations are final and binding.
Charts and relevant information, including geodetic data, permanently describing the outer limits of its continental shelf must be transmitted to the Secretary-General of the United Nations who must give due publicity thereto.

2.3.2 - Rights and duties of the coastal State

The coastal State exercises over the continental shelf sovereign rights for the purpose of exploring it and exploiting its natural resources.
These rights are exclusive in the sense that if the coastal State does not explore the continental shelf or exploit its natural resources, no one may undertake these activities without the express consent of the coastal State.
The rights of the coastal State over the continental shelf do not depend on occupation, effective or notional, or on any express proclamation.
The natural resources consist of the mineral and other non-living resources of the seabed and subsoil together with living organisms belonging to sedentary species, that is to say, organisms which, at the harvestable stage, either are immobile on or under the seabed or are unable to move except in constant physical contact with the seabed or the subsoil.

The right and duties of the coastal state regarding artificial islands, installations, and structures on the continental shelf are similar to those in force for such constructions in the exclusive economic zone. Also, the coastal State has the exclusive right to authorize and regulate drilling on the continental shelf for all purposes.

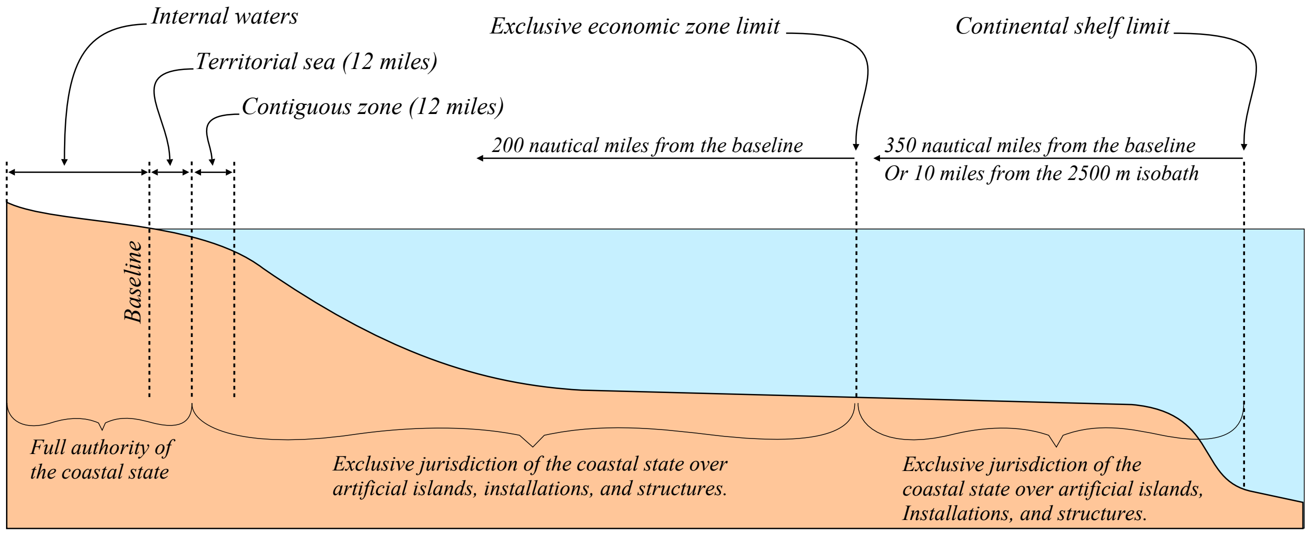
The exercise of the rights of the coastal State over the continental shelf must not infringe or result in any unjustifiable interference with navigation and other rights and freedoms of other States. Also, the coastal State must make payments or contributions in kind in respect of the exploitation of the non-living resources of the continental shelf beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured. These payments and contributions are made annually with respect to all production at a site after the first five years of production at that site. For the sixth year, the rate of payment or contribution is 1 percent of the value or volume of production at the site. The rate is increased by 1 percent for each subsequent year until the twelfth year and remains at 7 percent thereafter. Production does not include resources used in connection with exploitation. However, a developing State which is a net importer of a mineral resource produced from its continental shelf is exempt from making such payments or contributions in respect of that mineral resource.
The payments or contributions are made through the Authority, which distributes them to States Parties to the Convention on the Law of the Sea, on the basis of equitable sharing criteria, taking into account the interests and needs of developing States, particularly the least developed and the land-locked among them.

2.3.3 - Rights and duties of the other states

All States are entitled to lay submarine cables and pipelines on the continental shelf.
Subject to its right to take reasonable measures for the exploration of the continental shelf, the exploitation of its natural resources and the prevention, reduction, and control of pollution from pipelines, the coastal State may not impede the laying or maintenance of such cables or pipelines. However, the delineation of the course for the laying of such pipelines on the continental shelf is subject to the consent of the coastal State.

When laying submarine cables or pipelines, States must have due regard to cables or pipelines already in position. In particular, the possibilities of repairing existing cables or pipelines shall not be prejudiced.

2.4 - Summary of the laws and rules applicable by states and the organizations they appoint



The sovereignty of a coastal state extends beyond its land territory and internal waters to the adjacent belt of sea described as “the territorial sea”. Also, the Coastal State has exclusive jurisdiction over artificial islands, installations, and structures, including jurisdiction concerning customs, fiscal, health, safety and immigration laws, and regulations in the “Exclusive economic zone” and the “Continental shelf” area under its jurisdiction. As a result, guidelines of independent non-governmental organizations are applicable in these areas only with the consent of the government of the coastal state. Also, a vessel transiting to the job site under the regime of “innocent passage” through waters that are under the jurisdiction of another State cannot undertake diving operations in such area without the consent of this State, even for training or testing purposes.

To develop the resources of the seafloor under their jurisdiction, coastal states often sign contract agreements with non-governmental organizations such as petroleum companies. Note that, except for those related to the petroleum industry, the procedures for the exploration and exploitation of the resources from the bottom of the sea are still not developed. Several types of contracts are signed between the selected company and the state, such as:

- Concession agreement:
  Such a contract gives the holder exclusive right to explore and exploit the seafloor for the resource he is authorized in a limited area. So, the selected company takes ownership of all production against the payment of a royalty to the state. Also, the contractor owns the equipment and installations used for this exploitation. Note that such a contract may involve a company or a consortium where a governmental organization may be part.
- Production sharing agreements
  The selected company or consortium provides technical expertise and capital and assumes project risk in return for exclusive rights of exploration and production in the chosen area. The State generally owns the equipment and installations. The selected organization usually pays income tax on profits to the State as well as any other fees and contributions provided for in the national legislation and the relevant contract. The charges paid by the organization may be indicated in detail in the agreement.
- Risk service agreements
  The State hires the service of a specialized company or consortium to benefit from its financial and technical expertise. The company or consortium assumes the risk and liability and is reimbursed by a service fee, usually paid in cash.

Note that when several companies are involved in a consortium, the company that has the most significant share is usually in charge of the management of the operations on site.
Depending on the type of agreement, the company in charge of the exploitation of the seabed may impose its rules on the diving contractor. These rules may be more stringent than those of the State, but cannot be less severe.
Also, based on the rights of the states regarding the exploitation of the seabed in the areas under its jurisdiction, in case of an incident, the State has the authority and the duty to organize an investigation.

3 - Team size and responsibilities

The size and composition of the diving team depend upon a number of factors that should have been discussed prior to starting the project. However, it is the duty of the persons in charge to make sure that the team will conduct the diving operation safely and effectively, and to take appropriate corrective measures in accordance with the practices promoted by recognized national and international safety organizations if they consider that the optimum conditions are not in place.
Note that the procedure for the recruitment of the personnel of the company is not explained in this chapter.

3.1 - Manning levels and working hours

3.1.1 - Minimum manning level and working periods

The minimum manning level of diving teams is usually indicated in the national regulation of the country where the operation is undertaken. However, many countries have no commercial diving legislation, and in this case, the guidelines from organizations such as IMCA, DMAC, and IOGP are usually taken as references and implemented.

- According to IMCA D 014, and D 022, the absolute minimum for air and nitrox diving operations using a ladder or a basket is five, consisting of:
    - Diving Supervisor
    - Working Diver
    - Standby Diver
    - Tender for Working Diver
    - Tender for Standby Diver

  Two of the divers must be certified diver medics → One diver medic must not dive and be ready to intervene into the chamber. → The standby diver must be clear of decompression penalty and be ready to rescue the diver.

  Note that IMCA D 22 /General Diving Procedures/ point 10.1 says: *The divers and standby diver all need to be medically fit to dive and clear of any decompression penalties*.
  IOGP has adopted this minimum manning level in appendix F "Mobile/portable surface supplied systems or scuba replacement" and appendix K "Surface supplied offshore diving – air" of their safety document No 411 "Recommended Practices for Diving Operations". It is also the case of ADCI in points 4.3.2 "Surface supplied air diving –100 fsw with planned decompression", and point 4.3.3 "surface supplied air diving 101-190 fsw".
- In point 5.2.5.2 of IMCA 14, it is said that the minimum team size for surface-supplied mixed gas diving is six, consisting of a diving supervisor and five personnel who are qualified to dive. However, in appendix M "Supplied mixed gas diving - heliox", IOGP 411 "diving recommended practices" considers that a team of seven people should be the minimum and organized as follows:
    - Diving Supervisor
    - Working Diver
    - Standby diver
    - Tender for Working Diver
    - Tender for Standby Diver
    - Surface standby diver
    - Tender surf. standby diver

  Two of the divers must be certified diver medics → One diver medic must not dive and be ready to intervene into the chamber. → The standby diver must be clear of decompression penalty and be ready to rescue the diver.

  IOGP also says that the minimum team should be organized according to the following rules:
    - One tender for each diver tended from the surface.
    - One stand-by diver for every two divers in the water. Standby diver to be located in the wet bell.
    - The team size should be risk assessed so that there must be a sufficient number of competent personnel to operate all the diving plants and provide support functions to the dive team. Thus, additional deck support personnel and other management or associated technical support personnel may be required.

  This evaluation is valid if the divers are tended from the surface, so with the umbilical passing through the bell as with a basket. Still, it does not clearly explain the configuration if the umbilicals are terminated in the wet bell and where the bellman acts as tender and standby diver (like with closed bells), which is the case with most wet bells. In this case, a surface standby diver must be ready to be sent to assist the bellman. However, as the use of the bell depends on the possibility to send the standby diver, a 2nd bell is recommended.

Note that the winch operator is not indicated in all these evaluations and that this person is essential. Also, maintaining the system is vital, so a certified technician is necessary. It is usually admitted that this technician also acts as the winch operator of the basket or the bell. In addition, personnel for the management of the bell's umbilical must be considered. Thus, we can say that the minimum manning level of diving teams is linked to the means of deployment used.

The working periods planned for the teams should also be taken into account to complement the above to decide the manning level. Most safety organizations have established that incidents and accidents are more likely when people work during long daily periods because their efficiency, concentration, and safety awareness deteriorate. For these reasons, long working periods should be done exceptionally. Among the published guidelines regarding this point, those from IMCA D 014, which says the following in point 5.3.1, can be taken as a reference:

1. Members of the diving team should not be asked to work for more than 12 hours without having at least eight hours of unbroken rest during the previous 24 hours. Similarly, the most prolonged period a person is asked to work, and only in exceptional circumstances, is 16 hours before being given eight hours of unbroken rest (note that what IMCA calls "exceptional circumstances" are situations linked to unforeseen events).

2. No person is expected to work a 12-hour shift without a meal break taken away from his place of work. Personnel also need toilet and refreshment breaks during their shifts.
   To allow for these breaks, the diving contractor needs to ensure that the planned work either has natural breaks (for example, during periods of strong tide) or that qualified and experienced personnel are available to act as relief during breaks. This is particularly important in relation to supervisors whose responsibilities are often onerous and stressful. Any such handovers of responsibility should be recorded in writing in the operations log.
3. Extended work periods offshore without a break can reduce safety awareness. Work will therefore need to be planned so that personnel do not work offshore for long periods without being allowed time onshore. These times may need to vary to suit operational needs or exceptional circumstances, but personnel should be given a reasonable onshore break related to the period spent offshore.

In complement to the elements suggested above, the diving supervisors are key people whose fatigue resulting in loss of attention should be taken into account. For this reason, procedures should be in place to diminish it. Having two diving supervisors on duty in a shift has become a rule with some contractors and clients. In addition, the limitation of the diving monitoring times is recommended in the following guidelines:

- IMCA R004 says in point 9.3, *"The maximum number of hours that a member of the ROV team pilots an ROV should not exceed six hours in every 24 hours period under normal circumstances"*.
- NORSOK standard U-100 says in point 8.4.6, *"The diving supervisor shall have a rest period from the direct communication control after a period of 4 h. The rest period shall be at least 30 min. The total time for this function shall be limited to 8 h in the course of a 12 h period. The workload should determine the length of the rest periods. Inside a 24 h period supervisory personnel should normally have a 12 h period of continuous rest"*.

Because they are already in force to manage diving operations in some countries or control machines, similar precautions should be applied and discussed with the client if he plans for a minimum team. Thus the supervisor should not manage 12 hours of continuous diving operations.

Note that a common practice to control the effects of fatigue on the personnel is to renew a half team every 6 hours. For example, a 1st half team is on duty from 0:00 to 12:00, 2nd half is 6:00 to 18:00, 3rd half is 12:00 to 24:00, and 4th half team is 18:00 to 6:00. Such an organization avoids a shift change in a middle of a dive.

The following tables summarize and take into account the elements discussed above to decide of the minimum team for each type of surface supplied diving operation:

Diving operations using a ladder as means of deployment:

Positions	***Duration of the daily operations***		
	12 hours < 8 hrs diving	***12 hours > 8 hrs diving***	***24 hours***
Diving supervisor	*At least 1*	*At least 2*	*At least 3*
Working diver	*1 or 2 each dive*	*1 or 2 each dive*	*1 or 2 each dive*
Standby diver	*1 for 2 divers each dive*	*1 for 2 divers each dive*	*1 for 2 divers each dive*
Tender working diver	*1 per diver each dive*	*1 per diver each dive*	*1 per diver each dive*
Tender standby diver	*1 per standby diver each dive*	*1 per standby diver each dive*	*1 per standby diver each dive*
Dive system technician	*At least 1*	*At least 1*	*At least 2*

Diving operations using baskets as means of deployment:

Positions	***Duration of the daily operations***		
	12 hours < 8 hrs diving	***12 hours > 8 hrs diving***	***24 hours***
Diving supervisor	*At least 1*	*At least 2*	*At least 3*
Working diver	*1 or 2 each dive*	*1 or 2 each dive*	*1 or 2 each dive*
Standby diver	*1 for 2 divers each dive*	*1 for 2 divers each dive*	*1 for 2 divers each dive*
Tender working diver	*1 per diver each dive*	*1 per diver each dive*	*1 per diver each dive*
Tender standby diver	*1 per standby diver each dive*	*1 per standby diver each dive*	*1 per standby diver each dive*
Dive system technician	*At least 1*	*At least 1*	*At least 2*
*Winchman**	*At least 1*	*At least 1*	*At least 2*
Winchman: It is admitted that the dive system technician cumulates the functions of the dive technician and winch operator if the baskets are not used at the same time or can be controlled from the same console. A winchman must be assigned to each basket if the two baskets need to be used simultaneously and cannot be controlled from a single console.*			

Diving operations using wet bells with the diver umbilicals terminated in the bell as means of deployment:

Positions	*Duration of the daily operations*		
	12 hours < 8 hrs diving	***12 hours > 8 hrs diving***	***24 hours***
Diving supervisor	*At least 1*	*At least 2*	*At least 3*
Working diver	*1 or 2 each dive*	*1 or 2 each dive*	*1 or 2 each dive*
*Bellman**	*1 each dive*	*1 each dive*	*1 each dive*
*Surface standby diver**	*1 each dive*	*1 each dive*	*1 each dive*
*Tender surface standby diver**	*1 each dive*	*1 each dive*	*1 each dive*
Dive system technician	*At least 1*	*At least 1*	*At least 2*
*Winchman**	*At least 1*	*At least 1*	*At least 2*
*Tender main umbilical**	*At least 1 per bell*	*At least 1 per bell*	*At least 2 per bell*

Bellman: As for diving operations from a closed bell, the bellman acts as tender and rescue diver.*

Surface standby diver: He can be deployed from a basket for dives above 50 m. However, it is recommended to deploy him with a 2nd bell. The 2nd bell should be mandatory for operations deeper than this 50 m limit.*

Tender surface standby diver: He operates at the surface or as a bellman in the bell, depending on the means of deployment used.*

Winchman: It is admitted that the dive system technician cumulates the functions of the dive technician and winch operator if the bells are not used at the same time or can be controlled from the same console. A winchman must be assigned to each bell if the two bells need to be used simultaneously and cannot be controlled from a single console.*

Tender main umbilical: At least one person should be assigned to help with the main umbilical deployment and recovery of each bell if these operations are not automatic (case of many wet bells).*

In complement to the tables above, the rescue procedures for the most extreme scenarios must be considered to decide the minimum manning level. The policy regarding successive dives must also be taken into account.
Also, it must be taken into account that operations organized with minimum personnel are uncomfortable for the supervisors, more subject to incidents due to fatigue, and can be interrupted due to the unavailability of team members due to undesirable events such as sickness, wounds, and others.

3.1.2 - Additional key personnel

Based on the elements discussed above, it is evident that a basic team is able to carry out only small tasks. For more important projects, additional personnel are needed, and a stronger management structure must be organized in addition of having two supervisors on shift.

3.1.2.1 - Diving superintendent

When the diving team is working twenty-four hours per day, it is necessary to appoint several diving supervisors. Besides, a diving superintendent, who is an experienced diving supervisor, should be appointed to coordinate the work of the shifts of divers.

3.1.2.2- Offshore manager

Most diving projects involve different skills and subcontractors. For this reason, companies usually appoint an offshore manager to co-ordinate and control all the aspects of the project, and to liaise with the client's representative. On small projects, it is possible that the Offshore manager cumulates his functions with those of diving superintendent.

3.1.2.3 - Project engineer

For most construction and repair projects, the diving contractor appoints one or several project engineers to coordinate and control engineering aspects of the work. These people work closely with the diving superintendent.

3.1.2.4 - Safety officer.

A safety officer should be onboard when 24 hours projects involving different activities are undertaken. His function is to ensure safety on board. He reports to the offshore manager and is helped by specialists, depending on the size of the project and its specifications.

3.1.2.5 - Onboard diving doctor or nurse.

The divers holding an IMCA "diver medic certificate" can be considered "advanced first aiders" (also called "Advanced first responders"), but are not medics. That is because it takes a 15 days courses to obtain this certificate, while the formation of an actual nurse takes five years, and ten years are necessary for a student to become a recognized doctor. Therefore, it is evident that "IMCA diver medics" have limited knowledge in medical

matters and need professional support onboard. Also, medical interventions are strictly regimented in some countries, which may limit the possibilities of intervention of the "IMCA diver medics", even under the remote direction of a doctor.
For these reasons, and even though this is not possible for small operations with a limited number of persons, at a minimum, a nurse who has a recognized formation in diving accidents and emergency medicine should be onboard the surface support when 24 hours operations are undertaken. Note that some companies cumulate the functions of the onboard medic with those of the safety officer to amortize the expenses linked to this function, which is essential in case of accidents or illnesses on board.
Implementing this medical support does not question the benefit of having what IMCA calls "diver medics".

3.1.2.6 - Diving system technician leader

Even though surface supplied diving systems are less complicated than saturation systems, they may include complex elements such as hot water machines, diver gas reclaims, and diver monitoring systems. In such cases, competent technicians must be onboard to maintain them and should be directed by a lead technician having an overall knowledge of the systems in use.

3.1.2.7 - Additional key people

The workload of key personnel such as the offshore manager, lead engineer, safety officer, and others should be considered. For this reason, it often happens that one or two secretaries are on board to help the people mentioned above. Their essential activities consist of doing paperwork up to date and transmitting those of the people they help.

3.1.3 - Organization of the personnel

The Person in charge of the project must take care not to have overlapped functions and sufficient experienced personnel. Also, the use of unqualified diving personnel in the team is not permitted.

3.1.3.1 - Overlapping

IMCA says that members of a diving team may perform more than one function in the course of a single dive provided that this does not detract from the safety of the operation by the interference of one function with another, particularly in an emergency.

3.1.3.2 - Experienced personnel

It is essential to employ newly qualified personnel to provide them sufficient experience to ensure the future of the diving company. However, the diving team should be mainly composed of experienced staff. Note that to ensure that this point is under control, a lot of clients limit the quota of beginners in their company rules (it is often 25% maximum). For this reason, it is highly recommended to liaise with the clients regarding this aspect of job organization.

3.1.3.3 - Additional personnel

IMCA says that additional personnel may be included in the diving team for the purpose of operating special equipment. Such personnel must not act as a diver or diving supervisor unless they are suitably qualified and experienced to do so, or are employed by the diving contractor and are covered by their employer's liability insurance.
In certain circumstances, where the size of a diving team may be insufficient for the task, it is sometimes suggested that it should be supplemented by additional personnel employed on other work on the DSV or installation. This is not to be permitted for the following reasons:

- Lack of knowledge of the diving rules and diving procedures, particularly in an emergency, on the part of the non-diving personnel.
- Potential difficulties for the diving supervisor in exercising control and authority over people who are not directly responsible to him for their work.
- Possible third party liability.

Therefore if the circumstances of the diving work change so as to require increasing the size of the diving team the diving contractor will be required to mobilise additional personnel for that purpose.

3.2 - Role and duties

The role and responsibilities of people involved in a diving project are dependent on the laws published by the states where the operations are performed, and international codes such as the International Safety Management (ISM) Code published by IMO (International Maritime Organization), when the activities are performed outside the water controlled by the states. Note that IMO is a specialized agency of the United Nations.
As the IMO codes are not sufficiently precise to manage diving operations, professional associations such as IMCA have emitted guidelines that are applied outside territorial waters and in states where no laws regarding diving are published. Note that most nations issuing diving rules are developed countries and that these rules are usually very similar. These laws may partially apply in the exclusive economic zone defined by the convention of the law of the sea 1982 that provides the states with sovereign rights for the purpose of exploring, exploiting, conserving and managing natural

resources, whether living and nonliving, of the seabed and subsoil and the superjacent waters and concerning other activities for the economic exploitation and exploration of the zone, such as the production of energy from the water currents and winds.

3.2.1 - Client

UK Diving at work regulations - Approved Codes Of Practice (ACOP) define the client as the operator or owner of the installation where diving operations take place, or a contractor acting on behalf of the operator or owner.
This code says that clients should:

- ensure that nominated on-site representatives are competent for the task;
- Ensure that any diving contractor selected is capable of complying with the diving regulations in force;
- make available to the diving contractor the results of any risk assessments undertaken by other people under other statutory legislation that could affect the health and safety of the dive team;
- agree to provide facilities and extend all reasonable support to the supervisor or diving contractor in the event of an emergency. The diving project plan should reflect this;
- consider whether any known underwater or above-water items of plant under their control may cause a hazard to the dive team. Such items may include ship propellers, water intakes or discharge points causing suction or turbulence, gas flare mechanisms that may activate without warning, or plant liable to start operating automatically. The diving contractor should be informed of the location and nature of such hazards. This information should be provided in sufficient time so that it can be taken into account by the diving contractor when preparing the risk assessment before producing the diving project plan. They should also provide the diving contractor, in good time, with details of any changes to this information occurring before or during the course of the diving project;
- ensure that suitable facilities and time are available to the diving contractor to allow for a familiarisation programme;
- consider whether other activities in the vicinity affect the safety of the diving project, for example, they may need to arrange for the suspension of loading or unloading of vessels, seismic operations, scaffolding work or similar activities;
- ensure that they have a formal control system in place to cover diving activities, for example a permit-to-work system;
- provide the diving contractor with details of any possible substance likely to be encountered by the dive team that would be a hazard to their health, for example drill cuttings on the seabed. This information should be provided in writing and in sufficient time to allow the diving contractor to carry out the relevant risk assessment and, if necessary, to take appropriate action;
- keep the supervisor informed of any changes that may affect the supervisor's diving operation, for example vessel movement, so that diving can be suspended if the diving site is, or may be, endangered.

In addition to onsite representatives, clients usually appoint a project manager who is in charge of the project on behalf of the company he represents. This person ensures that the requirements above are applied and that the financial aspects of the project are within those initially planned by the management. He is often not qualified in diving activities and uses the services of the client representative or a permanent specialist for this purpose.

3.2.2 - Diving contractor

The diving contractor is the employer of the personnel engaged in the diving project.

Due to the cost of diving operations, it is usually a company that has sufficient resources to organize such works.
According to the UK Approved Codes Of Practice (ACOP), the diving contractor shall ensure, so far as is reasonably practicable, that the diving project is planned, managed and conducted in a manner which protects the health and safety of all persons taking part in that project. For this reason, the diving contractor should ensure that:

- the diving project is properly and safely managed;
- risk assessments have been carried out;
- the place from which the diving is to be carried out is suitable and safe;
- a suitable diving project plan is prepared which includes emergency and contingency plans. The diving project plan should be authorised and dated by a responsible person acting on behalf of the diving contractor;
- the supervisor and dive team are fully briefed on the project and aware of the contents of the diving project plan;
- there are sufficient personnel in the dive team to enable the diving project to be carried out safely;
- the personnel are qualified and competent;
- supervisors are appointed in writing and the extent of their control fully documented;
- a suitable mobilisation and familiarisation programme is completed by all the members of the dive team. Other personnel involved in the diving project, for example ship's crew, may also need to complete the programme;
- adequate arrangements exist for first aid and medical treatment;
- suitable and sufficient plant is provided and that it is correctly certified and maintained;
- the divers are medically fit to dive;
- diving project records are kept containing the required details of the diving project;

- a clear reporting and responsibility structure is laid down in writing;
- all other relevant regulations are complied with.

Note that with complex projects involving several contractors, one of them is to be appointed the main contractor who represents the interests of the others who act as sub-contractors. The company selected is usually the one having the most significant share of the project. In this case, the main contractor is in charge of organizing the project and coordinating the operations of the sub-contractors.

3.2.3 - Contractor's project manager

The Project Manager manages all aspects of offshore/onshore projects, including client interaction, offshore or onshore activities, personnel, & project cost control for the diving contractor in charge of the diving project. He reports to the Diving/ROV/Marine and the HSE/quality managers of the company he represents, and he is responsible for:

- developing project plans, procedures and budgets for the specific work scope;
- ensuring project compliance with company quality and HSE policies and client guidelines;
- selecting and managing the project team(s), including all crew, engineering, and sub-contractor personnel;
- ensuring that selected personnel and equipment are suitable;
- managing modifications and changes with the relevant departments;
- controlling financial planning and progress of projects;
- conducting workplace inspections on site;
- advising and providing input to tenders and contract negotiations;
- Having regular consultation with his/her management and the client throughout the project.

3.2.4 - Offshore Construction Manager *(also called Offshore Manager)*

The offshore manager is the diving contractor's representative at the work site and is generally appointed on large projects.

Offshore managers have overall responsibility for the project execution and their responsibilities and tasks include:

- Ensuring that activities are carried out in accordance with the requirements in the diving project plan and the applicable laws and regulations
- Ensuring that personnel are competent, qualified and familiar with the work procedures, safety precautions to be taken, laws and regulations to be applied and guidelines from well known competent bodies such as IMCA, IOGP, and others.
- The offshore manager is the primary point of contact with the client representative working offshore. He may or may not have a diving background. Note that if the offshore manager has no diving background, a diving superintendent must be appointed to assist him.

For the reasons listed above, this person should have competencies in management and leadership, and be familiar with the management and working procedures of the company he/she represents.

3.2.5 - Diving superintendent

A diving superintendent should be appointed on projects requiring more than one supervisor.

If an offshore manager has not been appointed, then the diving superintendent is the diving contractor's representative at the work site.

Diving superintendents are responsible for and competent to manage the overall diving operation (Ref. IMCA C 003). They have authority to forbid the start or order the termination of diving operations for safety or other reasons. Their responsibilities, tasks, and duties include:

- Ensuring the activities are carried out in accordance with the requirements in the diving project plan and the applicable laws and regulations
- Ensuring the personnel are competent and qualified and familiar with the work procedures, safety precautions to be taken, laws and regulations, and guidelines and information notes from national and international safety organizations.
- If qualified and holding a letter of appointment the diving superintendent can act as a diving supervisor. Regarding this last point, IMCA C 003 says that the diving superintendent should have demonstrated competence as a bell or air supplied dive supervisor. However, this requirement applies if the dive superintendent acts as a supervisor whilst in the role of dive superintendent and is required to be in charge of the panel. If qualified as an air diving supervisor, then the dive superintendent cannot act as a bell diving supervisor. For this reason, most companies and clients request a supervisor in this position.

As for the offshore construction manager, this person should have competencies in management and leadership, and be familiar with the management and working procedures of the company he represents.

3.2.6 - Vessel master

The Master is responsible to the owner, or, if the vessel is under a charter, to the charterer, for the operation of the vessel. Regarding the project, he reports to the offshore construction manager and follows his instructions.

Nevertheless, he is responsible for the safety of his vessel and his passengers. Thus, in the case of a situation where, based on his knowledge of safe marine practices, he considers that the safety of the vessel and passengers can be compromised, he has the power to order to terminate the operation in progress to return his vessel to a safe position.
The Master is in charge for:

- the navigation and the care and safety of the vessel;
- the safety and well being of the crew and all other personnel on board as well as the safety of the equipment and
- cargo carried on board;
- the employment of the crew in a safe and efficient manner to carry out the assigned missions of the vessel;
- the cargo operation in ports which includes loading, unloading, and cargo planning;
- maintaining proper order and discipline on board at all times;
- keeping himself fully informed of, and adhering to, all relevant laws, regulations and directives affecting the operation of the vessel;
- the respect of the rules in force in the ports visited;
- the security of the ship both in port and at sea;
- the maintenance of the vessel he is in charge of;
- looking after supply, overtime, cost control records, purchase order, requisition, and other paper work on behalf of shore management.

3.2.7 - Chief mate

When the master is at rest, he is replaced by the Chief officer, who is second in command. The chief officer has similar duties as the master, and is responsible for:

- reporting to and following the instructions of the master;
- the vessel navigation watch duties;
- the cargo operation in ports which includes loading, unloading, and cargo planning;
- the maintenance of cargo gears and cargo carried on board the ship;
- the stability of the ship;
- the maintenance of ship’s hull and accommodation;
- the life saving and fire fighting appliances;
- scheduling and distributing work to deck crew;
- the co-ordination with other departments and take part in conflict resolution;
- the garbage management for the deck and accommodation part of the ship;
- the ballast and de-ballasting operation done on board;
- making sure that all the crew members are complying with latest rules of MARPOL, SOLAS and STCW (Standards of Training, Certification and Watchkeeping).
- the training in all the above regulations and conventions are to be carried out by the chief officer as per company policy.
- the security of the ship both in port and at sea.
- the safety of the deck crew.

3.2.8 - Project Engineer

His role is to coordinate engineering tasks that are planned or in process. The engineering tasks are inspection or construction. He works in coordination with the Project Manager and the Offshore Construction Manager. Note that inspection coordinators 3.4 U are considered inspection engineers. He is responsible for:

- Collecting the information necessary for the planned works and ensuring they are accurate. Assisting the engineers and technicians in the preparation of the planning and the selection of working methods.
- Assisting the engineers and project teams during the mobilization of projects, and during projects.
- Representing the engineering department of the company during project preparation meetings.
- Recording and analysing information transmitted by the project teams.
- Giving instruction, guidance, and advice.
- Assisting the engineers in preparing the final report, and making sure that the reports are technically consistent. and commercially acceptable (content and presentation).
- Assisting the human resources department for recruiting engineers.

3.2.9 - Diving supervisor

The diving supervisor should have competencies in leadership, and be familiar with the management and working procedures of the company he represents. An accurate definition of the function and duties of the diving supervisor is given in IMCA D 014 that says:

- Supervisors are appointed by the diving contractor in writing and are responsible for the operation that they have been appointed to supervise.

- Unless an offshore manager or diving superintendent has been provided by the diving contractor, then the diving supervisor is the diving contractor's representative at the work site.
- A diving supervisor should only hand over control to another supervisor appointed in writing by the diving contractor. Such a handover will need to be entered in the relevant operations logbook.
- Supervisors can only supervise as much of a diving operation as they can personally control, both during routine operations and if an emergency should occur.
- The supervisor responsible for the operation is the only person who can order the start of a dive, subject to appropriate work permits, etc. Other relevant parties, such as a diving superintendent, offshore manager, ship's master, client representative, or the installation manager, can however, tell the supervisor to terminate a dive for safety or operational reasons.
- When the supervisor needs to liaise closely with other personnel, such as the vessel master or the DP operator. The supervisor must recognise that the vessel master has responsibility for the overall safety of the vessel and its occupants.

To ensure that the diving operation is carried out safely, supervisors should:

- explain the risks, hazards and mitigations needed for safe diving operations to people who may not have a full appreciation of such operations;
- ensure that the legal documents and proof of competencies of his team are adequately updated;
- check, as far as they are reasonably able, that the diving personnel are fit and in possession of a valid medical certificate of fitness;
- ensure that they are in possession of a letter from the diving contractor appointing them as a diving supervisor.
- ensure of the well being of their team and report any problem to the relevant person in charge;
- ensure that they and their team are competent for the operations that are planned;
- ensure that the team they are in charge of understand the work;
- ensure that the relevant documentation for the project, which includes the diving project plan, tasks plans with the appropriate risk assessments, and the Emergency Response Plan, is in place;
- ensure that the dive system is adequate for the operations, properly certified, maintained, audited, and documented;
- ensure that the operation they are being asked to supervise complies with the best practices.
- review the task plans and ensure that some hazardous situations have not been forgotten or under-evaluated;
- ensure that all hazards are fully understood by all relevant parties and that, if required, training is given.
- ensure that if the situation has changed, further risk assessment and management of change are undertaken.
- ensure that work permits and dive permits are in place and signed by the people in charge before launching any operation;
- ensure that audible and visual communications with any personnel under their supervision are in place (that includes the divers inside the bell or the transfer lock);
- Ensure that the rules for the communications with divers are in place and followed:
    - The supervisor has direct communications with any diver in the water at all times, even if another person needs to talk to, or listen to, the diver.
    - In case another person is talking to the diver a number of fundamental rules should be followed to ensure the continued safety link between the diver and supervisor.
        - The supervisor must not pass over the total communication responsibility to anyone, other than another properly appointed diving supervisor.
        - At all times, the diving supervisor needs to be able to hear the diver's voice communication and breathing pattern, even if another person is joined into the communications link.
        - In any communications system the diving supervisor needs to be able to disconnect all other personnel immediately so that the direct link between the diver and supervisor is uninterrupted.
- ensure that the relevant means of communication with the bridge, ROV Pilot, crane driver, and key personnel are in place;
- ensure that all vessel alarms are in place and are checked
- ensure that work permits and dive permits are in place and signed by the people in charge before launching any operation;
- ensure that the dive is started only when authorized, and that people on board the vessel (or the facility) is aware that diving is starting;
- ensure that the procedures are always followed;
- ensure that proper records of the diving operations are maintained;
- report any incident to the relevant persons in charge.

3.2.10 - Dive technician (*Note that the elements indicated below are also displayed in "Maintenance of the diving system".)*

The correct functioning of the equipment is essential to the well-being of the divers and other members of the dive team. For this reason, the services of dive technicians are essential.
Also, it is an obligation of the contractor to ensure that such personnel are correctly trained and have the required level of

competence for the equipment and in the operations they are conducting.
IMCA C 003 says that a dive technician should possess detailed knowledge of one or more of the following: Electrical, electronic, mechanical or hydraulic engineering. This knowledge should be obtained through academic education or experience and qualification in a military environment. Note that some diving schools such as Interdive http://www.interdive.co.uk/ or the National Hyperbaric Center (NHC) https://www.jfdglobal.com/training propose a dive technician module.
Also, a lot of IOGP members request the dive technician to be certified by an agreed training establishment. In addition, some IOGP members ask that the technicians have gauge calibration and high-pressure regulator maintenance certificate in addition of their mechanical and/or electrical qualification. These clients also require that at least one technician is in possession of a helmet maintenance certificate or equivalent.
However, these requirements which aim is to be sure that the technician is appropriately trained do not fully take into account the complexity of modern systems. For this reason, it is important to keep in mind that the level of training required and the level of competence for an individual will depend upon the complexity and range of equipment he/she is to work on, and that many last generation diving systems that are fully computerized require specific competencies that were not asked in the past. For these reasons, the owners of the last generation diving systems should ensure that the technicians are familiar with the design and computer programming procedures of the system they work on in addition to its particular mechanical and electronic designs.
Also, the level of the technicians working on a system must be classified according to their competencies and degrees of experience. To answer to this problem, the last IMCA guidance D 001 “Dive technician - Competence and training” give the following classification and recommendations:

- New entrants to the industry should be considered as trainees until they are considered sufficiently experienced to work without supervision. Also, they should hold a certificate of qualification from a recognized organization or have completed a recognized apprenticeship in one or several following topics.
    - Electronics or telecommunications
    - Mechanical engineering
    - Hydraulic engineering
    - Electrical engineering
    - Marine engineering
    - Motor vehicle engineering
    - Aviation technician (any discipline)
    - Agricultural machinery maintenance and repair
    - Plumbing
    - Shipbuilding
- Based on the skills and the previous experience of the person, a training programme should be in place. IMCA says that this training can be shared between periods on the job and periods in various training establishments. This training plan should be part of the competence assurance and assessment scheme of the company.
- A confirmed dive technician is a person who has demonstrated sufficient experience and competence to work without supervision. IMCA says that it implies that this person has been assessed by his/her employer. He/she should be qualified for one or several topics listed above

IMCA D 001 says that a senior dive technician is expected to have the knowledge of the equipment he/she is in charge of and demonstrate problem-solving and diagnostic abilities. That includes certification, testing, maintenance requirements, and permit to work and other administrative routine procedures.
The dive technician must:

- Ensure that the diving system is working correctly and is suitable for the planned operations
- Maintain the system, and make sure that the certifications are up to date through the Planned maintenance system
- Report any equipment faults
- Know the routine and emergency procedures;
- Report any potential hazards, near misses or accidents.
- Take reasonable care for his own safety and that of other persons who may be affected by his acts or omissions at work;
- Where he/she does not have any other additional role and if he/she is employed by the diving contractor the technician may also be used in non-specialist functions, e.g. winch operator, where competent to do so.

Note that it is recommended to select dive technicians with complementary skills to cover all the technical aspects of the diving system. Also, one technician should be a senior technician
Discontinuities in the maintenance of these complex pieces of machinery may result in breakdowns and catastrophic events. For this reason, it is recommended to organize for the same senior technicians to be in charge of a system. If it is decided to assign them to other tasks, the persons who replace them should be sufficiently competent to take over.

3.2.11 - Divers

- IMCA 14 says that divers are responsible for undertaking duties as required by the diving supervisor and should:

- Inform the diving supervisor if there is any medical or other reason why they cannot dive;

- Ensure that their personal diving equipment is working correctly and is suitable for the dive;
- Ensure that they fully understand the dive plan and are competent to carry out the planned task;
- Know the routine and emergency procedures;
- Report any medical problems or symptoms that they experience during or after the dive;
- Report any equipment faults, other potential hazards, near misses or accidents;
- Check and put away personal diving equipment after use;
- Keep their logbooks up to date and presenting them for signing by the diving supervisor after each dive
- Know the routine and emergency procedures;
- Report any potential hazards, near misses or accidents.
- Take reasonable care for his own safety and that of other persons who may be affected by his acts or omissions at work;
- Where he/she does not have any other additional role and if he/she is employed by the diving contractor the technician may also be used in non-specialist functions, e.g. winch operator, where competent to do so.

3.2.12 - Deck support personnel

The tending of the umbilicals is made from the bell by the bellman.
Deck support people are generally divers. They are responsible for undertaking duties as required by the diving supervisor. These duties are linked to the recovery and the deployment of the bell and the deployment of tools to the divers.
It may happen that some people are not divers. In this case, their competencies must be assessed and be established based on previous experiences and training. Note that only trained and qualified divers should be employed for operations such as the the connection of the bell, transfer of the divers to and from the chambers, and the check lists.

The deck support personnel must:

- Understand what is asked of them and the method of deployment of the bell. Also, they must be aware of actions that can affect the divers or lead to catastrophic events.
- Know the routine and emergency procedures and report any problem or misunderstanding.
- Take care of their own safety and the safety of others;
- Report any incident or dangerous condition;
- Ensure that the parts of equipment they are responsible for are correctly checked and maintained;
- Keep their log book updated.

3.2.13 - ROV manager

He is in charge of the management of the ROV operations and the relations with the project manager, the Offshore Construction Manager who manage the operations. Depending on the size of the diving company appointed for the project, he is in charge of the ROV department of this company or is the representative of an independent contractor. He is responsible for ensuring that:

- there are sufficient competent personnel for the project, and they are accepted by the client;
- the certificates of the ROV team are adequately updated;
- relevant equipment is supplied, and correctly certified;
- sufficient spare parts and consumables have been provided;
- the installation onboard the vessel or on the facility is safe and conform to the regulations;
- the planned maintenance system is in place and the ROV audited as required;
- the working time of the ROV team conforms to those of the regulations and in force in the company;
- the accommodations of the ROV team conform to the minimum required by ILO (international Labour Organization);
- the chain of command is in place and agreed by the client;
- the system of reporting is in place (that includes the incident reporting system);
- the ROV project plan with worksite analysis is in place and accepted by the client;
- the task plans and their risk assessments are in place and accepted by the client;
- the emergency response plan is in place and accepted by the client;
- transportation of the teams to the worksite are in place.

3.2.14 - ROV supervisor

IMCA says that ROV supervisors are responsible for the operation that they have been appointed to supervise, and they should only handover control to another suitably qualified person. Such a handover needs to be entered into the relevant operations logbook.

The rights and duties of the ROV supervisor are similar to those of the diving supervisor. However, the diving supervisor has authority over the ROV supervisor (or pilot) when dual operations are being carried out, and diving operations are underway. Also, the vessel's master has legal responsibility for the overall safety of the ship and all onboard crews.

Similarly to the diving supervisor, the ROV supervisor has authority over other personnel than the team he is in charge of, not taking into account any hierarchy, for the following cases:

- He is the only person who can order the start of an ROV dive when the work and dive permits are in place. However, the vessel master, Offshore Construction Manager (OCM), diving supervisor, client representative, and the Offshore Installation Manager if the operation is performed from a facility (the OIM is the person in charge of the facility), can order him to terminate the action underway.
- IMCA also says that the ROV supervisor can give direct orders relating to health and safety to any person taking part in the ROV operation, including client representative. For example, the supervisor may order personnel to leave the control area.

The ROV supervisor should:

- liaise with the diving superintendent, OCM, and the vessel master or the OIM;
- explain the risks, hazards and mitigations needed for safe ROV operations to people who may not have a full appreciation of such operations;
- ensure that the legal documents and proof of competencies of his team are adequately updated;
- ensure of the well being of his team and report any problem to the relevant person in charge;
- ensure that himself and his team are competent for the operations that are planned;
- ensure that his team understand the work;
- ensure that the relevant documentation for the project is in place. That includes the ROV project plan, tasks plans with the relevant risk assessments, and the Emergency Response Plan;
- review the task plans with his team and ensure that some hazardous situations have not been forgotten or under-evaluated;
- ensure that work permits and dive permits are in place and signed by the people in charge before launching any operation;
- ensure that the ROV system is adequate, properly certified, maintained, and audited;
- ensure that audible and visual communications with any personnel under their supervision are in place;
- ensure that the relevant means of communication with dive controls, the bridge, and key personnel are in place;
- update the planned maintenance system, and unsure that sufficient consumables and spare parts are present in the store.
- ensure that all relevant parties are aware that an ROV operation is going to start or continue;
- ensure that the pilot is in permanent communication with the bridge of the vessel or the control room of the Offshore Installation Manager in case of operation from a facility;
- ensure that the pilot is in permanent communication with the diving supervisor during simultaneous operations;
- ensure that the procedures are always followed;
- report any incident to the relevant persons.

3.2.15 - Other members of the ROV team

IMCA says that ROV personnel need to act in a responsible manner according to their position in the ROV team. For this reason, they should:

- understand and apply the procedures of the company they work for;
- ensure that their certificates of competency are adequately updated;
- actively participate in the toolbox talks, ensure they understand the work and that they are able to do it. Also, give their point of view regarding the safety procedures in place;
- follow the instruction of the ROV supervisor;
- report any aspect of the job that is unsafe, and stop the job if necessary;
- report any incident to the ROV supervisor;
- actively participate in the maintenance of the ROV and report of every defect found;
- ensure that all internal communications of the team are in place and are working satisfactory;
- ensure that all external communications of the team are in place and are working satisfactory.

3.2.16 - External personnel

These personnel can be involved in a project when the company is using subcontractors for tasks requiring specific skills, or when working on a project as subcontractor. These personnel should:

    - Ensure that their activity does not conflict with the diving operations
    - When they act as subcontractors: Ensure that they fully understand what is asked to them
    - Provide what is asked to the team and work in symbiosis with it
    - Report any problem or misunderstanding
- Know the routine and emergency procedures on the dive station
- Take care of their own safety and the safety of others

3.3 - To summarize

The minimum manning level depends on the task to be performed, and the diving system to be used. Sufficient personnel must be present to provide support functions to the dive team at all times, and particularly during the most critical situations. Thus, additional deck support personnel and other management or associated technical supports are often necessary. For this reason, it is essential to ensure and demonstrate that all the key points have been covered and that the team will be able to face any foreseen or unforeseen situation. That should be done through the study of emergency scenarios using risk assessment procedures.

As already said previously, it is not a wise idea to plan for a very minimum team. It is thus more advisable to plan for sufficient people to be sure that any position can be quickly fulfilled. It is also essential to discuss such points with the client and ensure that he agrees with the team's composition.

4 - Maintenance of the diving system

4.1 - Organize a reliable surface supplied diving system

4.1.1 - Purpose

Diving systems are not mass-produced items, and for this reason, they are expensive investments that represent several millions of dollars in which amortization is rarely possible at short term notice. Also, built-in systems are part of ships that have been built around them in such a manner that their replacement would imply a partial dismantling and reconstruction of the vessel.
Besides, these sophisticated pieces of machinery are assemblies of complex components that are interconnected such that they can be in the breakdown due to the failure of one of them. As a result, minor disruptions can rapidly extend to the entire system and then may lead to more significant breakdowns that may have the potential of threatening the divers and their supporting teams if they are not detected and solved sufficiently early.
For these reasons, it is the primary importance of organizing a relevant maintenance system that can solve unexpected breakdowns and manages to have such events not happening.

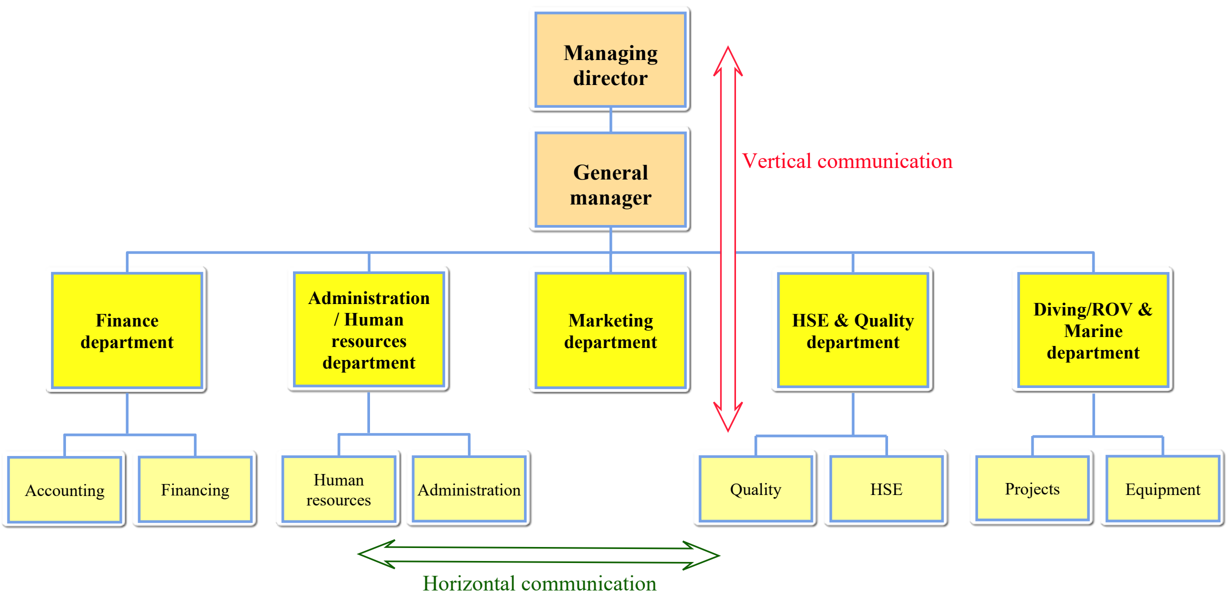
4.1.2 - Elements necessary to implement a maintenance system

Two types of maintenance are to be organized with diving systems:
- The solving of breakdowns of systems during the operations.
- The preventive maintenance of systems in use and stored.

As a result, the maintenance of diving systems implies an organization that cannot be implemented at the last minute of a project. For this reason, companies have to organize a specific structure for this purpose. Note that clients and international organizations for quality management systems such as ISO (International Standards organization), OSHA (Occupational Safety and Health Administration), and others request such a structure.

4.1.2.1 - Organization of the management system of a company and maintenance structure

To be able to work efficiently, diving and maritime companies are structured in departments that are grouped by function. This basic organization is the same for all companies. However, depending on whether the company is a multinational company introduced on the stock market or a family structure, this organization may slightly differ.
In the basic classical scheme displayed below, which is from a small existing diving contractor, each department is organized to perform the function that has been assigned to it, and under the responsibility of a manager who reports to the "General manager" who reports directly to the "Managing Director" who oversees the operations of the company. For more efficiency, the department can be divided into "branches". Each branch manages a dedicated part of the missions assigned to the department. These branches can be divided into smaller sections.
With this organizational system, the lower levels of the organization give information to employees that are at a level immediately above and follow the commands from these employees who are doing the same with the level directly above them. Thus, the transmission of information and orders to and from the management are made vertically, and the transfer of information between people, divisions, departments, or units within the same level of the organizational hierarchy is made horizontally.
This type of organization that reflects a hierarchy is called "Pyramidal structure". It aims to organize the full control of the key elements by the "managing director". Note that more complexes systems of management exist, but this one is the most encountered.



In the example above, the company has several diving systems but is not sufficiently powerful to have boats. So the boats are rented, and for this reason, the marine department and diving department are grouped. However, such departments are often separate in more powerful organizations.
When creating a maintenance structure, the problem of management teams is to ensure that they have adequate controls on it, and that it can work efficiently without being disturbed by too many administrative controls. For these reasons, they usually organize it such a way that it works closely with the following departments:

- Human resources:
  This department is in charge of recruiting personnel according to the necessary competencies for staff performing maintenance work and others. For this reason, the requirements and method of sourcing should be evaluated with the management in charge of the maintenance structure. Note that besides, this department is usually in charge of the organization of training or other actions to achieve or increase the necessary competencies of the personnel.
- Finance department:
  Finance departments are usually divided into several sub-departments such as accounting, purchasing, financing, procurement, etc., where each of them has a particular function. Maintenance of equipment means that spare parts have to be bought and that interventions of external suppliers have to be organized. As a result, a system for selecting and paying these suppliers should be in place. This selection is not only based on the prices practiced but on the quality of the services proposed by suppliers, which can be analyzed by competent technicians only.
- Heath, Safety, Environment (HSE), and Quality departments:
  These functions are often grouped with small companies and separate in more important organizations. The HSE department makes sure of the consistent quality of services by developing and enforcing good safety practices, validating processes, and providing documentation and safety specialists.
  The aim of quality management is to fulfill the customer's expectations in terms of quality, delivery, budget, and safety.
  People in charge of the maintenance of the diving systems are involved with these two departments as the safety of the divers and the quality of the services of a company depends on the reliability of the diving system.

To conclude with this point, the structure in charge of the maintenance of the diving systems must be part of the management system of the company, and work in symbiosis with the other departments. These relationships must be in place at all times, as the efficiency of the maintenance team could be compromised if it is not the case.

4.1.2.2 - Select the technicians and define their function

This point is the most crucial for the implementation of the maintenance system: Managers will not be successful in implementing it if there are not good competent people to do it.

Competence is a combination of knowledge, skills, experiences and behaviour that give a person the ability to perform a specific task successfully.

- Knowledge is the information a person has in a specific work area. Example: A diving supervisor is supposed to know the physiology associated with diving.
- Skills are the ability to perform certain mental or physical tasks. Example: The ability to perform underwater welding, or the ability to manage a team.
- Traits are physical characteristics and consistent responses to situations. Example: Physical fitness and self-control are essential for divers.
- Experience is the accumulated knowledge or practical wisdom gained from what one has observed, encountered, or undergone. As an example, a young diver has knowledge but limited experience.
- Behaviour is the manner of conducting oneself. Two elements that have impact on behaviour are often highlighted:
  - Motives are the reasons for a certain course of action whether conscious or unconscious.
  - Self-esteem is a term used to refer to how someone thinks about, evaluates, or perceives himself.

A competency model categorizes which core skills are needed to be successful in a particular position. This process is often called "competency mapping" by the specialists. The following steps should be performed:

1. Conduct a job analysis.
2. Identify a competency model.
3. Once a clear competency model has been identified, ideal candidates can be identified by matching them against the identified criteria.
4. Taking the competency model one step further, an evaluation to identify in what competencies individuals need additional development or training is made.

The required competencies for a particular position are identified into a matrix. This matrix should be categorized into several parts: Knowledge, skills, experience and behaviour.

Competency guidance have been developed by IMCA to provide a framework on which competence schemes can be built. These guidelines aim to:

- Specify minimum standards for qualifications and, where applicable, minimum experience required to ensure that personnel are competent to fulfil their safety-critical and other relevant responsibilities and fulfil their roles.

- Specify a competence assurance framework showing how proficiency can be developed, demonstrated, accepted and maintained.
- Provide a reference document detailing the procedures, criteria and recording system to be applied when assessing the competence of personnel engaged in all positions but especially safety-critical positions.

IMCA C 003 says that a dive technician should possesses detailed knowledge of one or more of the following: Electrical, electronic, mechanical or hydraulic engineering. This knowledge should be obtained through academic education or experience and qualification in a military environment.
Note that some diving schools such as Interdive http://www.interdive.co.uk/ or the National Hyperbaric Center (NHC) https://www.jfdglobal.com/training propose a dive technician module.

Also, a lot of IOGP members request the dive technician to be certified by an agreed training establishment. In addition, some IOGP members ask that the technicians have gauge calibration and high-pressure regulator maintenance certificate in addition to their mechanical and/or electrical qualification. These clients also require that at least one technician is in possession of a helmet maintenance certificate or equivalent.
However, these requirements aim to be sure that the technician is appropriately trained do not fully take into account the complexity of modern systems.
For this reason, it is important to keep in mind that the level of training required and the level of competence for an individual will depend upon the complexity and range of equipment he/she is to work on, and that many last generation diving systems that are computerized require specific competencies that were not asked for in the past.
For these reasons, the owners of the last generation diving systems should ensure that the technicians are familiar with the design and computer programming procedures of the system they work on in addition to its particular mechanical and electronic designs.
Also, the level of the technicians working on a system must be classified according to their competencies and degrees of experience. To answer to this problem, the last IMCA guidance D 001 "Dive technician - Competence and training" give the following classification and recommendations:

- New entrants to the industry should be considered as trainees until they are considered sufficiently experienced to work without supervision. Also, they should hold a certificate of qualification from a recognized organization.
  - Electronics
  - Mechanical engineering
  - Hydraulic engineering
  - Electrical engineering
  - Marine engineering
  - Motor vehicle engineering
  - Aviation technician (any discipline)
  - Agricultural machinery maintenance and repair
  - Plumbing
  - Shipbuilding
  - Telecommunications

  Based on the skills and the previous experience of the person, a training programme should be in place. IMCA says that this training can be shared between periods on the job and periods in various training establishments. This training plan should be part of the competence assurance and assessment scheme of the company.
- A confirmed dive technician is a person who has demonstrated sufficient experience and competence to work without supervision. IMCA say that it implies that this person has been assessed by his/her employer. He/she should be qualified for one or several topics listed above
- IMCA D 001 says that a senior dive technician is expected to have the knowledge of the equipment he/she is in charge and demonstrate problem-solving and diagnostic abilities. That includes certification, testing, maintenance requirements, and permit to work and other administrative routine procedures.

The dive technician must:

- Ensure that the diving system is working correctly and is suitable for the planned operations
- Maintain the system, and make sure that the certifications are up to date through the Planned maintenance system
- Report any equipment faults
- Know the routine and emergency procedures;
- Report any potential hazards, near misses or accidents.
- Take reasonable care for his own safety and that of other persons who may be affected by his acts or omissions at work;
- Where he/she does not have any other additional role and if he/she is employed by the diving contractor the technician may also be used in non-specialist functions, e.g. winch operator, where competent to do so.

Note that it is recommended to select dive technicians with complementary skills to cover all the technical aspects of the diving system. Also, one technician should be a senior technician
Discontinuities in the maintenance of these complex pieces of machinery may result in breakdowns and catastrophic

events. For this reason, it is recommended to organize for the same senior technicians to be in charge of a system. If it is decided to assign them to other tasks, the persons who replace them should be sufficiently competent to take over.

4.1.2.3 - Select suppliers and service providers

Dive systems are assemblies of elements in which some parts require particular skills the technicians in charge do not have, or which need the use of expensive tools which investment in is not justified. For this reason, most companies use the services of external service providers. Also, diving companies use the services of manufacturers and resellers who provide them the equipment they need.
Note that gains to be made in cost, time and quality through working in partnership with suppliers are significant. Nevertheless, choosing a supplier involves much more than scanning a series of price lists. The choice will depend on a wide range of factors such as value for money, quality, reliability and service.
The most effective suppliers are those who offer products or services that match, or exceed the needs of a company.
It is important to have a choice of sources, as buying from only one supplier can be dangerous: While exclusivity may spur some suppliers to offer a better service, others may simply become complacent, or not be able to serve the company properly during the critical phase of a project. Also, commercial issues may happen that can let the company in a critical Situation.

- Criteria for evaluation

Supplier performance is usually evaluated in the areas of pricing, quality, delivery, and service.
Note that the lowest price is not always the best value for the money: The balance between cost, reliability, quality and service should be considered.

- Pricing
    - The prices proposed should be favourably comparable to those of suppliers providing similar product and services.
    - Prices should be reasonably stable over time. Also, there should be a notice prior to any change in price.
    - The prices indicated on the invoices conform with those indicated on the purchase orders.
    - Invoices are easy to read and understand. The average length of time to receive invoices should be reasonable.
- Quality
    - The supplier should comply with terms and conditions stated in the purchase order.
    - The products or services conform to the specifications identified in the proposal and the purchase order.
    - The equipment sold by the supplier is reliable: They have limited breakdowns and reasonable durability.
    - A quality support program with immediate response and resolution of the problems is available.
    - Repairs of equipment are acceptable.
    - The length and provisions of warranty protection offered is reasonable: Problems are resolved in a timely manner.
    - The supplier offers products and services that are consistent with the industry standards.
- Delivery
    - The supplier delivers products and services on time.
    - The vendor delivers the correct items or services in the contracted quantity.
    - The average time for delivery is at least comparable to that of other vendors for similar products and services.
    - Packaging is sturdy, suitable, properly marked, and undamaged. Pallets should be of the proper size.
    - Proper documents (packing slips, invoices, technical manual, etc.) with correct material codes and proper purchase order numbers are provided at the delivery .
    - The supplier can organise emergency delivery if requested.
- Service
    - The supplier's representatives are courteous and professional. They handle complaints effectively.
    - The supplier answers promptly to demands of quotation. He provides regularly up-to-date catalogues, price information, and technical information.
    - The supplier should display knowledge of the company needs. It should also be helpful.
    - An efficient emergency support for repair or replacement of a failed product is in place with a follow-up on status of problem correction.
    - The supplier should have sufficient cash flow and a line of credit to fulfil his obligations.

- Suppliers can be found through a variety of channels such as:

- Recommendations.
- Directories such as yellow pages, Internet research engines etc.
- Trade associations such as IMCA.
- Business advisors such as international business organisations, governmental agencies, or private consultants.
- Exhibitions (they offer the opportunity to talk with a number of potential suppliers).
- Trade magazines (advertisements).

- List of selected suppliers

  A price enquiry with a precise description of what is required is transmitted to the potential suppliers.
  Wherever possible it is a good idea to meet the potential suppliers, and see how their business operates. A list of the suppliers that are compliant is then established. It is important to keep this list for further research. Nevertheless, it is also important to record the suppliers that are not compliant to avoid contacting them again during subsequent research.

- Selecting the supplier

  Once the list is established, the team in charge of the evaluation compares the potential suppliers. A decreasing classification is established with the most compliant supplier at the top and the least compliant at the bottom.
  Note that lower prices may reflect poorer quality of goods and services that, in the long run, may not be the most cost-effective option.
  If the selection is for a short term business, and the relation with the supplier not strategic, only the rate quality - price may be considered. Nevertheless, the supplier must be able to handle the mission for which he has been engaged.
  For this reason, the team should make sure that the supplier is sufficiently solid, or that the goods delivered can be easily found with another vendor.
  When the supplier is selected, the company can move on to negotiating terms and conditions and drawing up a contract. This part of the work is usually finalised by the Procurement Department and controlled by the general manager or the person he has nominated for this purpose.
  Note that when the supplier is only occasional, it often happen that a purchase requisition with the complete file of evaluation based on the elements described previously is transmitted to the procurement department.

4.1.2.4 - Create a library and implement processes that are mandatory in the industry

Numerous standards have been used during the manufacturing of the diving system that must be kept and updated. Also, organizations emit new standards and guidelines that have to be collected and transmitted to the technicians in charge of the maintenance of the system. For this reason, a library which function is to update the standards in force in the company and collecting useful documents should be created.

Also, several tools have been developed for the diving industry to increase the quality of the equipment in service and protect the divers from failures Such as:

1. Certification and classification
2. Failure Mode Effect Analysis (FMEA)
3. Planned Maintenance System (PMS)
4. Auditing

A significant function of the maintenance team is to implement the procedures indicated in these documents and maintain these processes updated for every equipment under their responsibility. These four tools are to be used together and are unavoidable documents as the clients and the safety organizations request them at all times. For this reason, they are described in detail in the next chapters.

4.1.2.5 - Organise training

Continuous training is a crucial element to make sure that the personnel involved in the maintenance of the diving system can perform their work in the best manner. Also, continuous training provides opportunities for promotion and motivates valuable employees.

To achieve the training targets, a plan must be established, discussed, and approved by the company director or the nominated competent person, who is usually the person in charge of the human resources. There are two sorts of training plans:

- A training plan linked to a project, that outlines the objectives and the required activities for developing, conducting, and evaluating the training during the project. It also establishes the costs of these activities and how the project team organizes to cover these costs.
- Individual educational plans, that are part of the strategy of the company, and are in place to increase its competencies. They apply to employees who want or need to reach an upper technical level. They are not linked to a particular project and can be external and/or internal.

Training can be given through the services of external establishments or internally.

- External training can be performed through relevant schools such as those involved in the formation of dive technicians like Interdive (http://www.interdive.co.uk/), and the hyperbaric diving center (https://www.jfdglobal.com/training). Also, specific courses regarding special equipment have to be organized with manufacturers. It is the case when a brand new system is bought or for particular items such as helmets, Compact Bailout Rebreathing Apparatus (COBRA), and others.
- Internal training is usually organized through senior technicians. However, it is also common to hire a specialist for such purpose.

4.1.2.6 - Organise equipment replacement and new acquisition

The function of the senior technician is not limited to repairing and maintain diving equipment. They are also involved in the process of evaluation of the items used in the dive system through the FMEA, Planned Maintenance system, and audits. Based on their reports, decisions can be taken to change some elements if those in service are unsatisfactory. The finance (accounting) department is usually associated with such a decision. Note that Senior technicians are generally involved in the selection of specialized equipment, and the conception of a new diving system, as they are the most qualified to decide if the technical design proposed suits to their needs regarding the ease of maintenance. Note that besides, life support and diving supervisors must be involved in such a process.

Also, a company rarely has the financial resources to buy such equipment without the help of a financing establishment due to the considerable investment it represents. For this reason, the financing department is always involved in calculating whether the cost of such machinery is sustainable by the company, and the way the investment can be paid and amortized. That may open a long process of discussion between the company and financing structures, which may result that the company needs to review its original plan.

Another option often implemented by companies is to rent the system. The advantage of renting a system is that its owner usually performs its maintenance and that the rented system is considered an expense and not an asset in the calculation of the taxes to be paid by the user. Note that renting is common in the transportation aviation industry, as such a solution provides more flexibility to the airways companies, in addition to the advantages previously discussed.

4.2 - Certification and classification

4.2.1 - Certification process

Certification is is a process of evaluation that is used to establish the technical level of equipment and whether it conforms to the specifications that arise from published standards and guidelines that are in force through national and international laws and directives. Note that an item cannot be put in service if it is not certified for the operations it has been designed for by a legal authority. This process is also used to check the condition of the equipment and determine prospects for repair and modernization.
The manufacturer usually certifies the equipment he produces according to selected standards and rules that are typically those in force in the area the item is planned to be used. During this process, all working parameters, controls, and regulation systems are checked, and the functions of the given equipment are precisely defined. Calculations such as kinematics and power are made, operating, and maximum tolerable parameters such as temperature and pressure are determined, and optimal operating modes are fixed.
In addition to what is said above, the tests for the certification of the components of diving systems are based on criteria issued by the authorities and also, technical notes, guidelines, and codes issued by recognized organizations involved in diving activities such as IMCA, NORSOK, ADCI, and others. Guidelines from oil companies are also commonly used, with those published by classification societies.

The certification bodies edit handbooks for their auditors and clients that explain the organization of the tests. Such documents describe elements to be in place, such as:

- Where and how the item to test must be installed
- The elements to be connected to the item to test
- The parameters to be applied. As an example, the pressure and flow, or the electrical voltage and amperage
- The elements to measure and criteria for the acceptance
- The personnel to be involved in the test
- The way the test is scheduled
- The documents to provide (Usually; drawings & specifications)
- What the auditor should look for and the reason the tests are applied

At the end of the certification process, a certificate, which is a technical document that contains information on the essential functions and particular applications of the equipment is issued. Usually, the document includes:

- The name of the manufacturer
- The product code
- The function of the item
- The standards the product conforms to
- The date of the certificate

Detailed information on the maximum capacity of the item are added on some certificates.
The reference number of the certificate is usually stamped on the equipment with the logo of the standardisation body. As an example “CE” for an item that has been tested according to the European standards and is usable in the countries applying these standards.

4.2.2 - Classification

Marine classification is a process of investigation used to verify the structural strength, integrity, reliability of the essential parts of a ship, facility, or equipment to be used at sea. The international and national statutory regulations applied in this process are those published by the flag administration of the vessel.
Classification societies are independent non-governmental organizations that are usually used to verify compliance with these rules on behalf of the flag authorities.
Note that some clients, particularly some members of the “International association of Oil & Gas Producers (IOGP)”, request that the diving systems used on their oilfields are classified.

4.2.2.1 - United Nations Conventions and classification societies

The United Nations Convention on the Law of the Sea (UNCLOS) indicates the rules and principles of the general international law of the sea and its uses, including the registration of a ship by a state.
Once a boat is registered, the flag state has duties laid out in the United Nations Convention on the Law of the Sea, particularly in article 94, that says that "Every state shall effectively exercise its jurisdiction and control in administrative, technical and social matters over ships flying its flag".
Regarding the construction and the maintenance of ships, it is said that every state must:

- Maintain a register of vessels containing the names and particulars of ships flying its flag, except those which are excluded from generally accepted international regulations on account of their small size.
- Take measures that are necessary to ensure safety at sea with regard to the construction, equipment, and seaworthiness of ships flying its flag.
- Ensure that each ship, before registration and thereafter at appropriate intervals, is surveyed by a qualified

surveyor of ships and has on board such charts, nautical publications, and navigational equipment and instruments as are appropriate for the safe navigation of the ship.

It often happens that states do not have the resources to ensure these duties through their administration, or want to promote "free trading", and for these reasons, delegate these duties to independent organizations. The resolution A.739(18) "Guidelines for the authorization of organizations acting on behalf of the administration", adopted the 4th of November 1993, covers this point.
This text says that under the provisions of regulation l/6 of SOLAS 74, article 13 of load lines 66, regulation 4 of annex 1 and regulation 10 of Annex 2 of MARPOL 73/78 and article 6 of tonnage 69, many flag states authorize organizations to act on their behalf in the surveys and certification and determination of tonnages as required by these conventions.
The text also says that control in the assignment of such authority is needed in order to promote uniformity of inspections and maintain established standards. Therefore, any assignment of authority to recognized organizations should determine that the organization has adequate resources in terms of technical, managerial, and research capabilities to accomplish the tasks being assigned, in accordance with the minimum standards for recognized organizations acting on behalf of the administration:

- The relative size, structure, experience and capability of the organization commensurate with the type and degree of authority intended to be delegated thereto should be demonstrated.
- The organization should be able to document extensive experience in assessing the design, construction and equipment of merchant ships and, as applicable, their safety-management system.
- For the purpose of delegating authority to perform certification services of a statutory nature in accordance with regulatory instruments which require the ability to review applicable engineering designs, drawings, calculations and similar technical information to technical regulatory criteria as dictated by the administration and to conduct field survey and inspection to ascertain the degree of compliance of structural and mechanical systems and components with such technical criteria, the following should apply:
    - The organization should provide for the publication and systematic maintenance of rules and/or regulations in the English language for the design, construction and certification of ships and their associated essential engineering systems as well as the provision of an adequate research capability to ensure appropriate updating of the published criteria.
    - The organization should allow participation in the development of its rules and/or regulations by representatives of the Administration and other parties concerned.
    - The organization should be established with a significant technical, managerial and support staff, catering also for capability of developing and maintaining rules and/or regulations; and a qualified professional staff to provide the required service representing an adequate geographical coverage and local representation as required.
    - The organization should be governed by the principles of ethical behaviour, which should be contained in a "code of ethics" and as such recognize the inherent responsibility associated with a delegation of authority to include assurance as to the adequate performance of services as well as the confidentiality of related information as appropriate.
    - The organization should demonstrate the technical, administrative and managerial competence and capacity to ensure the provision of quality services in a timely fashion.
    - The organization should be prepared to provide relevant information to the administration.
    - The organization's management should define and document its policy and objectives for, and commitment to, quality and ensure that this policy is understood, implemented and maintained at all levels in the organization.
    - The organization should develop, implement and maintain an effective internal quality system based on appropriate parts of internationally recognized quality standards no less effective than ISO 9000 series, and which, among other things, ensures that:
        - the organization's rules and/or regulations are established and maintained in a systematic manner; .
        - the organization's rules and/or regulations are complied with;
        - the requirements of the statutory work for which the organization is authorized, are satisfied;
        - the responsibilities, authorities and interrelation of personnel whose work affects the quality of the organization's services are defined and documented;
        - all work is carried out under controlled conditions;
        - a supervisory system is in place which monitors the actions and work carried out by the organization;
        - a system for qualification of surveyors and continuous updating of their knowledge is implemented;
        - records are maintained, demonstrating achievement of the required standards in the items covered by the services performed as well as the effective operation of the quality system; and
        - a comprehensive system of planned and documented internal audits of the quality-related activities in all locations is implemented.
    - The organization should be subject to certification of its quality system by an independent body of auditors recognized by the Administration.
- For the purpose of delegating authority to perform certification services of a statutory nature in accordance with regulatory instruments which require the ability to assess by audit and similar inspection of the relevant safety-management system attributes of shore-based ship management entities and shipboard personnel and systems, the following should, in addition, apply:

- The provision and application of proper procedures to assess the degree of compliance of the applicable shore-side and shipboard safety-management systems.
- The provision of a systematic training and qualification regime for its professional personnel engaged in the safety management system certification process to ensure proficiency in the applicable quality and safety-management criteria as well as adequate knowledge of the technical and operational aspects of maritime safety management.
- the means of assessing through the use of qualified professional staff the application and maintenance of the safety-management system, both shore-based as well as on board ships, intended to be covered in the certification.

Resolution A.739(18) also says that there must be formal written agreement between the administration and the organization being authorized which should as a minimum include the elements listed below, or equivalent legal arrangements:

1. Application
2. Purpose
3. General conditions
4. The execution of functions under authorization
    - Functions in accordance with the general authorization
    - Functions in accordance with special (additional) authorization
    - Relationship between the organization's statutory and other related activities
    - Functions to co-operate with port States to facilitate the rectification of reported port State control deficiencies or the discrepancies within the organization's purview
5. Legal basis of the functions under authorization
    - Acts, regulations and supplementary provisions
    - Interpretations
    - Deviations and equivalent solution
6. Reporting to the Administration
    - Procedures for reporting in the case of general authorization
    - Procedures for reporting in the case of special authorization
    - Reporting on classification of ships (assignment of class, alterations and cancellations), as applicable
    - Reporting of cases where a ship did not in all respects remain fit to proceed to sea without danger to the ship or persons on board or presenting unreasonable threat of harm to the environment
    - Other reporting
7. Development of rules and/or regulations - Information
    - Co-operation in connection with development of rules and/or regulations liaison meetings
    - Exchange of rules and/or regulations and information
    - Language and form
8. Other conditions
    - Remuneration
    - Rules for administrative proceedings
    - Confidentiality
    - Liability
    - Financial responsibility
    - Entry into force
    - Termination
    - Breach of agreement
    - Settlement of disputes
    - Use of sub-contractors
    - Issue of the agreement
    - Amendments
9. Specification of the authorization from the Administration to the organization
    - Ship types and sizes
    - Conventions and other instruments, including relevant national legislation
    - Approval of drawings
    - Approval of material and equipment
    - Surveys
    - Issuance of certificates
    - Corrective actions
    - Withdrawal of certificates
    - Reporting
10. The Administration's supervision of duties delegated to the organization
    - Documentation of quality-assurance system

- Access to internal instructions, circulars and guidelines
- Access by the Administration to the organization's documentation relevant to the Administration's fleet
- Co-operation with the Administration's inspection and verification work
- Provision of information and statistics on, e.g., damage and casualties relevant to the Administration's fleet.

In addition to the elements indicated above, the administration should:

- Specify instructions detailing actions to be followed in the event that a ship is found not fit to proceed to sea without danger to the ship or persons on board, or presenting unreasonable threat of harm to the marine environment.
- Provide the organization with all appropriate instruments of national law giving effect to the provisions of the conventions or specify whether the Administration's standards go beyond convention requirements in any respect.
- Specify that the organization maintains records which can provide the Administration with data to assist in interpretation of convention regulations.

To finish with this point, the administration should establish a system to ensure the adequacy of work performed by the organizations authorized to act on its behalf. Such a system should, among other things, include the following items:

- Procedures for communication with the organization
- Procedures for reporting from the organization and processing of reports by the Administration
- Additional ship's inspections by the Administration
- The Administration's evaluation/acceptance of the certification of the organization's quality system by an independent body of auditors recognized by the Administration
- Monitoring and verification of class-related matters, as applicable.

To reinforce resolution A.739 (18), the International Marine Organization (IMO) has published resolution A.789 (19) "*Specifications on the survey and certification functions of recognized organizations acting on behalf of the administration"* which has been adopted the 23rd of November 1995.
This document contains additional specifications for organizations recognized as capable of performing statutory work on behalf of a flag state administration in terms of certification and survey functions connected with the issuance of international certificates. It covers modules such as: Management, technical appraisal, surveys, and qualifications and training, and says the following:

1. Management:
   The management of the Recognized Organization (RO) should have the competence, capability and capacity to organize, manage and control the performance of survey and certification functions in order to verify compliance with requirements relevant to the tasks delegated and should, among other things:
   - Possess an adequate number of competent supervisory, technical appraisal and survey personnel.
   - Provide for the development and maintenance of appropriate procedures and instructions.
   - Provide for the maintenance of up-to-date documentation on interpretation of the relevant instruments.
   - Give technical and administrative support to field staff; provide for the review of survey reports and provision of experience feedback.
2. Technical appraisal:
   - Regarding hull structure, the Recognized Organization should have the appropriate competence, capability and capacity to perform the following technical evaluations and/or calculations pertaining to longitudinal strength; local scantlings such as plates and stiffeners; structural stress, fatigue and buckling analyses; materials, welding and other pertinent methods of material-joining, for compliance with relevant rules and convention requirements pertaining to design, construction and safety.
   - Regarding subdivision and stability, the Recognized Organization should have the appropriate competence, capability and capacity to perform the technical evaluations and/or calculations pertaining to intact and damage stability; inclining test assessment; grain loading stability; watertight and weathertight integrity.
   - Regarding load line and tonnage, the Recognized Organization should have the appropriate competence, capability and capacity to perform the following technical evaluations and/or calculations pertaining to freeboard calculation; conditions of assignment of freeboard; and tonnage computation.
   - Regarding structural fire protection, the Recognized Organization should have the appropriate competence, capability and capacity to perform technical evaluations and/or calculations pertaining to structural fire protection and fire isolation; use of combustible materials; means of escape; ventilation systems.
   - Regarding safety equipment, the Recognized Organization should have the appropriate competence, capability and capacity to perform the following technical evaluations and/or calculations pertaining to life-saving appliances and arrangements; navigation equipment; fire detection and fire alarm systems and equipment; fire-extinguishing system and equipment; fire control plans; pilot ladders and pilot hoists; lights, shapes and sound signals inert gas systems.
   - Regarding oil pollution prevention, the Recognized Organization should have the appropriate competence, capability and capacity to perform technical evaluations and/or calculations pertaining to monitoring and control of oil discharge; segregation of oil and ballast water; crude oil washing;

protective location of segregated ballast spaces; pumping, piping and discharge arrangements; shipboard oil pollution emergency plans (SOPEP's).
   - Regarding prevention, the Recognized Organization should have the appropriate competence, capability and capacity to perform technical evaluations and/or calculations pertaining to list of substances the ship may carry; pumping system; stripping system; tank-washing system and equipment; underwater discharge arrangements.
   - Regarding radio, the Recognized Organization should have the appropriate competence, capability and capacity to perform technical evaluations pertaining to radiotelephony; radiotelegraphy; Global Maritime Distress and Safety System (GMDSS). Alternatively, these services may be performed by a professional radio installation inspection service company approved and monitored by the RO according to an established and documented programme. This programme is to include the definition of the specific requirements the company and its radio technicians are to satisfy.
   - Regarding carriage of dangerous chemicals in bulk, the Recognized Organization should have the appropriate competence, capability and capacity to perform technical evaluations and/or calculations pertaining to ship arrangement and ship survival capacity; cargo containment and material of construction; cargo temperature control and cargo transfer; cargo tank vent systems and environmental control; personnel protection; operational requirements; list of chemicals the ship may carry.
   - Regarding carriage of liquefied gases in bulk, the Recognized Organization should have the appropriate competence, capability and capacity to perform technical evaluations and/or calculations pertaining to ship arrangement and ship survival capacity; cargo containment and material of construction; process pressure vessels and liquid, vapour and pressure piping systems; personnel protection; use of cargo as fuel; operational requirements.
3. The Recognized Organization should have the appropriate competence, capability and capacity to perform the required surveys under controlled conditions as per the Recognized Organization's internal quality system and representing an adequate geographical coverage and local representation as required. The work to be covered by the staff is described in the relevant sections of the appropriate survey guidelines developed by the Organization.
4. Qualification and training
   - The Recognized Organization personnel performing, and responsible for, statutory work should have as a minimum a qualifications from a tertiary institution recognized by the Recognized Organization within a relevant field of engineering or physical science (minimum two years' programme), or qualifications from a marine or nautical institution and relevant sea-going experience as a certificate ship officer, and should have proficiency in the English language commensurate with the work.
     Other personnel assisting in the performance of statutory work should have education, training and supervision commensurate with the tasks they are authorized to perform.
     The RO should have implemented a documented system for qualification of personnel and continuous updating of their knowledge as appropriate to the tasks they are authorized to undertake. This system should comprise appropriate training courses, including, among other things, international instruments and appropriate procedures related to the certification process, as well as practical tutored training. It should provide documented evidence of satisfactory completion of the training.
   - Surveys may be done by a professional radio installation inspection service company approved and monitored by the RO according to an established and documented programme. This programme is to include the definition of the specific requirements the company and its radio technicians are to satisfy, including, among other things, requirements for internal tutored training covering at least radiotelephony; radiotelegraphy; Global Maritime Distress and Safety System (GMDSS); initial and renewal surveys.
     Radio technicians carrying out surveys should have successfully completed, as a minimum, at least one year of relevant technical school training, the internal tutored training programme of his/her employer and at least one year of experience as an assistant radio technician. For exclusive radio surveyors to the RO, equivalent requirements as above apply.

A classification society is an organization that complies with the above requirements and is authorized by one or several flag administrations to verify the compliance of the construction of a vessel with its published rules and to periodically check this compliance during the classed ship’s service life. Also, the classification society publishes a register of classed ships on behalf of the administration.
Note that the requirements asked by the International Marine Organization (IMO), are more specific to boats rather than dive systems. However, this description indicates the high level requested IMO to these organizations, and this technical level is also the one required for dive systems. Also, note that dive systems that are integrated into a boat are considered a part of the vessel and must be classified with it.

4.2.2.2 - Classification societies member of the International Association of Classification Societies (IACS)

There are approximately 50 organizations that define their activities as marine classification services providers in the world. However, not all of them meet in full the requirements of the IMO resolutions A.739 (18) and A.789 (19) given in the previous point. For this reason, a lot of clients require that the organizations issuing classification certificates are a member of the International Association of Classification Societies (IACS). It is, for example, the case of Total.
This association that has been officially founded the 11th of September 1968 is a not for profit membership organization of classification societies that establish minimum technical standards and requirements that address maritime safety and

environmental protection and ensures their consistent application. The association provides a quality system certification scheme that its members comply with, as an assurance of professional integrity and uniformly high standards. IACS is recognized as the principal technical advisor of IMO.
The association is currently composed of the following members:

Name and used abbreviation	*Year of creation*	*Head quarters*	*Date membership*	*Comments*
Lloyd's Register of Shipping (LR)	*1760*	*London*	*11/09/68*	*This company is one of the founders of the association.*
Bureau Veritas (BV)	*1828*	*Paris*	*11/09/68*	*This company is one of the founders of the association.*
Registro Italiano Navale (RINA)	*1861*	*Genoa*	*11/09/68*	*This company is one of the founders of the association .*
American Bureau of Shipping (ABS)	*1862*	*Houston*	*11/09/68*	*This company is one of the founders of the association .*
DNV GL (DNV)	*1864 & 2013*	*Oslo*	*11/09/68*	*This company is from the merger of two founders of the association in 2013: Det Norske Veritas and Germanischer Lloyd*
Nippon Kaiji Kyokai (NKK)	*1899*	*Tokyo*	*11/09/68*	*This company is one of the founders of the association.*
Russian Maritime Register of Shipping (RS)	*1913*	*Saint Petersburg*	*01/11/69*	*Previously called "USSR Maritime Register of Shipping"*
Korean Register of Shipping (KR)	*1960*	*Busan*	*01/09/75*	
China Classification Society (CCS)	*1956*	*Beijing*	31/05/88	
Indian Register of Shipping (IR Class)	*1975*	*Mumbai*	22/06/10	
Croatian Register of Shipping (CRS)	*1858*	*Split*	03/05/11	
Polish Register of Shipping - Polski Rejestr Statków- (PRS)	*1936*	*Gdansk*	03/06/11	

Note that the five companies on the top of the list are those the most involved regarding the classification of the diving systems. However, other companies may be occasionally engaged or plan to enter this market. It must be considered that classification societies are commercial organizations whose purpose is also to make a profit through the development of their business. For this reason, each company selects markets where it is more competitive than others. For this reason, it is not surprising to see that some IACS members are not very involved with diving.

Comments regarding the selection of a classification society:
It has happened several times that clients have rejected diving systems because of the organization in charge of the classification of the boat and the diving system that was not approved by their technical services. For this reason, it is of primary importance to select a reputed classification society that is accepted everywhere. Considering the fact that some clients also require that the classification societies of the vessels and systems operating on their oilfields are members of IACS, the wise strategy should be to select one of the members of this association.

4.2.2.3 - Classification process of a diving system

For the reasons explained before, the general rules explained in this point are those promoted by IACS members.

As indicated in the previous point, a lot of clients require that the diving systems used on their oilfields are classed. That is still not mandatory with all companies, but there is a risk that it will be the case in the future. So, another wise decision when investing in a new diving system is to class it.
Note that integrated (built-in) systems are considered a part of the ship where they are installed and should be classified at the same time. As a result, only the classification of portable systems is to be done separately from their surface supports.

The main difference between a non-classed and a classed diving system is that the non-classed system may be constituted of elements from various origins that are assembled to create a diving system. In contrast, the provenance, suitability, and

their interaction with the other components of the diving system is reviewed. Thus, the diving system is entirely tested for safety, efficiency, robustness, and conformance to the standards selected by the classification society. So the system complies with what is indicated in the United Nations Convention on the Law of the Sea (UNCLOS) and is considered safe for the operations it has been designed for by a recognized competent body.
Common scopes of the classification of diving systems include:

1. The reviewing of the specifications and drawings
   - Manufacturer documentation review
   - Audit of the quality management system
   - Evaluation of the materials and equipment planned
   - Review of the general design and the interface with the support vessel.
   - Evaluation of the design criteria, and verification that they are in accordance with specified codes and standards
   - Additional calculations for certain systems and components
   - Final review and acceptance of the design for construction
2. The survey during the construction
   - Evaluation of the manufacturing management system and the quality management system and implement corrective actions.
   - Evaluation of the fabrication methods, and confirmation of compliance with the planned manufacturing specifications or implement corrective actions.
   - Review of the manufacturing procedures and qualification tests
   - Surveillance based on spot checks during the construction of the system to ensure that the delivered products have been produced in accordance with the established manufacturing specification
   - Review the final documentation of the elements that are part of the diving system

   Note: During this phase, the person in charge for the classification society ensures that the design, certificates and tests planned are in place. As an example, regarding the construction of the hulls of the chambers:
   - Metal plates, bolts, extrusions, and forgings must conform to relevant standards of fabrication.
   - Plates are ultrasonically examined and toughness testing is common for forgings and steel plates.
   - All welding procedures and the qualifications of the welders are to be submitted and approved.
   - Identification of the elements welded and their alignment is checked with the penetration of the welds. Nondestructive examination and impact testing are common for this purpose, and the procedures used for these tests must conform to those of the classification society.

   The table below summarizes the major verifications and tests performed on a surface supplied diving system during the preparation and the construction processes. Note that more checks may be required.

Elements	***Raw material verification***	***Welding procedures***	***Pressure tests***	***Function tests***	***Product certificate***	***Design review***
Chambers, wet bells,						
Hull	X	X	X		X	X
Basket & wet bell structure	X	X	X		X	X
Doors, clamps, and mating devices	X	X	X	X	X	X
Viewports	X		X		X	X
Penetrators (pipes and electrical)	X		X		X	X
Valves	X		X	X	X	X
Relief valves	X		X	X	X	X
Pressure gauges				X	X	X
Communication systems				X	X	X
Close Circuit Television (CCTV)				X	X	X
Bell & basket transponder				X	X	X
Scrubbers				X	X	X
Analysers (O2 & CO2)				X	X	X

Elements	*Raw material verification*	*Welding procedures*	*Pressure tests*	*Function tests*	*Product certificate*	*Design review*
Thermometer and hygrometer				X	X	X
Fixed fire fighting system chambers						
Pressure vessels	X	X	X		X	X
Valves, pipes, and fittings	X		X	X	X	X
Sprinklers and nozzles	X			X	X	X
Fire detection				X	X	X
Portable fire fighting systems						
Portable extinguishers					X	X
Gas distribution systems						
Gas panels	X		X	X	X	X
Oxygen pipework (including regulators)	X		X	X	X	X
Other Pipework	X		X	X	X	X
Flexible hoses and couplings	X		X		X	X
Pressure relief valves	X		X	X	X	X
Manifolds and filters	X		X	X	X	X
Built in Breathing Systems (BIBS)			X	X	X	X
Compressors and blowers						
Compressors and blowers			X	X	X	X
Electrical supplies				X	X	X
Pipeworks	X		X	X	X	X
Relief valves	X		X	X	X	X
Gas storage						
Seamless gas cylinders	X		X	X	X	X
Pipeworks quads & tubes	X		X	X	X	X
Gas reclaim system divers (If used for heliox diving)						
Compressors			X	X	X	X
Scrubbers			X	X	X	X
Filters				X	X	X
Gas receivers & volume tanks	X		X	X	X	X
Hot water system bell and divers						
Hot water machine				X	X	X
Pressure vessels &	X	X	X	X		X
Manifolds	X	X	X	X	X	X

Elements	*Raw material verification*	*Welding procedures*	*Pressure tests*	*Function tests*	*Product certificate*	*Design review*
Pumps				X	X	X
Flexible hoses			X	X	X	X
Pipework	X		X	X	X	X
Umbilicals						
Bell umbilical			X	X	X	X
Bell umbilical winch	X			X	X	X
Diver umbilicals			X	X	X	X
Launch And Recovery System (LARS)						
Bell lifting winches	X			X	X	X
Lifting wires	X			X	X	X
Lifting frame	X	X		X	X	X
Heave compensation (usually not present)				X	X	X
Electrical & electronic systems				X	X	X
Electrical installation dive system						
Switchboards				X	X	X
Electrical motors and generators				X	X	X
Batteries				X	X	X

3. Installation (Built in systems only)
    - Evaluation of the installation management systems
    - Verification of the procedures of installation
    - verification of the conformity of the installation with the layout drawings and specifications
    - Surveillance during installation activities: The checks listed on the previous page are usually performed.
4. Testing and commissioning
   When the installation is completed, or the portable system is ready for use, the diving system must be tested in compliance with an approved test program in the presence of the person in charge for the classification society.
    - Procedures review to ensure that the test procedures are in accordance with the design requirements.
    - Verification of the conformity of the installation with the layout drawings and specifications.
    - Verification of the certificates of the diving system components and the marking plates.
    - Verification of the cleanliness of the breathing gas piping and their marking in accordance with the official colour code.
    - Verification of the oxygen gas storage area, piping, valves and alarms
    - Surveillance during testing and completion activities. The diving system is tested at sea trials according to an approved programme.
        - Pressure vessels for human occupancy pressure testing and gas leak testing (chamber complex, diving bell, Hyperbaric Rescue Unit)
        - Visual examination of the insulation of Pressure Vessels for Human Occupancy (PVHO)
        - Visual examination of the doors, hatches and their locking mechanisms. Also, visual examination of the medical and transfer tools locks.
        - Visual examination of the flow fuses and valves used for the same function.
        - Breathing gas system testing (piping, fittings and gas cylinders).
        - Diving control panel and life support control panel testing.
        - Depth gauges calibration and testing.
        - Sanitary system (toilets, sewage and fresh water), Chamber bilge drain system testing.
        - CO2 removal testing (chambers and diving bell).
        - Gas reclaim system testing.
        - Gas transfer system testing.

- Gas transfer system testing.
- Fire-fighting system testing
- The launch and recovery system is tested to the maximum depth.
- Bell function tests
- Diver heating system
- The ability to transfer an injured diver to the chamber, and to compress the chamber, within the time frame stipulated by the applied decompression tables are checked.
- Testing of the ballast release system in water, when relevant.
- Testing of the bell emergency systems

- The final commissioning usually includes a non-manned diving test with the diving bell lowered to the rated depth:
    - Leak tests
    - Checks of electrical and communication systems
    - Breathing gas supplies and recovery system
- Reviewing of the final documentation.
- Delivery of the classification document.

4.2.2.4 - In service surveys and renewal of the classification

The validity of the class certificate is usually five years. However, a classed system cannot be modified without the approval of the classification body. Also, the system must be audited at regular intervals to ensure that it is well maintained and safe for use. Note that the class certificate of the diving system ceases to be valid if its owner neglects to perform these audits.

IACS members follow similar rules regarding the frequencies of inspections that should be done in addition to the normal IMCA audits D 024 & D 053 (These audits apply to IMCA members, but are required by the majority of clients):

- The annual survey usually consists of performing function tests such as:
    - Function test and calibration of the instruments
    - Function test of the main and back up systems such as gas & electrical supplies, bell main and emergency systems, etc.
    - Function test of the handling systems
    - The heat protection of the bell can be partially removed with some penetrators to check possible corrosion and deterioration.
    - Hyperbaric evacuation system testing (Drills should be performed)
- The intermediate survey is performed between the 2nd and the 3rd year after the delivery of the certificate (so, 2,5 years). In addition to the elements tested during the annual survey, the following test are usually performed:
    - Gas leaks and function test of the safety valves
    - Function test of the fire detection and firefighting systems
    - Function tests of the life support and alarm systems
    - Function tests of the mechanical and electrical systems
- The class renewal is performed every 5 years. In addition to the elements tested during the annual and intermediate surveys, the following test are usually performed:
    - Bell buoyancy materials, heat protection, penetrators, windows and attached members are removed for inspection of possible corrosion and deterioration. Viewports are checked and should be replaced every 10 years.
    - Pressure tests and inspections are carried out according to the procedures selected by the classification society.
    - The working mass of the bell of pressure containing equipment is checked.
    - Static load tests of the bell handling systems are performed
    - If applicable, the bell's releasable ballast system with attachments are checked and tested (load tests)
- Occasional surveys for damage, repairs, reactivation and alterations:
  An inspection either general or partial according to the circumstances should be made every time a defect is discovered or an accident occurs which affects the safety and certification of the diving system or whenever a significant repair or alteration is made. The inspection should prove that the repairs or alterations carried out have been done effectively and are in full compliance with the guidelines of the classification body.
- Additional rule for portable systems:
  The rule applied is that the diving system is to be inspected and tested in accordance to the commissioning procedure before it is put back into service. For this reason, The owner of the system must inform the classification society about any installation and decommissioning operations of a portable diving system.
- Systems temporarily not used:
  It may happen that the equipment is not to be used for a long period. In this case, some classification societies propose specific procedures where periodic inspections are organized until the system is re-commissioned, so the class certificate is on hold, but not lost.

Alternative inspection techniques:

- Some classification societies say that it may be acceptable to carry out a pneumatic pressure test in lieu of hydraulic pressure testing. In this case, specific safety precautions, and downgrading the existing working pressure by the applicable safety factor provided in their documents (minimum 1.3) are to be applied.
- Another alternative promoted by some organizations is the use of Eddy current inspection techniques. In this case, upon completion of a successful leak test carried out to the Maximum Allowable Working Pressure (MAWP), eddy current testing is carried out on the weld surface of all external welds of windows, locks and interconnecting trunks.
- Also, note that classification societies usually accept test of seamless gas cylinders using acoustic emission in accordance with EN 16753, and also described in point 5.7 of the diving study CCO Ltd "Organize the maintenance of diving cylinders" that can be downloaded for free.

Systems downgraded to lower depths:
The classification society may decide to downgrade a system to a lower depth for various reasons such as:

- Carry out periodical pressure testing pneumatically.
- Following the installation of elements with a lower design pressure than the chambers
- Any other causes which may or may not imply a reduction of strength of the pressure vessel. It is often the case with old dive systems that are usually downgraded to a lower maximum depth by precaution.

4.2.2.5 - Select the classification society

As indicated previously, the organizations the most involved with the classification of diving systems are:

- DNV-GL (DNV)
- Bureau Veritas (BV)
- American Bureau of Shipping (ABS)
- Lloyd's Register of Shipping (LR)
- Registro Italiano Navale (RINA)

Other organizations may propose their services. However, the description of modern saturation systems demonstrates that they are intricate pieces of machinery. For this reason, an engineer specialized in boats will be lost if he has not a minimum experience of diving operations and diving systems.
Also, even though the organizations indicated above are among the most reputed and powerful classification companies, they are not well represented everywhere. For this reason, the selection of the classification society must not depend on only the financial and reputation aspects but also on the services the organization can provide in the country where the diving contractor acquiring the new system operates.
Also, the owner of the system must be aware that his choice will engage him with this organization for the life of the system. Changing a service provider is indeed possible. However, that will imply additional costs as, for such cases, most classification bodies re-start the process of classification from scratch. Nevertheless, in case that the new and the previous classification society involved with the classification of the dive system are members of IACS, the following process is usually applied:

- Examination of the drawings and documents (that must be stamped by the previous IACS member)
- Examination of materials and components certificate.
- Close examination of the diving system

For these reasons, it is recommended to:

- Ensure that the construction surveyors proposed are experienced with diving systems.
- Ensure that the relationship of the classification surveyors with the personnel of the company is smooth.
- Ensure that the relationship of the classification surveyors with the manufacturer is also smooth.
- Ensure that the classification society is established in the country for a long time.
- Ensure of the availability of the organization (as an example, can they intervene quickly for the mobilization of a portable system?)

Note that manufacturers are used to work with the classification societies they select. However, in case a problem is detected, the client has usually the possibility to ask for another certification body.

4.3 - Failure Mode Effect Analysis

4.3.1 - Purpose

The primary function of the Failure Mode Effect Analysis (FMEA) is to provide a comprehensive, systematic and documented system of investigation which establishes if the effects of the failure of one or more components of the diving system would lead to a life-threatening situation for the personnel, or unacceptable damage to the diving system or the environment, or a loss of production. Also, the Failure Mode Effect Analysis is a tool that is to be used to:

- Identify the weaknesses of equipment and which are its sensitive parts. Such records should be used for the implementation of corrective actions, and be transmitted to the manufacturer for guarantee purposes and help him to improve his products.
- Identify the control measures that can be implemented to increase the reliability of the equipment, solve the problem identified, and reduce the potential of failure. A lot of solutions can be implemented, internally or with the help of the manufacturer or external specialists such as increasing the maintenance frequency, modify the design of the machine, modify the operating procedures, modify the maintenance procedures, replace some genuine parts by others that are more reliable, etc.
- Select new equipment: The assessment of the reliability of the device may lead to its replacement with more reliable equipment if the control measures above are not satisfactory. The records of the problems encountered can be used when selecting the brand new device.
- Identify the spare parts to provide in priority: The records of the systems or components whose failure could be critical to the safe operation allow to mitigate such events by carrying essential spares.
- Identify the immediate control measures to be in place in case of failure of the equipment to make sure that the divers will never be in a life-threatening situation. These control measures can be backup systems ready for use, and procedures to alert the divers and recover them as soon as possible to a safe place. These procedures are to be introduced in the diving manual.
- Identify the necessary personnel for the maintenance of the system and their interfacing with the dive team and other parties on the worksite. Identification of the staff includes the number of people and their competencies to be sure of having 24 hours of assistance during the diving operations. Also, it allows identifying the persons who should be in charge of the maintenance of the system when it is not in use.

Note that an FMEA is usually required to comply with safety and quality requirements such as the certification and classification processes of equipment, ISO 9001, and others.

Common steps for performing an FMEA include:

1. The creation of a competent team.
2. The definition of the scope, and the establishment of guidelines.
3. The gathering of relevant documentation.
4. The identification of the items and processes to be analyzed.
5. The identification of the failures with their causes, effects, and their possible controls
6. The verification onsite of the issues identified and their corrective actions
7. The revision of the corrective actions and the re-evaluation of the risks.
8. The publication of the preliminary document and its final evaluation
9. The publication and the distribution of the final document.

4.3.2 - Types of Failure Mode Effect Analysis

There are many types of Failure Mode Effect Analysis that companies adapt to cover their industrial activities and differ with their risk evaluation methods. Three main approaches are commonly used, which are classified into two categories: The FMEA (Failure Mode Effect Analysis), and the FMECA (Failure Mode Effect Critically Analysis).

- "Risk Priority Numbers" (RPN) is a system of analysis used with Failure Mode Effect Analysis (FMEA) process that is based on the product of three criteria: Severity, likelihood, and detection.
  - Severity encompasses what is essential for safety, environment, production continuity, and damaged reputation. A score between 1 and 10 is often assigned *(see below)*, but some specialists prefer more simplified rates.
    - 1 = No disturbance
    - 2 = Effects extremely limited - Divers or/and surrounding, and company reputation not affected
    - 3 = Negligible effects - Divers or/and surrounding, and company reputation very slightly affected
    - 4 = System slightly affected - Divers or/and surrounding, and reputation slightly affected.
    - 5 = Some restriction of usability - Divers or/and surrounding, and reputation moderately affected
    - 6 = Failure of a few main functions - Divers or/and surrounding, and company reputation affected
    - 7 = Functions affected - Divers or/and surrounding, and company reputation highly affected
    - 8 = Major disruptions - Divers or/and surrounding, and company reputation extremely affected
    - 9 = Divers or the surrounding threatened - Violation of law possible
    - 10 = Extreme threat - Violation of the law.

- The likelihood indicates the frequency of an error. It is also often ranked between 1 and 10.
    - 1 = No failure recorded
    - 2 = Extreme low probability of failure
    - 3 = A very little number of failures may happen
    - 4 = A few failures are probable
    - 5 = Occasional failure may happen
    - 6 = Medium number of failures are probable
    - 7 = Failures are probable
    - 8 = High number of failures are probable
    - 9 = A failure is almost certain
    - 10 = A failure will certainly happen
- Detection is the possibility to be warned of the problem before it happens, and is also often ranked from 1 to 10.
    - 1 = Immediate detection
    - 2 = Very high probability
    - 3 = High probability
    - 4 = Occasionally high probability
    - 5 = Medium probability
    - 6 = Almost medium probability
    - 7 = Little probability
    - 8 = Very little probability
    - 9 = extremely low probability
    - 10 = No detection

The scores of these three criteria are multiplied to calculate the Risk Priority Number *(RPN = Severity x likelihood x detection)*. Then, the team decides on the evaluation of the Risk Priority Number. Two methods are commonly used:

- A lot of organizations select an RPN limit to determine which failure mode requires corrective action and which risks are acceptable. As an example, 125 (5 x 5 x 5) is often considered a maximum limit, and values between 50 and 125 considered "As Low As Reasonably Practicable (ALARP)" with rankings based on ten levels. Some specialists say that the risk with this method is that the team may trend to minor values to be below the threshold, which can result in critical situations. The example of the matrix below is based on this method.

			Likelihood											
			No failure	Extremely low	Very little probability	Few failures probable	Occasional failure	Medium number	Probable	High number	Almost certain	Certain		
			1	2	3	4	5	6	7	8	9	10		
Severity	No disturbance	1	1	2	3	4	5	6	7	8	9	10	1	Immediate	Detection
	Extremely limit	2	4	8	12	16	20	24	28	32	36	40	2	Very high probability	
	Negligeable	3	9	18	27	36	45	54	63	72	81	90	3	High probability	
	Slightly affected	4	16	32	48	64	80	96	112	128	144	160	4	Occasionally high	
	Some restrictions	5	25	50	75	100	125	150	175	200	225	250	5	Medium	
	Failure few main functions	6	36	72	108	144	180	216	252	288	324	360	6	Almost medium	
	Functions affected	7	49	98	147	196	245	294	343	392	441	490	7	Little probability	
	Major disruptions	8	64	128	192	256	320	384	448	512	576	640	8	Very little probability	
	Threats	9	81	162	243	324	405	486	567	648	729	810	9	Extremely low	
	Extreme threats	10	100	200	300	400	500	600	700	800	900	1000	10	No detection	

- Other organizations address the corrective action for the top RPNs. After that, the team resets and find another top RPNs for the next improvement process. Some specialists prefer this method as it is reputed to promote continuous improvement. Nevertheless the absence of an upper limit may also lead to a condition where too high risks are accepted.

- The "quantitative criticality analysis" is a method of evaluation used with Failure Mode Effect Critically Analysis (FMECA) that consists in:

- Defining the unreliability of each item at a given operating time.
- Identifying the portion of the items that can be attributed to each potential failure.
- Rating the probability of severity that results from each failure that can happen.
- Calculating the criticality for each potential failure by the product of the three factors: *Item unreliability x Ratio of unreliability x Probability of severity.*
- Calculating the criticality of each item by the sum of the criticalities for each failure that has been identified: *Item Criticality = SUM of Mode Criticalities.*

- The "qualitative criticality analysis" is another method used with Failure Mode Effect Critically Analysis (FMECA) that consists in evaluating risks and prioritising corrective actions:
  - The severity is evaluated similarly as for a risk assessment, so a rate is given according to the potential effects of the failure on people, environment and asset. See below an example with three levels:

	Harm to people	*Impact on environment*	*Damage to equipment*
Low = 1	Minor injury	Minor impact	Minor damage
Medium = 2	Serious injury	Serious impact	Serious damage
High = 3	Fatality and multiple injuries	Major impact	Major damage

  - The likelihood of occurrence is evaluated and rated. See below an example with four levels:

Very low = 1	*May occur only in extreme circumstances*
Low = 2	*Unlikely to occur*
Medium = 3	*Would probably occur*
High = 4	*Likely to occur within a very short period*

  - The failures are compared using a matrix that indicates the severity on one axis and the likelihood on the other one to determine whether the risk is low, medium, or high using a preset risk tolerance.

1 = Low	*No warning: The activity can continue as the risk reducing are adequate*
2 to 5 = Medium risk	*Warning: The activity may continue, provided that the additional control measures identified in the task risk assessment are implemented.*
6 to 12 = High risk	*Danger: The activity must be stopped as long as the risk is not eliminated or adequately mitigated.*

	Likelihood			
Severity	*1*	*2*	*3*	*4*
3	3	6	9	12
2	2	4	6	8
1	1	2	3	4

The selection of the system of analysis is generally decided by the team during the process. It usually depends on the complexity of the system and the purposes for which the FMEA is designed. However, FMEAs using "Risk Priority Numbers", and FMECAs using "qualitative criticality analysis" seems more frequently used in our industry than FMECAs based on "quantitative criticality analysis".
Note that the final document published must provide immediate answers to solve any problem encountered as soon as possible, and ensure that the divers are never in a threatening situation.

4.3.3 - Creation process of a Failure Mode Effect Analysis system

IMCA D 039 provides detailed guidelines for the creation of an FMEA that can be downloaded at this address: https://www.imca-int.com/publications/228/fmea-guide-for-diving-systems/. This guidance can be used as a reference for the creation of an FMEA adapted to diving systems. However, other sources can be gathered as a complement to create a model fully adapted to the diving system in service and the needs of the people operating it.

1 - Creation of a competent team:

IMCA says that the team in charge should be multi-disciplined. These people can be in-house personnel or third-party specialists from different companies. However, they must be competent for this task, and for this reason, there should be a system in place to identify the minimum standards for their selection, such as an example:

- Excellent knowledge of the guidelines to apply.
- Competencies in management controls, communications, and administration.
- A technical level based on experience in the industry and relevant academic qualifications.
- A level of expertise in FMEA, risk analysis, and diving system auditing.
- Track records and references relating to previous similar works.

Regarding the selection of third party personnel, note that a lot of companies prefer using the services of classification societies. The advantage of this choice is that these competent bodies are generally involved in the evaluation, and the creation of FMEAs as these documents are among the supporting documentation they request for the classification process of diving systems. So they are fully qualified for such tasks. Some companies also use the services of independent specialists referenced by a government or recognized competent bodies.

IMCA says that a typical team should be composed with at least the following competencies:

- A leader who manages the overall process, and can be a specialist in a particular technical domain.
- A mechanical engineer with experience and knowledge of the components of dive systems such as gas systems, hydraulic systems, pressure vessels, handling systems, etc.
- An electrical engineer with knowledge of power distribution, control, and instrumentation systems.
- Operational input from diving supervisors, life surface supervisor, and people involved with the system.

In addition to what IMCA says, we can see in chapter #2 of this book that computing applications are today parts of diving systems and that this trend is now increasing. So a computing specialist should be included in such a team. Also, the team leader should be multidisciplinary. The reason is that although he is not the most competent in each domain, he is the person who must have an overall picture of the process ongoing. Also, he is the person in charge of the communication of the team with the management of the company and external entities, so having such skills is essential for such a task. Note that the number of team members may vary during the process according to particular help the core team may need.

2 - Definition of the scope and establishment of guidelines:

To clarify the scope of work and the guidelines for the creation of the FMEA, an essential task is to investigate the boundaries of the design and the operating procedures of the diving system and the conditions it is planned to be used. Note that IMCA says that the functional design specification of the system should define:

- The environments in which the diving system is expected to operate and the performance level expected with the environmental conditions that can be the source of failures.
- The diving system class notation and the limitations imposed by the classification society or the certifying authority.
- The boundaries of the equipment to be assessed as part of the diving system.

As a result of this first description, and based on previous experiences, the team should have a rough idea of the scope of work and of the guidelines to be implemented to eliminate or mitigate the impact of unacceptable failures to ensure that the protections of the divers are in place with adequate redundancy.

In addition, IMCA says that an adequate timescale must be given for the creation process with deadlines for:

- Issue of the preliminary FMEA report, including any recommendations and necessary sea trial tests.
- Closing out of those recommendations made as a result of the FMEA: It is essential that every recommendation made is addressed and the action taken is recorded, even if a decision is taken not to take action.
- Issue of the final FMEA report, including the actions taken as a result of any recommendations made and the results of the sea trial tests.

Note that it is prudent to calculate for additional time than necessary instead of the opposite not to put the team under pressure in case of unexpected problems are found.

IMCA also says: *"For a new diving system, the FMEA should ideally be commissioned as early as possible in the project. It is advisable that a high-level analysis at the design outline stage is specified, so that the initial FMEA output can be used as guidance in the engineering phase".* Regarding this point, we can say that the FMEA is today usually at the responsibility of the manufacturer as this document is part of the certification process that is typically performed by an independent competent body. Thus, most FMEA undertaken today by diving contractors are linked to modifications of an existing system, the replacement of equipment by a different one, or a quality and safety process such as the implementation of a new management system. Nevertheless, it is usual that the diving contractor delegate some personnel to be involved in the FMEA process when a new system is bought.

3 - Gathering the relevant documentation:

When the steps above are completed, the team members select and collect the supporting documents they need. Regarding this point, IMCA says that the team should have access to the necessary IMCA documentation. In complement, we have seen that diving systems are also built according to other standards the team must have access to. For this reason, a list of relevant guidelines and standards should be established, and a library created. Additional documents may be necessary during the design process of the FMEA. The references used for the creation of the FMEA will have to be then listed in the final document.

Note that IMCA guidelines are available for free for IMCA members, but not for the others. Also, the majority of the published standards are to be bought and they are often expensive. For this reason, a budget must be provisioned for this purpose. Of course, the documentation to be gathered includes calculation notes and construction drawings of the diving system. Regarding this point IMCA gives the following list:

- General arrangement drawings.
- Electrical and control system single-line drawings and circuit schematics.
- Gas system single line drawings and circuit drawings/schematics.
- Fluid systems single line drawings and circuit drawings/schematics.
- Handling system drawings and schematics.

- Operating and emergency manuals.
- Planned maintenance details and defect reports.

In addition to this list from IMCA, the software designs of the components of the system should be documented. Also, the six months and one-year audit, and the certification, and classification files, should be available if the system is already in service.

4 - Identification of the items and processes to be analyzed:

When the team has the relevant documentation indicated above, the identification of the processes to be analyzed can start, so the team can establish a list of the systems, subsystems, and components to be analyzed.
It is crucial to classify the elements to analyze so that they can be easily identified and referenced. Teams often rank them according to their criticalities. As the diving system works through the interaction of many components and subsystems, such classification is not easy to organize, and the teams often reference the main elements and then their subsystems that may require a particular FMEA. Nevertheless, depending on the solution selected by the team, it is possible to link the main components to the Diving Equipment Systems Inspection Guidance Notes (DESIGN) IMCA such as D 023, D 037, or D 040 and the Planned Maintenance System (PMS) on the "general" FMEA, so the items referenced there can be easily found by the supervisors and indicated to the technician when a problem is detected.
Also, IMCA D 039 says that applying FMEA techniques to a diving system can yield a great deal of information relating to its failure behaviour, but can be time consuming and expensive. For this reason, this guidance recommends to understand and define the objectives of the analysis clearly. This topic is more discussed in point 4.3.1.

5 - Identification of the failures, their causes, effects, and their possible controls:

When the systems and process to be analysed are identified, the team can work in detail on them, so that critical operating modes can be detected and addressed. Based on the documents and the limitations of the system, the team is normally fully aware of the process to follow to identify potential hidden failures and determine their effects. Note that such a process may highlight some problems of conception that will have to be addressed. The team should also be able to decide which method of analysis is the most appropriate. Thus, select an FMEA or an FMECA format.
This phase of the task must be fully documented using the drawings, engineering calculations, and safety evaluations. These analysis are usually performed on worksheets. Regarding this point, IMCA says that for each failure mode the team should identify:

- The effect of a system or component failure on the particular system, sub-system or component.
- The effect of such a failure on other related systems or sub-systems.
- The effect of such a failure on the continued safe operation.

6 - Verification onsite of the issues identified, and their corrective actions:

The worksheets should be verified onsite to confirm that the analysis is relevant. IMCA says that this review should include the verification of the accuracy of the data provided to perform the analysis, and focus on the implementation of mitigation features for identified failure modes such as:

- Redundancy of components.
- Operating and emergency procedures.
- Spare parts stockholding and maintenance procedures.

IMCA also says that the testing phase, which data are to be incorporated into a trials report and then the final report, is necessary to confirm:

- That the hardware is installed and operated in the manner that is set out in the FMEA, and that mitigation features set out in the FMEA worksheets are in place and effective.
- That the system operators and maintainers are fully familiar with the operation of the equipment and systems, including emergency features or procedures, and that the findings of the analysis are accurate.

7 - Revision of the corrective actions and re-evaluation of the risks:

At the end of the initial testing phase, the suitability of the corrective actions should be carefully assessed to ensure that there is no unseen problem. Also, this testing phase may not be fully successful, and that some problems that require other solutions or additional control measures may have to be addressed and may require additional tests.

8 - Preliminary document and last verification:

A preliminary document should be published that can be used as support for the final tests. Then, as recommended in IMCA D 039, trials in operational conditions should be performed that focus on the failure modes identified in the analysis phase which have an impact on safety, pollution, financial impact or other determining factors. The trial documents should set out each test protocol and should include:

- The systems, sub-systems, or components to be tested.
- How each test should be performed, with the expected results, and the actual results.
- Whether the tests are satisfactory with appropriate comments.
- Following the last trial, the final FMEA document should be finalised, and transmitted to all parties for acceptance.

9 - Publication and distribution of the final document:

The final document is to be published through the management system of the operator. This document is usually a full file that explains:

- The methodology for the creation of the FMEA.
- The description of the system analysed.
- The analysis performed, and the reasons for this choice
- The failures discovered, and the solutions implemented to solve them.
- The conclusions, and the recommendations.
- Drawings, charts, analysis matrix, and guidelines to solve problems.

Note that conclusions and recommendations from the FMEA are to be included in the operational manuals.

4.3.4 - Updating the Failure Mode Effect Analysis procedures

The FMEA is a document that provides safety solutions and means of investigation and interventions according to the technology available and the working practices in force during the period it has been created. It will become obsolete as a result of changes in operating procedures and modifications of the diving system such as an example, the change of a component by another one from another manufacturer, or the upgrading to a new technology such as the adaptation of a diving monitoring system to an old generation system. Also, some solutions published in the final document may be perfectible and unexpected events may happen. For these reasons, the FMEA should be checked and reviewed at regular intervals:

- IMCA suggests performing a trial every year and at each mobilization for the portable systems, which is, in fact, the frequency of auditing of a diving system.
- Undesirable events that may happen should be recorded, investigated, analyzed, and be adequately solved. For this reason, a system of reporting must be in force. Detailed recording of events is usually the responsibility of the senior dive system technician in charge of the diving system, who communicates directly with the equipment manager of the company.
- A system of updating of the operating procedures of contractors is usually asked by the clients, notably the IOGP members. It is admitted that, depending on the quality of the manuals, the size of the company, and the complexity of the equipment it uses, such reviews can be made at a frequency between one and three years, except for updates that require immediate implementation.
  Based on the fact that the revision of the company operating procedures may have an impact on the way the equipment is used and may lead to technical modifications, we can say that the update of the FMEA of the dive systems should be scheduled at the same period. However, it must be considered that the full revision of an FMEA takes time and that the company may use numerous diving systems that cannot be checked at the same time. For this reason, such updates are to be organized through the Planned Maintenance System.
  Regarding this point, IMCA suggests that provided that any changes that are made during the life cycle of the diving system are appropriately analyzed, and the FMEA is updated following the change control management procedure, it may not be necessary to update the FMEA formally regularly, and that, depending on the contractor, a frequency between one or two years could be acceptable.

Note that IMCA D 039 proposes a model of a worksheet and another one for the record of the change in its appendix:

- The worksheet records the following elements:

- Identification of the system
- Function and operating mode
- Failure mode identified and the cause of this failure
- The effects of the failure
- Critical analysis
- Mitigation and notes

- The FMEA management of change sheet indicate the following elements:

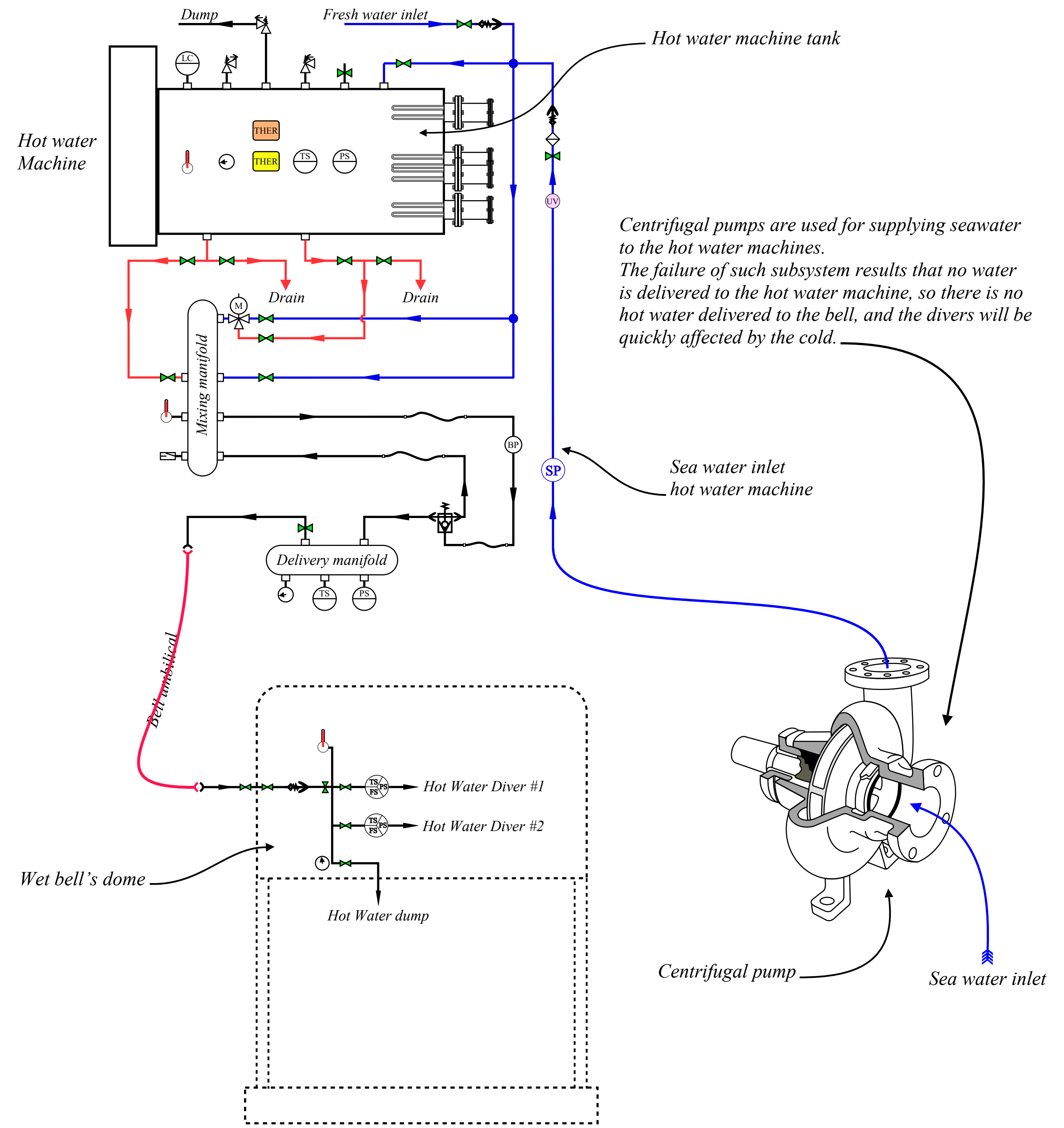
- Diving system identification
- Date
- Reference FMEA
- System and item affected
- If the change results from an incident
- The reasons for the change
- Effect of the change on the diving system
- Whether the change affects the FMEA
- Whether function tests and FMEA trials have been carried out
- Whether the change affects the company manuals
- Whether the change applies to other company diving systems
- The circulation list *(dive supervisors, Life support supervisors, Chief engineer, dive system technicians)*
- The technical department supervisor signature
- The Operation manager signature

These documents are completed by a list of the systems and sub-systems that may be used as a guide.

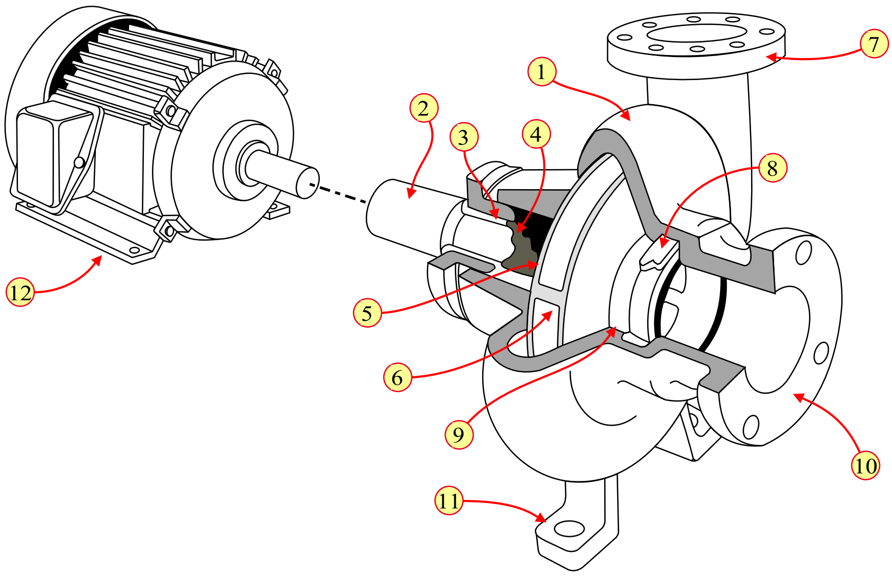
4.3.5 - Failure Mode Effect Analysis forms adapted to dive systems

It often happens that several FMEA formats are used with a diving system. The reasons are that diving systems are ensembles of elements from several manufacturers who provide the FMEAs they consider the most appropriate for the products they design and sell. In addition, although a FMEA may be sufficient to describe the primary function of the diving system, subsystems may have criticalities that need to be specified through a FMECA. Of course, during the process of certification of the diving system, the acceptance of the FMEAs of the manufacturers is usually the responsibility of the competent body in charge who has the authority to require modifications.

Numerous formats can be selected or adapted to the needs of a contractor, and some operators may prefer having a FMEA system that uses one or a limited amount of company forms to ensure that everybody discusses the same elements of their diving systems. However, the difficulty of such a management procedure is to create suitable formats that cover the main systems, subsystems, and the components of theses subsystems that are needed by the people who operate the diving system.
As already said in step #4 of point 4.3.3, It is necessary to give a limit, because an FMEA can yield a great deal of information relating to failure behaviour that can be time-consuming to record, challenging to organize and interpret, and finally not really useful for the personnel operating the dive system.
As an example, the centrifugal pump used to feed seawater to the hot water machines that supply the bell and the divers is a subsystem in which the breakdown results that no more seawater is coming into the tank of the hot water machine. Then, no more hot water is supplied to the bell and the divers. who will be quickly affected by the cold. It is the reason a backup device should be ready to go online. So, the FMEA of the supervisor may not need to be developed further as his concern is to be sure that he has a control measure, to supply the divers with hot water in such a situation.



If the team decides to provide further details, it is necessary to describe the components of this subsystem which is an assembly of the following elements which some of them can be a source of breakdown:



Nb	Item	Function	Possible failure
1	Housing	It houses the impeller and the parts that allow it to rotate and create a suction. It is the frame of the pump.	It can be damaged by the failure of the parts in movement in it, or a dropped object if the pump is not installed in a protected place.
2	Shaft	It is connected to the driving motor and transmits its motion to the impeller.	It can be damaged by the failure of the parts that hold it that may create exaggerated gaps leading to vibrations and wear.
3	Bearing shaft	It maintains the shaft and the impeller in line and allows them to turn freely. It usually has bronze rings, ball-bearings, or roller-bearings.	Its failure results in the shaft and the impeller possibly being damaged. Such damages can extend to the housing as well.
4	O-rings	They are usually in the shaft sleeve and designed to make a perfect seal.	A failure results in a leak with water coming out, and the suction that cannot be established.
5	Junction shaft - impeller	Attachment of the impeller to the shaft. It can be bolted or welded.	Bolt failure is possible as a result of vibrations. However, such a breakdown is rare.
6	Impeller	Create the suction and the ejection of the water as a result of its rotation.	It can be damaged by foreign objects entering the housing if there is no filtration, or by cavitation effects if the piping is improperly designed, or the failure of one of the parts indicated above.
7	Connecting flange to the outlet pipe	It allows for a perfect mechanical connection and seals with the outlet pipe. It is usually bolted	The failure of the seal results in water coming out and the sealing of the pipe that cannot be established. A similar problem should happen in the case of loosened bolts.
8	Bearing impeller	Same function as #3	Same failure as #3
9	O-ring impeller	Same function as #4	Same function as #4
10	Connecting flange to the inlet pipe	It allows for a perfect mechanical connection and seals with the inlet pipe. It is usually bolted	The effects are those indicated in #7, with in addition the suction that cannot be made.
11	Fixation legs	They maintain the pump in place on the chassis it is installed on. The fixation is usually by bolting. Silent blocks may be used to absorb noise and vibrations.	A loosen bolt may generate exaggerated vibrations that will impact the elements listed above and transmit to other parts of the system through the vibrations generated to the piping.
12	Electric motor	It is the subsystem that drives the pump. It is composed of a rotor, bearings, shaft, stator, etc.	A failure of the motor results in the pump that is not in motion, so it is unable to supply water.

The example above shows that introducing too many sub-systems obliges to deal with numerous information that can lead to a complex presentation, and at last a document that becomes unreadable because too many things are in it. For this reason, the main FMEA should be limited to a reasonable level to which more specific FMEAs that can be from manufacturers can be linked.
Note that a lot of suppliers provide their FMEA on formats that are designed to be updated by the operator of the diving system or the manufacturer.
The example on the next page is a compilation of several FMEA company formats using “Risk Priority Number” (RPN)

Tables of contents

The sheet below is oriented in the "portrait" mode for convenience. However, landscape orientation is usually employed with FMEAs forms.
The purpose of this example is not to publish the "ideal sheet", but to explain how they are usually designed. For this reason it is intentionally limited to the main subsystems. It is to the people organizing the FMEA to add additional levels or not, taking into account the problems highlighted on the previous pages.

1- Identification	***Failure Mode Effect Analysis (Name + logo company)***			
	Dive system: *Lichtenstein*	***Revision number:*** *1*	***Document #:*** *01*	
	Date: *7/5/20*	***Auditors:*** *Chris*	***Sheet number:*** *1 of ...*	
	Part of the system: *Diver heating system*	***Item:*** *Hot water machine*	***Manufacturer:*** *Comanex*	
2 - Identification component and description of the potential failures	***Component***	*Centrifugal pump seawater inlet*	*Centrifugal pump*	*Component #2*
	Function item	*Supplying seawater to the machine*	*Idem*	
	Operating mode	*Automatic when the machine is started*	*Idem*	
	Identified failure modes	*Leaks*	*Electric motor*	
	Main/local effect	*No suction / pressurization: No water supply to the hot water machine*	*Pump not actuated*	
	Subsequent failures & effects	*No hot water to the divers*	*No hot water*	
3 - Controls	***Existing safeguards***	*Daily visual inspection & close inspection every month*		
	Additional control measures	*Backup hot water machine ready*		
4 - Initial Risk analysis (RPN)	***Severity (Rate: 1 to 10)***	*4*		
	Likelihood (Rate: 1 to 10)	*3*		
	Detection (Rate: 1 to 10)	*3*		
	RPN = Severity x Probability x detection	*36*		
5 - Identification and description of the rectifications implemented	***Suggested rectification***			
	Person in charge			
	Planned date of rectification			
	Rectification performed			
	Rectification trial			
	Rectification completion date			
6 - Residual Risk analysis (RPN)	***Residual severity (Rate: 1 to 10)***			
	Residual probability (Rate: 1 to 10)			
	Residual detection (Rate: 1 to 10)			
	RPN = Severity x Probability x detection			
7 - Notes	***Notes / recommendations***			

- 1 - FMEA record sheets are to be identified. The following information are usually displayed:
    - Name and logo of the manufacturer or of the owner of the system is usually displayed.

- Reference of the dive system.
- Reference of the document and its revision number.
- The number of the sheet and the total number of sheets
- Date of audit
- Names of the auditors
- Part of the diving system analysed and the item (Main component of this part)
- Manufacturer *(not used when the FMEA is performed by the manufacturer)*

- 2 - The 2nd step is the identification of the component and the description of its potential breakdowns. These columns that are usually on the left side of the sheet when it is oriented in "landscape" mode, give the following information:
  - Identification of the component and its function
  - The operating mode of the component
  - Identified failure modes
  - The direct effect of the failure
  - Subsequent effects of the failure

- 3 - The 3rd step is the identification of the protections in place to mitigate the effect of breakdowns.
  - Existing safeguards
  - Additional control measures *(note that a lot of companies group the means of control in only one box)*

- 4 - Step #4 is the analysis of the initial risk using the method of analysis selected *("Risk Priority Number" (RPN) in this example).*

- 5 - Step #5 is the identification of the corrective actions to mitigate the effect of breakdowns.
  - Suggested rectification
  - Person in charge
  - Planned date of rectification
  - Rectification performed
  - Rectification trial *(a trial should be performed to ensure the the rectification is adequate)*
  - Completion date *(the date when the equipment can be or has been returned to service)*

- 6 - Step #6 is the analysis of the residual risk after rectification.

- 7 - There is usually a box where the persons in charge of the analysis can give recommendations and other comments.

To conclude with this point:
When studying the FMEA, the ideal solution is to involve people in charge of the exploitation of the diving system since the beginning of the process to obtain documents that suit to the procedures in force in the company, and easy to exploit.
As demonstrated, the most significant difficulty will be to define the extends of this document to be sure it suits the needs for efficient control of the diving system, which is sophisticated machinery.
One of the functions of the FMEA is to allow investigating a technical problem to make an immediate decision regarding the safety of the divers, and then repair the breakdown. For this reason, it may be preferable to develop a model that is simple and describes only the main functions of the diving system to which FMEAs of the sub-systems (that could be those made by the manufacturers) can be linked, instead of doing a more detailed FMEA which may be challenging to design and exploit, and finally not to be an efficient tool.

4.4 - Planned maintenance system (PMS)

4.4.1 - Purpose

The Planned Maintenance System (PMS) allows diving operators to carry out the maintenance of their diving systems at scheduled intervals according to the requirements of manufacturers, classification societies, IMCA, and other diving or safety organizations. Also, note that this equipment management system is mandatory by most of the organizations indicated above, the clients, and also in International Maritime Organization (IMO) that says in the International Safety Management Code (ISM): *The Company should establish procedures to ensure that the ship is maintained in conformity with the provisions of the relevant rules and regulations and with any additional requirements which may be established by the Company. In meeting these requirements the company should ensure that:*

I. *inspections are held at appropriate intervals,*
II. *any non-conformity is reported with its possible cause, if known,*
III. *appropriate corrective action is taken, and*
IV. *records of these activities are maintained.*

Because diving systems used offshore are onboard vessels, we can say that the implementation of the planned maintenance system of diving systems is mandatory for all companies working at sea. The senior dive system technician usually supervises this task onboard the vessel, and communicates with the equipment manager in the headquarters.

4.4.2 - Elements to be in the record documents

The planned Maintenance System must be organized and the documents recorded as follows:

- There should be a chart indicating how the maintenance system is organized and how the documents must be filled. Also, the language used should be understood by everybody. For this reason, English is used.
- There should be the inventory of the items included in the maintenance program.
- The certificates must be updated and available for the diving & life support supervisors, and every person involved in the organization and the following of the dives. IMCA says that there should be no doubt on which day maintenance has been carried out and by whom. IMCA also says that it important that more than one copy of these documents exists. So a copy or the original should be kept in the office onshore. Note that every copy should provide evidence that conforms to the original.
- The intervals at which the maintenance jobs are to take place must be indicated. The scheduling of the maintenance, documentation used, and procedures applied should be according to the recommendations of the manufacturers and the classification society.
- Also, as I recommend using the Diving Equipment Systems Inspection Guidance Notes IMCA D 023, D 037 & D 040 for the audits of the dive systems, the recommendations from these documents and the guideline IMCA D 018 “Code of practice for the initial and periodic examination, testing and certification of diving plants and equipment” should be followed as well. Note that if a conflict arises between the manufacturer rules and those from IMCA or the document selected, the most stringent standard should be applied.
- When maintenance work is performed, the documentation used as a guideline should be indicated in the records. Also, these records should show the planned and the unplanned works performed. In the case of an unexpected intervention, the document should also specify the reason for this intervention. If the repair follows a breakdown that resulted in an incident, that must be indicated with the file of the incident report in the attachment. If the maintenance of an item is delayed, the reasons for the delay and the date planned for the intervention must be indicated with the control measures in place not to affect the safety of the people.
- The previous maintenance jobs carried out should be recorded and kept available in the history files of each element of the dive system. IMCA D 018 says that certificates should be retained in a register for a minimum period of two or five years depending on the item of equipment and its application. As already indicated, there should be several copies of these documents.
- The availability of adequate spares to allow routine and non-routine replacement should be indicated.
- There must be traceability to the person who carried out the work on an item of equipment. For this reason, precise reports must be filled and signed by the technician in charge. Such documents should be checked and also signed by the senior technician in charge of the system.

4.4.3 - Organize the Planned Maintenance system

4.4.3.1 - Personnel in charge

As already indicated in point 4.1.2.2, managers will not be successful in implementing an efficient Planned Maintenance System if there are no competent people to do it. Thus, this point is the most critical and challenging to implement.
Also, there are maintenance operations that cannot be performed by every technician, so the people in charge must ensure to provide such competencies. Regarding this point, the document IMCA D 018 that gives guidelines regarding the appointment of competent persons says: *No official body appoints competent persons for the purpose of examining and testing diving plant and equipment. This is entirely a matter to be decided by the person or organisation which wishes to obtain the certification. The competence of any particular individual or organisation may, however, be challenged by any relevant national authority in its enforcement role.*

IMCA D 018 references four levels of competencies for the examination of diving plants and equipment:

1. An IMCA or equivalent level diving or life support supervisor duly appointed by the diving contractor: His competency should be limited to external visual examinations and function tests of the equipment he is familiar with, unless he has additional specific training.
2. A technician or other person specialising in such work who may be an employee of an independent company, or an employee of the owner of the equipment (unless specific legal restrictions apply), in which case his responsibilities should enable him to act independently and in a professional manner.
3. A classification society or insurance company surveyor, or chief engineer certificated in accordance with IMCA C 002 guidelines and competence tables: Marine Division (Job Category A06) but who may also be an “in-house” chartered engineer or equivalent (unless specific legal restrictions apply), or person of similar standing.
4. The manufacturer or supplier of the equipment, or a company specialising in such work which has, or has access to, all the necessary testing facilities. That may also be a technician employed by the owner of the equipment provided that he has been fully trained and certified for the specific operation and has access to all necessary equipment and facilities.

Note that, as indicated in point 4.1.2.3, the use of external service providers is usual for the maintenance of diving systems that are assemblies of elements in which some parts require particular skills the technicians in charge have not, or which need the use of expensive tools which investment is not justified. The selection of these providers should be performed according to the guidelines also indicated in point 4.1.2.3.

4.4.3.2 - Prepare relevant documents

The principle of the Planned Maintenance System has been invented before the democratisation of computers during the nineties. These initial equipment management systems were based on intervention sheets and store lists that were recorded in a book where the operations performed and planned were logged by hand-writing. There is probably no company using such a not computerized system today. However, the same organizational frame is conserved for the creation of management systems using computers.

A diving system is composed of many items that are identical but installed in different parts of the system. It will be necessary to identify each of them, as each component of the dive system must be appropriately tested and maintained. As an example, there are many gauges on a diving system, and each one has a particular function. For this reason, the technician in charge of the maintenance of the system must be able to identify each gauge. That obliges the people organizing the Planned Maintenance System to indicate:

- The diving system where the item is installed
- The part of the system the gauge is installed
- The function of the panel where the gauge is installed
- The function of the gauge (depth gauge or gas supply gauge)
- The model and the name of the manufacturer, and whether it is analog or digital
- The position of the gauge on the panel

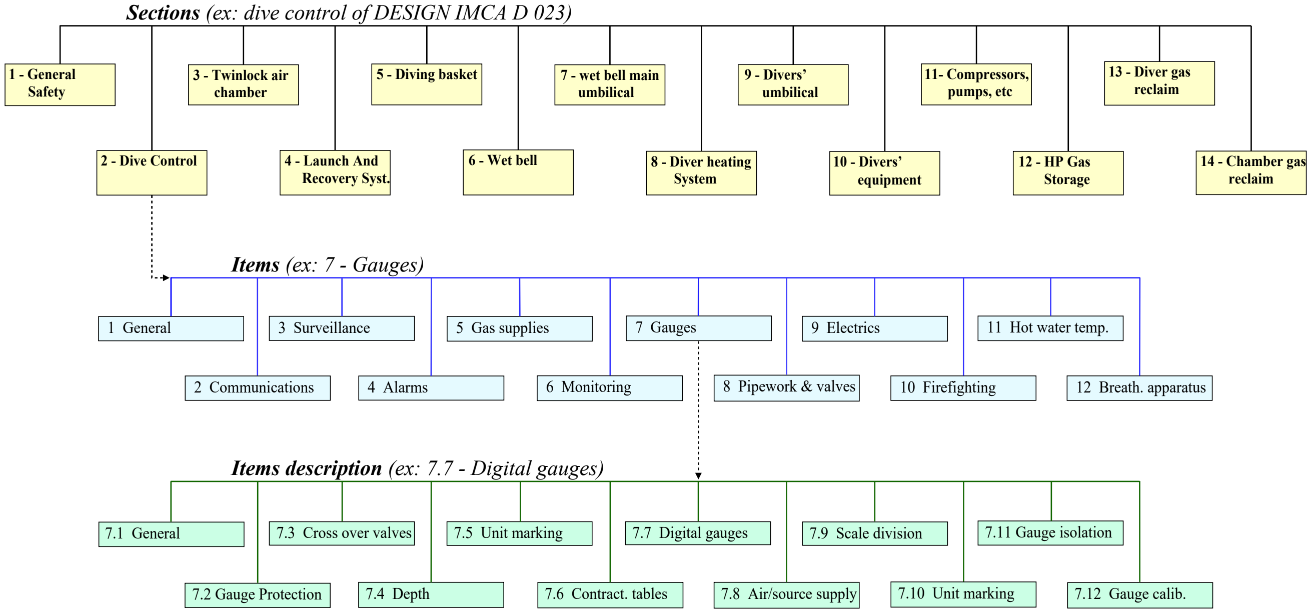
Reference numbers are the identification system most used. It usually allows to indicate where the element is installed, and its function and model. These reference numbers must be listed and also indicated in a reference document.
To locate the exact position of the elements, a precise scheme/drawing of the system where all the elements are precisely indicated must be edited. Photos can also be used as a support to avoid confusion. These scheme and drawings must be attached to the Planed Maintenance System and the documents used to audit the diving system.
Note that if acronyms are used they must be explained in a glossary that is attached to the list and the drawings.

Another point regarding the reference numbers is that they are linked to the way the dive system is referenced, as some differences exist regarding this critical point that is linked to the management system of the company exploiting it, and whether it is permanently installed onboard the surface support or is a portable unit. No specific rule is currently published for the moment except that the technicians and people working with the diving system must be able to find the maintenance documents they need quickly. For this reason, numerous technics of referencing exist that would be too long to describe. However, we can roughly classify the methodologies encountered as follows:

- Some companies arrange their referencing scheme according to the IMCA Diving Equipment Systems Inspection Guidance Notes (DESIGN), so they can refer to the IMCA audits of the system to find the corresponding maintenance documents and prepare the next ones. The advantages of such system is that the preparation of the IMCA DESIGN audit is more comfortable and that this method of reference is based on documents that have proved their efficiency regarding the identification and the following of the components of a diving system. However, this method may conflict with others referencing procedures.
- Some companies base their PMS on the system used by the classification company during the classification process of the system. The advantage is that the preparation of the surveys planned by the classification society is easier, but that oblige the contractor to classify the documents in another manner if the classification society uses another system of reference than the one used in the IMCA DESIGN documents. Thus, to avoid having double tasks, the wise idea is to ask the classification society to organize a Planned Maintenance System that can be used for the two audits. Such discussion is essential during the process of selection of the manufacturer and the classification society, as to be obliged to use several systems of referencing leads to additional costs and possible confusion.
- Some contractors prefer using a system of reference that can be one of the mother organization that owns the

company (in case the company is part of a group), the one in force on the boat the diving system is installed, or merely the method used by the software used to manage such operations. The inconvenience of such classification is that it may create additional tasks to link the documents of the Planned Maintenance System to the class surveys and the IMCA audits.

Note that the IMCA Diving Equipment Systems Inspection Guidance Notes (DESIGN) are organized as follows:

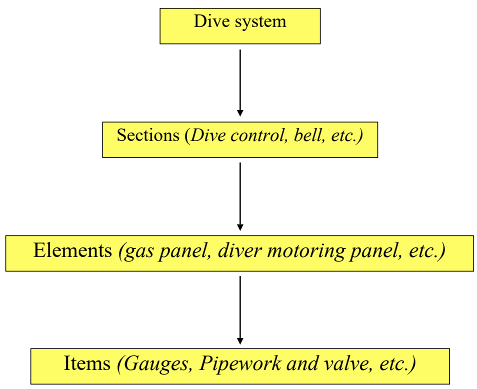


With this method of referencing, the items (as an example, the gauges) are grouped by function in the dive control. As an example, the gauges are all listed in the same file where the role and situation of each of them are to be indicated.

Some people may prefer a system of referencing that describes these items (gauges, valves, etc.) and their function in the elements that compose the dive control, such as those indicated below:

- Gas supply panel
- Gas reclaim management panel
- Gas analysis panel
- Diver monitoring panel
- Wired communications to and from the divers and through water communication
- Communications to the bridge and other parts of the boat
- Diver monitoring system
- Video recording system
- Hot water machine control panel
- Power supply controls

In this case, the referencing procedure is organised as follows :



To organize the structure of the planned maintenance system, people referencing the items must lean on the drawings and organizational scheme of the diving system to locate each element and provide support the reader can refer to. For this reason, a folder should be created where the drawings of the elements constituting the dive system are grouped. These schemes/drawings can be those made by the manufacturer or by a competent person category 2 or 3. The person in charge must ensure that:

- If some modifications have been made they are precisely indicated.
- That the drawings/schemes are easy to read.
- That the drawings/schemes are easy to find.
- That a copy of each drawing is in a safe place.

The documents used during the construction of the dive system must be available. For this reason, the folder where the drawings are classified should also contain:

- The documents that have been used for the “classification” of the diving system plus the certificate of classification.
- The elements that have been used to write the Failure Mode Effect Analysis (FMEA) plan plus the FMEA plans that are classified chronologically.

When the structure of the Planned Maintenance System is established, the people in charge should make sure that the items can be easily identified. For this reason, they should:

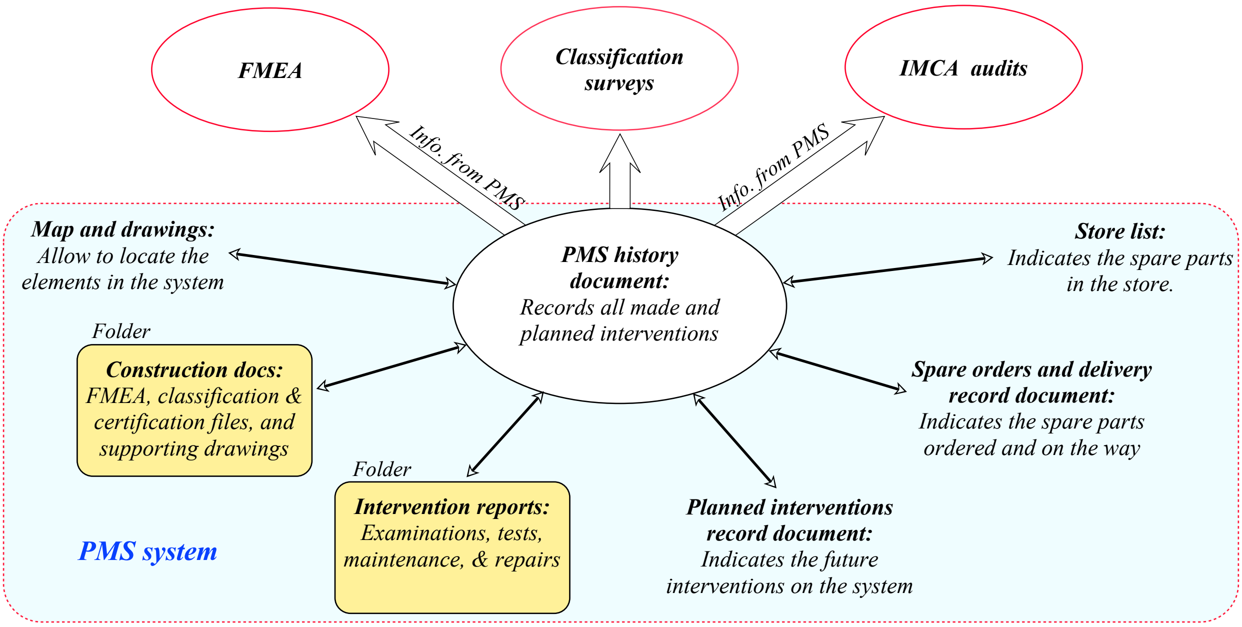
- Make sure that each item is precisely located and easy to find. If necessary photos can be used.
- Give a reference number or code to each item
- Write a glossary of acronyms or codes that are used
- Write a list of the items that are represented on the schemes/drawings and indicate where to find their detailed drawings and technical documents.

It is necessary to create forms that can be used by the technicians to log the maintenance and examinations performed on each item that composes the dive system, and that give a history of these various interventions.
As indicated in points 4.4.1 & 4.4.2, it is mandatory that the planned Maintenance System provides a history of the interventions performed on the system. Also, as discussed in point 4.3 “FMEA”, the planned maintenance system is a tool that allows detecting the problems encountered with an item, and take appropriate decisions regarding its preventive maintenance, or its modification, or its replacement by a more reliable model to avoid unexpected breakdowns.
So a document that summarizes the examination, testing, certification, and maintenance that have been carried out on an item or a sub-Item and from which the testing and intervention reports can be easily found is essential. Remember that IMCA says that depending on the article, the history should be at least 2 to 5 years. However, IMCA gives a minimum, and the recommendation is to have the history of all the components since the system has been put in service. Forms reflecting the history of components should provide the information, indicated previously such as, but not limited to:

1. Identification of the item:
   - The reference of the diving system.
   - The description of the item, and in which part of the system it is installed *(drawings can be used).*
   - The reference number from the manufacturer.
   - The reference number of the item in the diving system.
2. The date *(day/ month/ year)* of each intervention.
3. Examinations, tests, and maintenance performed:
   - Description of the examinations, test, maintenance performed, and spare parts changed.
   - The reference numbers of the recording documents and certificates emitted during in-house and external examinations, tests, and repairs, and where these documents are stored. Copies of these documents should be linked by hyperlinks, so they are easy to find.
4. The supporting documents used
   - The Reference of the sheet IMCA D 018.
   - The recommendations from the manufacturer.
   - Other supporting documents that have been used.
5. Description of the planned next intervention:
   - The date and purpose of the planned next intervention.
   - Spare parts to order for the next intervention.
6. Traceability:
   - The name and signature of the technician in charge.
   - The name and credential of the third parties involved
   - The name and signature of the senior technician in charge.
   - Stamp of the company

Note that the document above usually does not allow the technician to log all the steps of a repair. For this reason, a detailed intervention reports should be used. It is also the case for the interventions performed externally, and the tests and examination certificates. As already indicated, in-house and 3rd party reports and certificates must be linked to the document that provides the history of the elements that compose the dive system. It is important to classify these documents in a specific folder, so they can be easily found. People in charge of these documents must always remember that they must be available at any time and that 3rd party auditors performing classification or a DESIGN audits are not employed to look for lost certificates.
Also, the attached reports of maintenance must provide very comprehensive information on the operations performed, so that a person reading these documents can understand what has been done and the reason it has been done. For this reason, the elements relating to the identification, date, operations performed, supporting documents used, and traceability should be clearly visible. So, a certificate from a service provider with incomplete information should be rejected.
In addition to the documents above, a form that records the spare parts ordered and the following of their delivery, and another one that records the next examination and preventive maintenance of the entire diving system should be implemented. Such documents are usually based on calculation sheets (as an example, Microsoft Excel) to which “conditional formatting of the cells” are applied to create alerts such as cells changing of colour when the next test or

examination is to be performed. Note that a lot of websites provide useful tutorials *(follow the links)*.



4.4.3.3 - Backup the documents

It is asked several times to make copies of the original documents in the previous texts. This point is crucial as a catastrophic event may happen that results in the company archives being destroyed. For this reason, it is prudent to have one or several back-ups of all the documents saved in another place.

4.4.4 - Software designed for Planned Maintenance System

The elements indicated in point 4.4.3.2 may become complicated to implement with companies using several diving systems. Also, employees must have a minimum knowledge to use calculation sheets (Microsoft Excel) efficiently, and format them takes some time that can be used more efficiently with other tasks.
For this reason, most companies use specific software that provides all the tools they need to manage their diving systems. A lot of software for the management of equipment and asset management can be found through the internet. The selection of such software depends on the management system of the company and also whether it is compatible with other applications. It would be too long to describe all the products that are proposed. For this reason, two specific applications that are common in the industry have been selected for this purpose: "DiveCert", which is offered by Namaka subsea, and "TM Master V2" that is proposed by Tero Marine.

4.4.4.1 - DiveCert

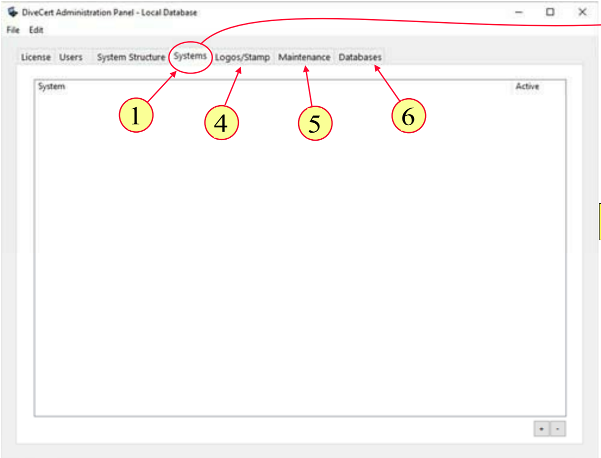
DiveCert is a certification, asset management, and planned maintenance software system, specifically designed for the diving industry by Namaka subsea that is designed to work with "Microsoft Windows" and "Apple OSX" operating systems. This software is designed to eradicate issues in the planned maintenance System and preparing IMCA audits efficiently. It is based on the following IMCA guidelines:

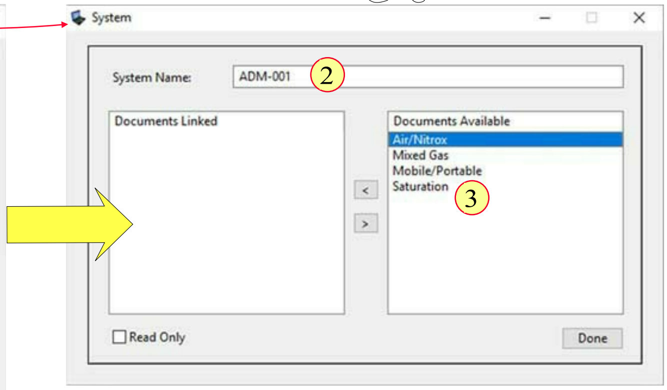
- IMCA D 018 - "Code of practice for the initial and periodic examination, testing and certification of diving plant and Equipment"
- IMCA D 023 - "Diving Equipment Systems Inspection Guidance Note for surface orientated (air) diving systems"
- IMCA D 024 - "Diving Equipment Systems Inspection Guidance Note for saturation (bell) diving systems"
- IMCA D 037 - "Diving Equipment Systems Inspection Guidance Note for surface supplied mixed diving systems"
- IMCA D 040 - "Diving Equipment Systems Inspection Guidance Note for mobile/portable surface supplied systems

This software can also be adapted to include additional (non-diving) equipment or alternative guidance documents.

The installation of the software on a machine running Microsoft Windows is as simple as every software. However, the installer does not include the database files that need to be installed by a member of the DiveCert support team. For the installation on a machine running "Apple OSX", it is necessary to ask for the support of Namaka subsea, as the software must be installed manually.

The admin application of the software is designed to provide restricted access to only authorized people. Also, it allows to give several degrees of privileges to the users from read-only to the control of assets associated with all systems within the database, which includes the creation, modification, transferring and printing of asset lists.
When the system is unlocked, several windows allow to control the diving systems used by the company. As an example, the tab "system" allows a window to open where the several systems under control are logged *(See #1 on the next page)*





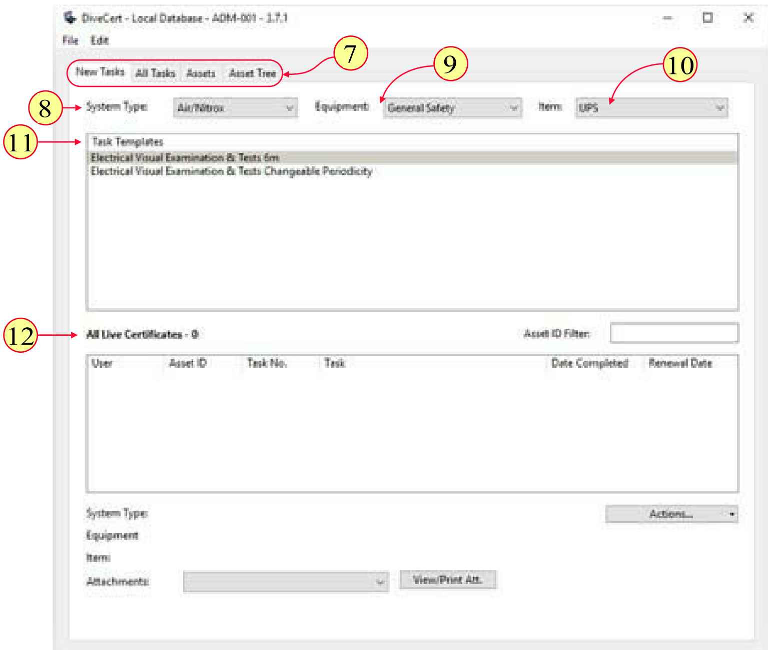
When the window “System” is opened, the operator can give a name to the dive system by highlighting the ‘System Name’ and retyping the name he desires *(See #2),* and select the type of system among the documents types *(see #3)*

There are four main document types available by default which are Air/Nitrox; Mixed Gas; Mobile/Portable; Saturation.
To link a document type to the company system, the operator selects one of them and clicks on the left pointing arrow.
To remove a document type, the operator reverses this process by clicking on the right pointing arrow.

The software allows the user to add a company stamp and a header or footer that will be printed on any documentation produced. A program that can be accessed by clicking the tab "Logo/stamp" allows the operator to choose or add the desired logo *(see #4 in the screenshot above)*.
Note that the tab "Maintenance" in the screenshot above *(see #5)* opens a restricted access section that is designed to allow the Namaka Subsea support team to carry out system maintenance when required. So the user cannot open the menu of this section.
The tab "Database" *(see #6 in the screenshot above)* gives access to the user to the menu allowing managing and mapping databases to different locations.
To log into the system, the user must select the dive system and then enters his name and password. So a technician cannot log into a diving system in which he is not authorized to intervene.

When the operator is logged into the system, a window opens with a taskbar in which four tabs "New Tasks", "All Tasks", "Assets" and "Asset Tree" give access to relevant menus *(see # 7 in the screenshot below)* . Some user interfaces may have an additional tab called “Global Assets” if they have been given permission on setup.
Other commands are displayed on the taskbar below:

- "System Type" allows selecting between "Air/Nitrox", "Saturation", "Mixed Gas" or “Mobile /Portable”, depending on how the system is set up *(see #8)*.
- “Equipment” allows selecting between different equipment found on diving, depending on what ‘System Type’ has been selected *(see #9)*.
- “Item” allows selecting between different items of equipment, depending on what “Equipment” has been selected *(see #10)*.



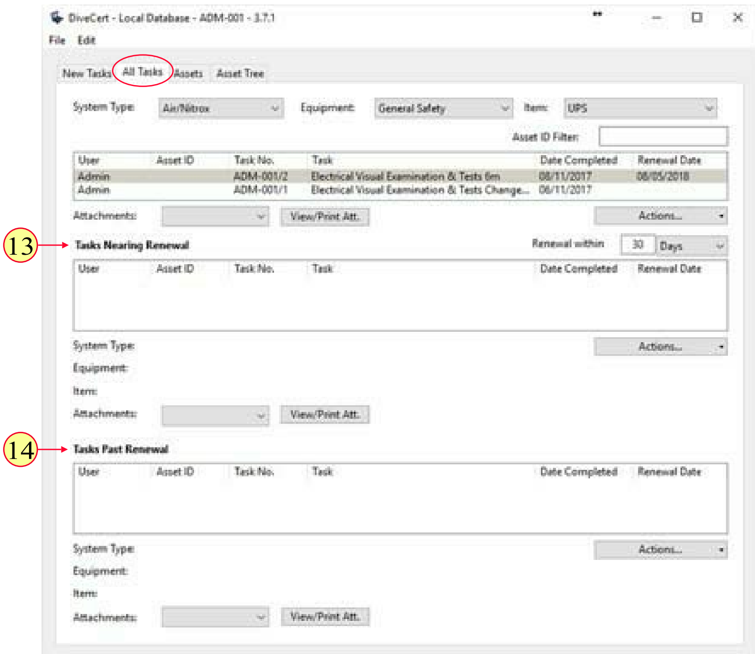
Two menu are visible when the tab "New Tasks" is selected:

- "Task Templates" *(see # 11)* displays the different task templates available.

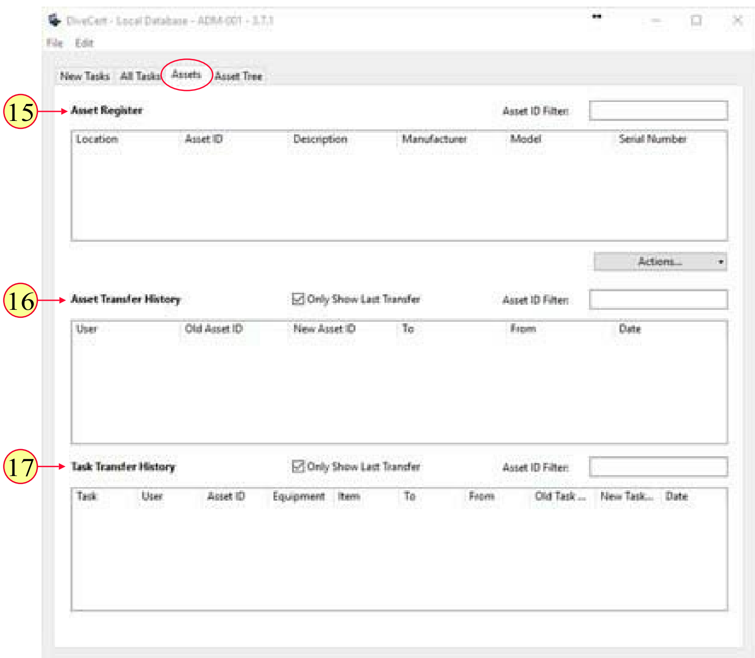
- "All Live Certificates" *(see # 12)* displays the current system live certificates, date completed, and renewal dates. This function of this section is the reviewing of live documents. Clicking the "Actions" button opens options such as:
  - "Print": Printing out a single selected certificate.
  - "Print all": Printing all currently archived certificates.
  - "Retire": Removing selected certificates from the system, which can still be viewed at any time.
  - "View": Allows examining any selected certificate.
  - "CSV report": This function allows producing a CSV file with detailed information of all certificates and assets. Note that a Comma-Separated Values (CSV) file is a delimited text file that uses a comma to separate values. These files are often used for exchanging data between different applications such as databases, listing, etc.
  - "Import Tasks" Allows importing a group of tasks.

When the tab "All tasks" is selected the taskbar "System Type" that allows selecting between "Air/Nitrox", "Saturation", "Mixed Gas" or "Mobile /Portable" is still present. The other menus "Task Templates" and "All Live Certificates" are replaced by two other menus:

- "Tasks Nearing Renewal" shows all tasks that are within 1 month of expiry, the periodicity is pre-determined to give the user advanced notice of task/work order renewal dates *(see #13)*.
- "Tasks Past Renewal" shows all tasks/work orders that are past their renewal dates, the periodicity is pre-determined to give the user advanced notice of task/work order renewal dates *(see #14)*.

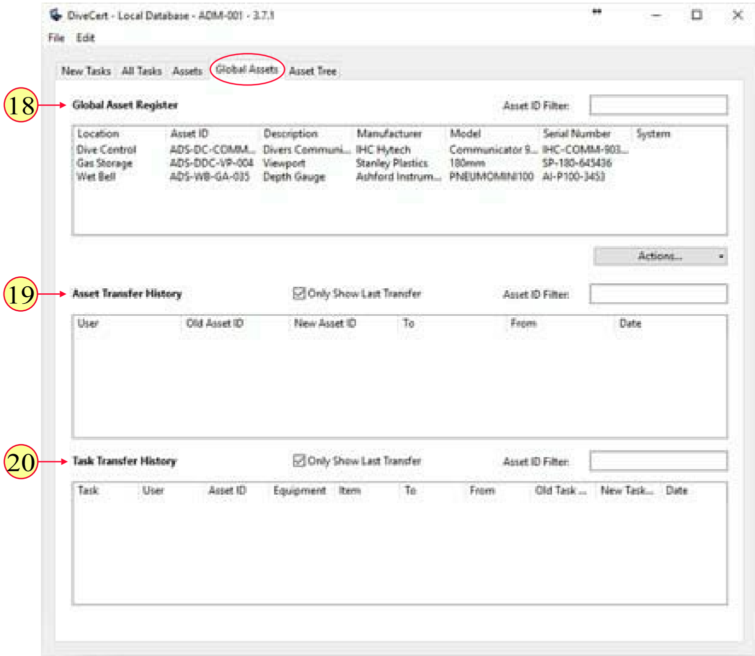


Clicking on "Asset" tab opens a window that shows the assets for the system the user has logged into. This panel allows to see the "Asset register" *(see #15)*, "Asset transfer history" *(see #16)*, and "Task transfer history" *(see #17).It* is accessible to all users that are limited by the privileges given by the software administrator.



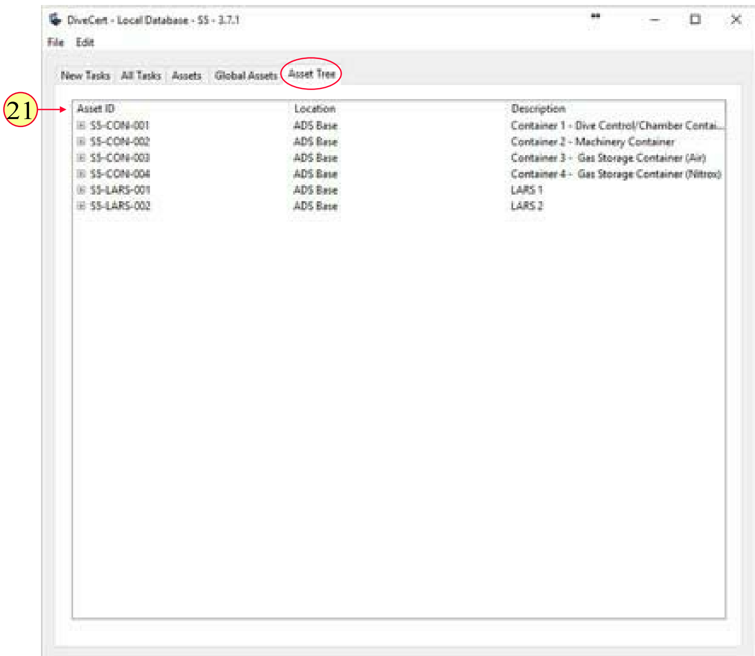
- “Asset Register” shows all the system asset identifications and descriptions, filtering the system assets can be achieved easily by using the Asset identification filter if required.
- “Asset Transfer History” shows the logs that are automatically performed when transferring an asset. The program identifies the asset location as well as dates of transfer. These logs can be filtered as above.
- “Task Transfer History” allows to see the logs provided to ensure all tasks are tracked between the system location or between multiple systems. The program identifies the task locations as well as dates of transfer. These can again be filtered as required.

Clicking on “Global Assets” tab opens a window that shows all assets for all available systems within the company database. Note that only users with access privileges will be able to view, this panel that shows "Asset register" *(see #18)*, "Asset transfer history" *(see #19),* and "Task transfer history" *(see #20)*. A lot of different actions can be carried out like in the "Assets panel", all of which are accessible from the "Actions" menu on the right of the panel.



- "Global Asset Register" shows all system asset identifications and descriptions within the company database, filtering the system assets for ease of location can be done by using the "Asset Identification Filter" function.
- "Asset Transfer History" shows the logs performed when assets are transferred. The program identifies the asset locations as well as the dates transferred. These logs can be filtered for ease of searching.
- "Task Transfer History" provides the logs performed when transferring a task. The program identifies the task locations as well as the dates of transfer. Again, filters can be used for ease of searching.

The “Asset Tree” tab allows the operator to see the structure between Parent & Child assets. Creating a relationship between assets allows a full transfer of an asset structure between systems/projects, including all associated documentation, with the click of a button *(see #21)*.



As a conclusion of the presentation above, this software is flexible and allows to manage all kind of scenarios that can happen when implementing a Planned Maintenance System (PMS). Also, the software designer provides a comprehensive manual that indicates step by step procedures to:

- Setup a new database
- Create assets, or import them from a Microsoft Excel spreadsheet template *(Note: There are many other office suites that provide similar programs than Microsoft. However, whether some suites are perfectly compatible, it is not the case of all)*
- Create custom tasks: The program that provides 700 templates allows to create custom tasks and templates.
- Import tasks: Tasks can be imported into the program via a Microsoft Excel spreadsheet template.
- Printing work-orders
- Renewing a task after a work-order has been completed and all relevant work carried out on equipment
- Importing & Exporting Systems: Any systems created within the software can be exported and imported when and if required.
- Transferring Assets: It is possible to transfer assets between systems within the same database.
- Produce a certification pack & Diving Equipment Systems Inspection Guidance Note (DESIGN): This function only applies to those who have the Dive DESIGN module add-on.
- Map a new Task: This document informs the system of what information to collate from the software and place into the live DESIGN document
- Backup & restore data. Suggestion: Save the backup on another hard disk.

Note that Namaka Subsea provides online technical support and can organize training

4.4.4.2 - TM Master V2

"TM Master V2" is an integrated marine information system proposed by Tero Marine, comprising modules for ship maintenance, procurement, human resources and quality assurance. This software that is designed for Microsoft Windows, starting from the “XP” version, provides the following modules: Fleet, Vessel, Inventory, Maintenance, Purchasing, My place, System, Tools, Contacts, and Chat.

- 1 - “Fleet” module gives an overview of the entire fleet through the nine following tools:

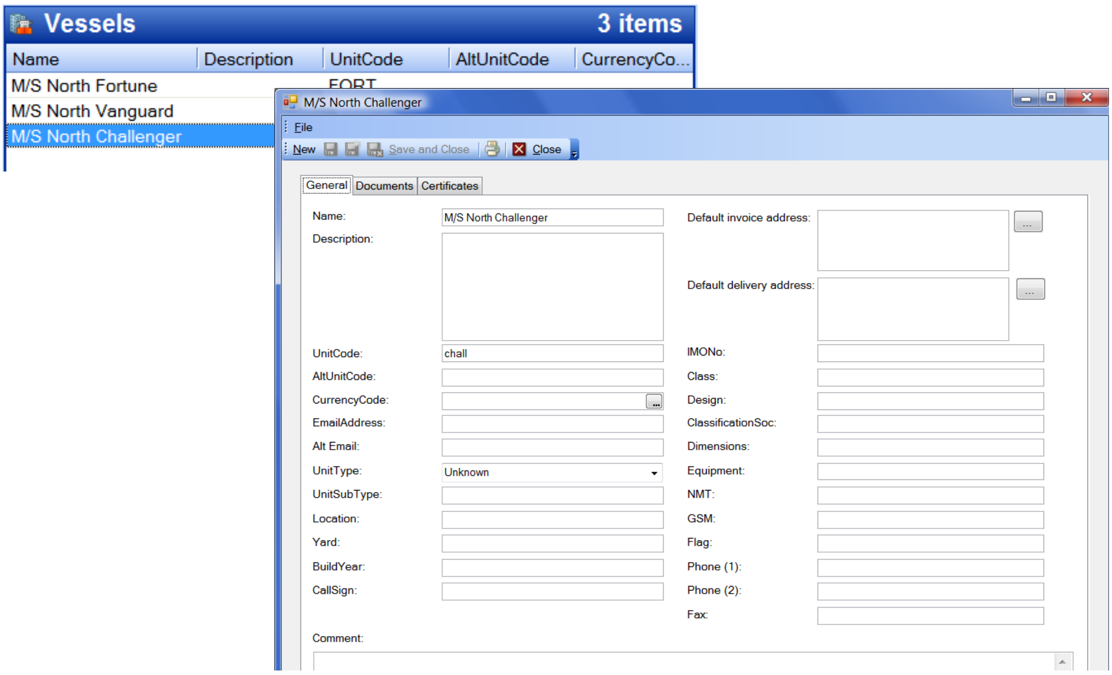
- Key Performance Indicators (KPI): This window, which is accessible through a button, gives an overview of all the jobs and orders to all of the ships in the fleet. Predefined Key Performance Indicators , fleet-wide due calculations, and history review are indicated. This windows is read only.

Overdue — M/S North Fortune

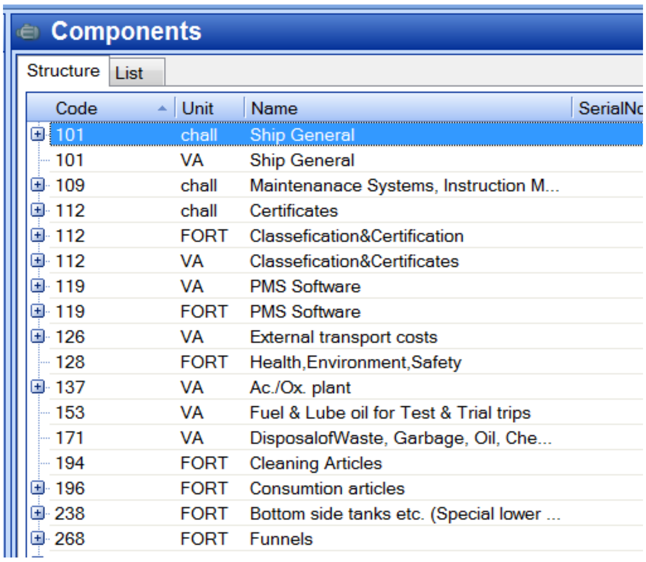
	Maintenance					Spare parts	POs and Budget				
Date			%								Total budget
19.09.2007 ...	591	29	399	0	0	9	2	17	0	0	0
18.09.2007 ...	566	27	399	0	0	9	2	17	0	0	0

  - “Maintenance” shows the number of jobs that are due with the percentage of actions overdue, the percentage of Key Performance Indicators, the jobs that have been postponed.
  - “Spare parts” shows how many spare parts have reached a low stock level.
  - "PO and budget" shows the number of drafts and requisitions, the active orders, the number of orders that have been delivered, the orders received by the agent.

- Vessel: Gives an overview of all the units within the fleet.



- Components: Show the components and systems of all vessels across the fleet.

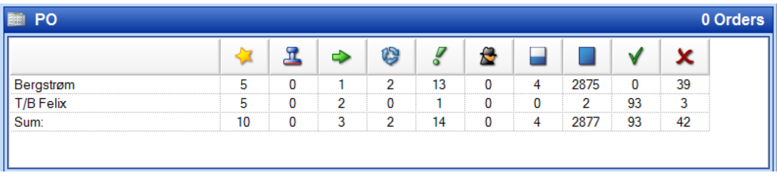


Components

Structure | List

Code	Unit	Name	SerialNo
101	chall	Ship General	
101	VA	Ship General	
109	chall	Maintenanace Systems, Instruction M...	
112	chall	Certificates	
112	FORT	Classefication&Certification	
112	VA	Classefication&Certificates	
119	VA	PMS Software	
119	FORT	PMS Software	
126	VA	External transport costs	
128	FORT	Health,Environment,Safety	
137	VA	Ac./Ox. plant	
153	VA	Fuel & Lube oil for Test & Trial trips	
171	VA	DisposalofWaste, Garbage, Oil, Che...	
194	FORT	Cleaning Articles	
196	FORT	Consumtion articles	
238	FORT	Bottom side tanks etc. (Special lower ...	
268	FORT	Funnels	

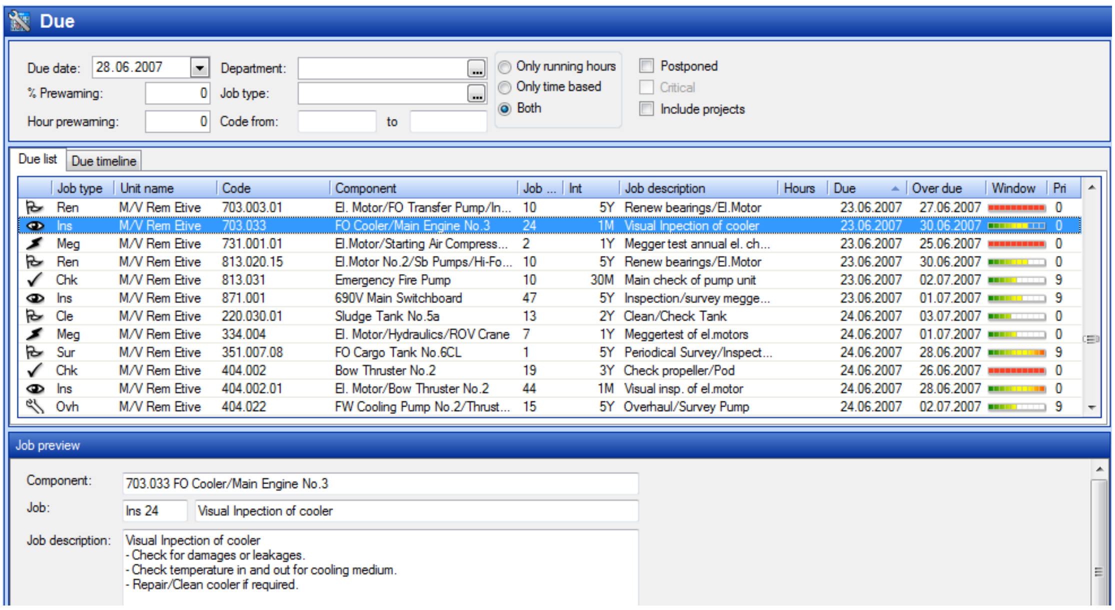
- "Purchase Orders (PO)" gives an overview of all Purchase Orders from the whole fleet such as:
  - Numbers of orders that aren't approved yet.
  - Orders that are approved, but not sent.
  - Orders sent, but not started.
  - Orders that have been sent but have not been received by the supplier yet.
  - Orders which are sent to the supplier.
  - Orders have been received by agents
  - Orders which are split and only partially received.
  - Orders that have been received.
  - Orders that are fully received and paid.
  - Orders that have been cancelled.



PO — 0 Orders

Bergstrøm	5	0	1	2	13	0	4	2875	0	39
T/B Felix	5	0	2	0	1	0	0	2	93	3
Sum:	10	0	3	2	14	0	4	2877	93	42

- Due: Gives an overview of scheduled jobs such as:
  - Checking jobs.
  - Annual survey, certificate renewal, service, check/clean components jobs.
  - Visual inspection type jobs
  - Lubrication and oil change jobs
  - Megger test jobs *(The Megger test is a method of testing making use of an insulation tester resistance meter that will help to verify the condition of electrical insulation)*.
  - Overhaul jobs



Due

Due date: 28.06.2007 | Department: | Only running hours | Postponed
% Prewarning: 0 | Job type: | Only time based | Critical
Hour prewarning: 0 | Code from: to | Both | Include projects

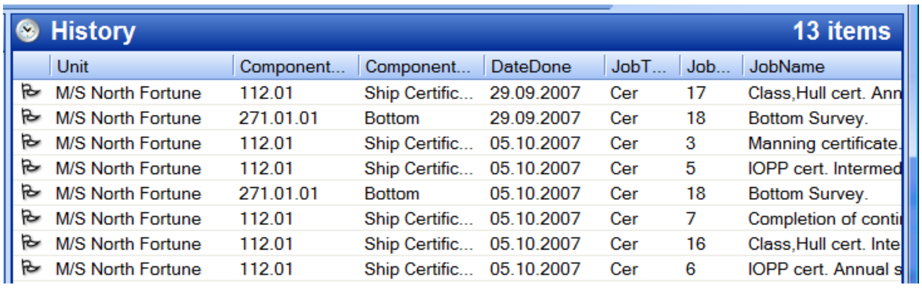
Due list | Due timeline

Job type	Unit name	Code	Component	Job ...	Int	Job description	Hours	Due	Over due	Window	Pri
Ren	M/V Rem Etive	703.003.01	El. Motor/FO Transfer Pump/In...	10	5Y	Renew bearings/El.Motor		23.06.2007	27.06.2007		0
Ins	M/V Rem Etive	703.033	FO Cooler/Main Engine No.3	24	1M	Visual Inpection of cooler		23.06.2007	30.06.2007		0
Meg	M/V Rem Etive	731.001.01	El.Motor/Starting Air Compress...	2	1Y	Megger test annual el. ch...		23.06.2007	25.06.2007		0
Ren	M/V Rem Etive	813.020.15	El.Motor No.2/Sb Pumps/Hi-Fo...	10	5Y	Renew bearings/El.Motor		23.06.2007	30.06.2007		0
Chk	M/V Rem Etive	813.031	Emergency Fire Pump	10	30M	Main check of pump unit		23.06.2007	02.07.2007		9
Ins	M/V Rem Etive	871.001	690V Main Switchboard	47	5Y	Inspection/survey megge...		23.06.2007	01.07.2007		9
Cle	M/V Rem Etive	220.030.01	Sludge Tank No.5a	13	2Y	Clean/Check Tank		24.06.2007	03.07.2007		0
Meg	M/V Rem Etive	334.004	El. Motor/Hydraulics/ROV Crane	7	1Y	Meggertest of el.motors		24.06.2007	01.07.2007		0
Sur	M/V Rem Etive	351.007.08	FO Cargo Tank No.6CL	1	5Y	Periodical Survey/Inspect...		24.06.2007	28.06.2007		9
Chk	M/V Rem Etive	404.002	Bow Thruster No.2	19	3Y	Check propeller/Pod		24.06.2007	26.06.2007		0
Ins	M/V Rem Etive	404.002.01	El. Motor/Bow Thruster No.2	44	1M	Visual insp. of el.motor		24.06.2007	28.06.2007		0
Ovh	M/V Rem Etive	404.022	FW Cooling Pump No.2/Thrust...	15	5Y	Overhaul/Survey Pump		24.06.2007	02.07.2007		9

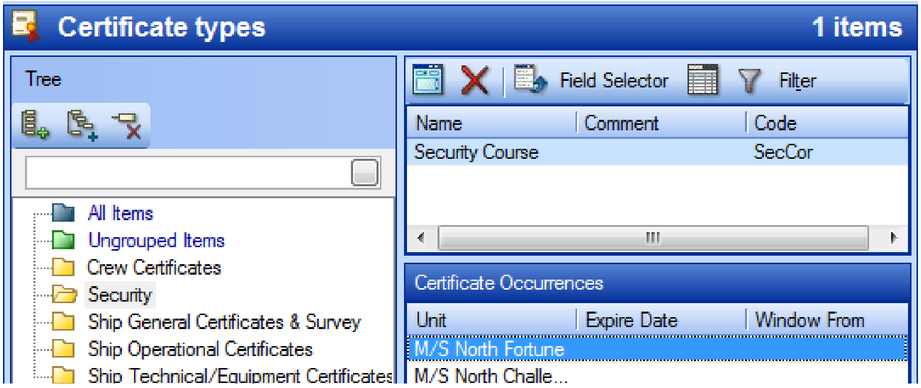
Job preview

Component: 703.033 FO Cooler/Main Engine No.3
Job: Ins 24 Visual Inpection of cooler
Job description: Visual Inpection of cooler
- Check for damages or leakages.
- Check temperature in and out for cooling medium.
- Repair/Clean cooler if required.

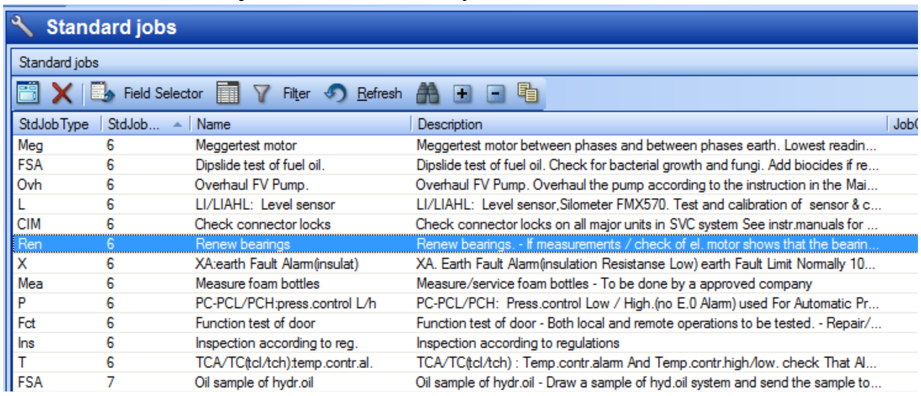
- History: shows all jobs that have been done on components on all vessels within the fleet.



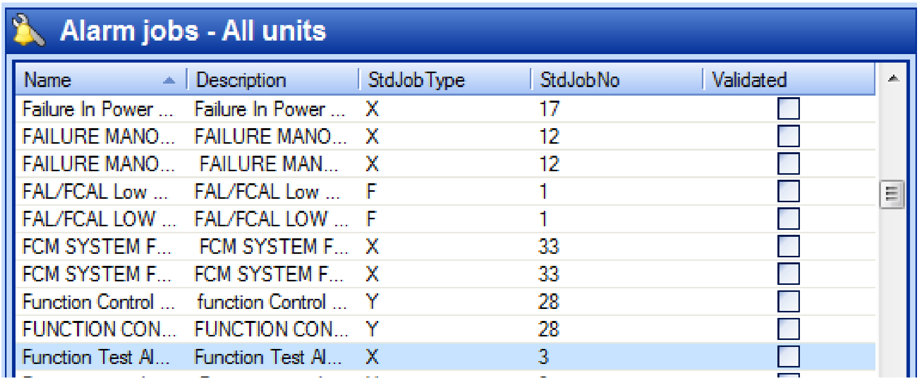
- Certificates overview: Shows an overview of the certificates within the fleet.



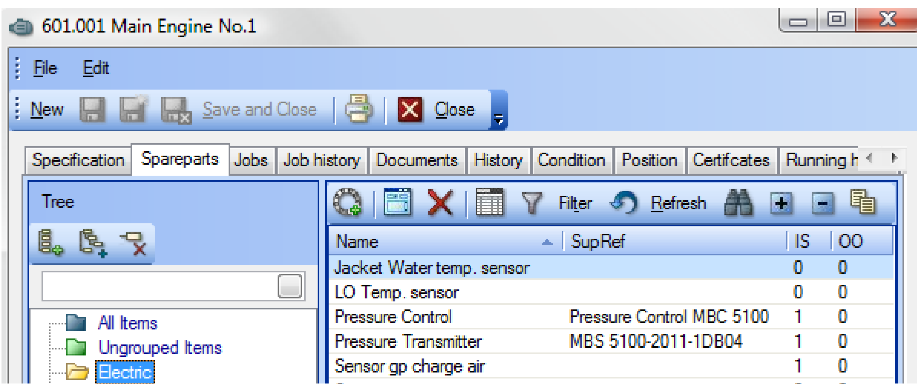
- Standard jobs: Shows all standard jobs defined on the system.



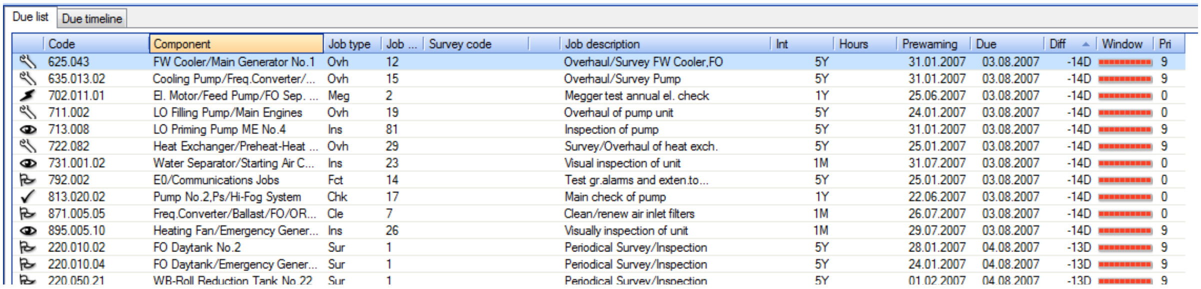
- Alarm jobs: Shows all alarm jobs set in the system



- Stock: Shows stocks across the fleet.



- 2 - "Vessel" module gives an overview and details of active orders, file-exchange (replication), and non-Conformances of a boat. The windows provided are of the same style as those used for the entire fleet. The following windows can be accessed:
  - "Overview" gives a general view of the orders, online users, job progress, non-conformities status, and certificates status.
  - "Details" shows all details regarding the vessel such as name, description, unit code, IMO number, email, phone number, etc.
  - "Crew" is the function allows to enter the personnel onboard and the people who have signed off, so it is possible to identify which person has performed s job.
  - "Change log" gives a cross fleet overview of all the major changes done to the component such as change of code, deleted codes and changes of standard jobs.
- 3 - "Inventory" module allows to control the components of the vessel. It provides the following tools:
  - "Components" program allows to list and locate all the components of the vessel.
  - " Catalogs" is a program that allows importing and classify catalogs.
  - " Spare parts" function shows all the items which are defined as spare parts. In the main window the operator can see general details about the spare parts, such as: Location, quantity, on order, etc.
  - "Alarm system" is a function that inform the user about boat alarms and jobs to perform to solve these problems. The overview window indicates: the criticality, the code, the system and component involved, the alarm type and description. Four tabs are provided to access to programs such as:
    - "General" is a program that gives general information about the alarm, such as "Alarm code", "alarm type", set point , etc.
    - "Jobs" that shows all the alarm jobs that are to be performed on the alarm, with details like interval and the next due date.
    - "Job history" that shows all jobs that have been done on the alarm.
    - "Change log" that shows the changes made on the alarm.
    - "Certificates" function gives an overview of the different types of certificates.
    - "Stock" function shows all the storage locations on board the vessel. Special filters are available such as "List Min Stock" function, that lists the items which are below the minimum specified quantity, "List Max Stock" function, that lists the items which are over the maximum specified quantity, and "List Expired Date" function, that shows the items which have expired or expire soon.
    - "Running hours" is a program that logs the running hours of each component of the vessel.
    - "Contact" provides the full contact list.
    - "Medical" is a program that provides a combination of a catalogue of different medicines and medical equipment that can be purchased, and a stock management of the medical items on board the vessel.
- 4 - "Maintenance" module allows to control the maintenance of the vessel that provide the following programs:
  - "Due List" is a program that allows the user to check and organize the due jobs: Codes, components, job description, planned intervals, date of intervention, and differential with the planned dates are indicated.

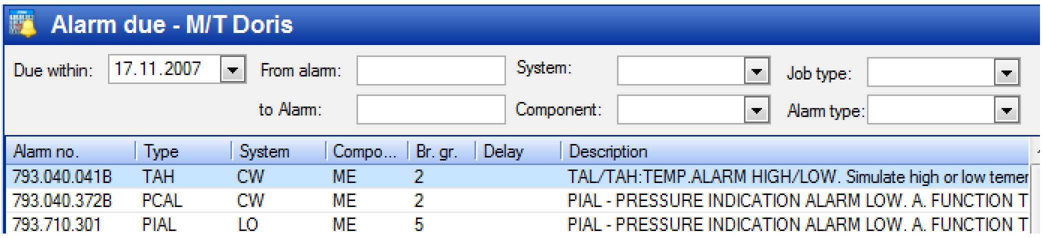


Due list | Due timeline

Code	Component	Job type	Job ...	Survey code	Job description	Int	Hours	Prewarning	Due	Diff	Window	Pri
625.043	FW Cooler/Main Generator No.1	Ovh	12		Overhaul/Survey FW Cooler,FO	5Y		31.01.2007	03.08.2007	-14D		9
635.013.02	Cooling Pump/Freq.Converter/...	Ovh	15		Overhaul/Survey Pump	5Y		31.01.2007	03.08.2007	-14D		9
702.011.01	El. Motor/Feed Pump/FO Sep. ...	Meg	2		Megger test annual el. check	1Y		25.06.2007	03.08.2007	-14D		0
711.002	LO Filling Pump/Main Engines	Ovh	19		Overhaul of pump unit	5Y		24.01.2007	03.08.2007	-14D		0
713.008	LO Priming Pump ME No.4	Ins	81		Inspection of pump	5Y		31.01.2007	03.08.2007	-14D		9
722.082	Heat Exchanger/Preheat-Heat ...	Ovh	29		Survey/Overhaul of heat exch.	5Y		25.01.2007	03.08.2007	-14D		9
731.001.02	Water Separator/Starting Air C...	Ins	23		Visual inspection of unit	1M		31.07.2007	03.08.2007	-14D		0
792.002	E0/Communications Jobs	Fct	14		Test gr.alarms and exten.to...	5Y		25.01.2007	03.08.2007	-14D		0
813.020.02	Pump No.2,Ps/Hi-Fog System	Chk	17		Main check of pump	1Y		22.06.2007	03.08.2007	-14D		0
871.005.05	Freq.Converter/Ballast/FO/OR...	Cle	7		Clean/renew air inlet filters	1M		26.07.2007	03.08.2007	-14D		0
895.005.10	Heating Fan/Emergency Gener...	Ins	26		Visually inspection of unit	1M		29.07.2007	03.08.2007	-14D		9
220.010.02	FO Daytank No.2	Sur	1		Periodical Survey/Inspection	5Y		28.01.2007	04.08.2007	-13D		9
220.010.04	FO Daytank/Emergency Gener...	Sur	1		Periodical Survey/Inspection	5Y		24.01.2007	04.08.2007	-13D		9
220.050.21	WB-Roll Reduction Tank No.22	Sur	1		Periodical Survey/Inspection	5Y		01.02.2007	04.08.2007	-13D		9

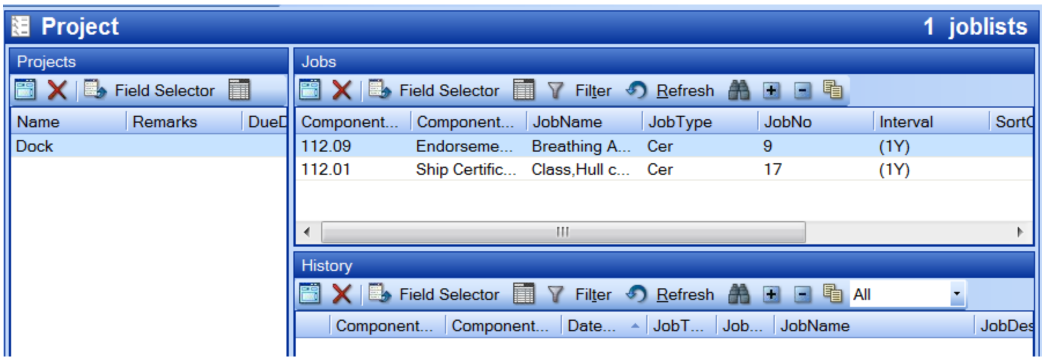
This program allows to:
  - search for jobs
  - indicate due job work details
  - organize and check the interval between two interventions
  - automatically withdraw spare parts from the stock if the job always require the use of particular spare parts.
  - designate the person in charge and the crew for the job, and enter an estimate for how long the job should take.
  - log the risk analysis for the tasks
  - attach any kind of document or file to the job. As an example, scanned pages from the instruction manual, or actual photographs of the job being performed.
  - log all changes made on the job, such as changes on the interval.
  - sign out a job and enter details about the job performed.
  - indicate a job status.
  - postpone a job

- "Alarm due" is a function that gives a list of all alarms that are due, and gives details about the alarm, and the status of alarm jobs done.

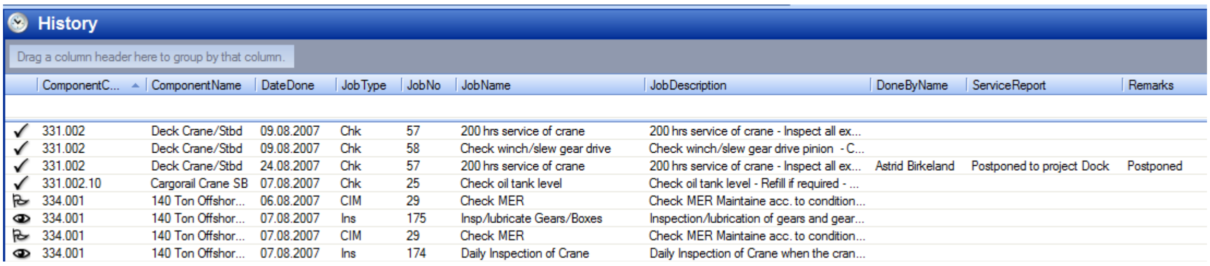


This program provide tabs that open windows that give details about the alarm, and allow to close the job.

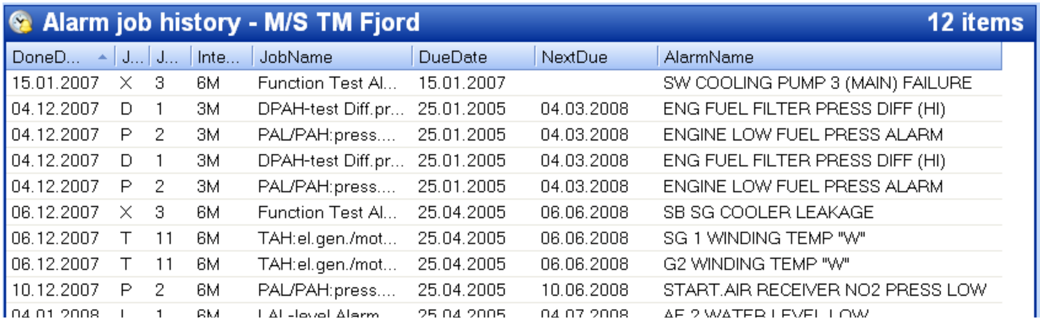
- "Project" is a function that allows the user to collect and group different jobs. If the user wants to postpone tasks until the vessel is going to dry dock, it is possible to create a project and delaying the job to this project.



- "History" is a function that shows the jobs which have been done. With the use of grid techniques like filtering, grouping and sorting, the user can separate specific job histories.



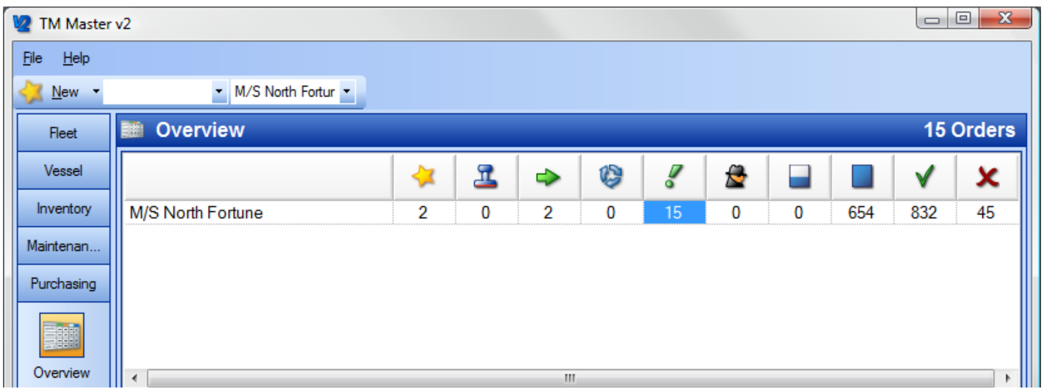
- "Alarm job history" is a function that shows the tests that have been done on alarms.



- "Standard Report Forms" is a function that provides templates that can be either a Microsoft Word template or Excel template.
- "Contacts" provides contact list with companies and contact persons.

- 5 - "Purchasing" module allows to control orders that have been made.

- The overview grid shows you how many orders there are within the different order status categories.

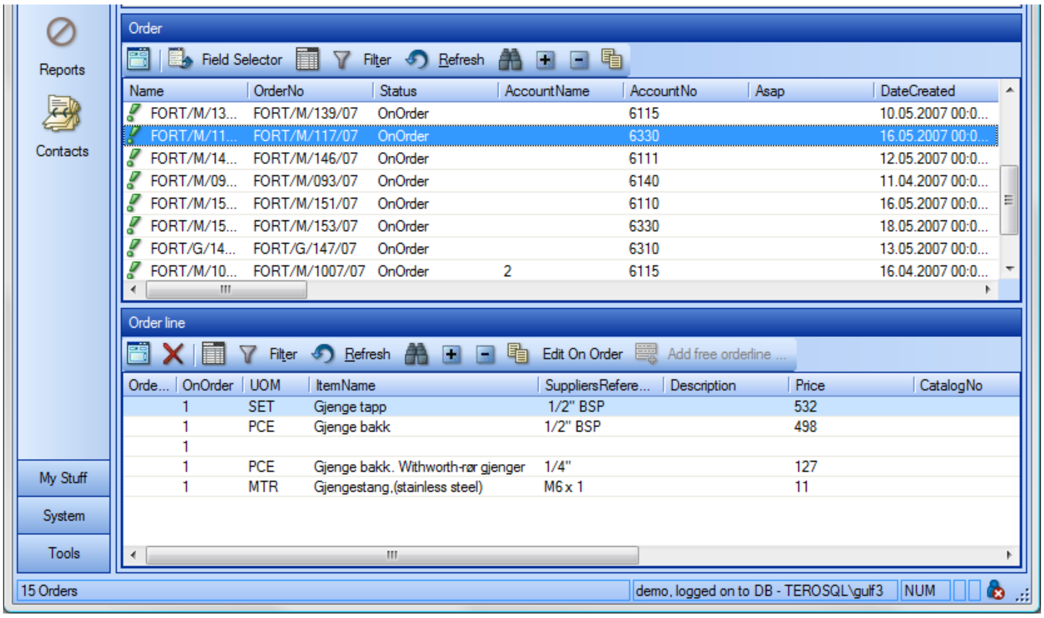


This window provides the following information:

- Orders not yet approved.
- Order approved as a direct order.
- Approved orders.
- Sent orders
- Orders in progress.
- Order delivered to an agent.
- Partially received order
- Received orders

Also, the user can create any from this window by clicking on the start "new" in the upper left had side of the taskbar. The program provides appropriate menu to archive this task easily.

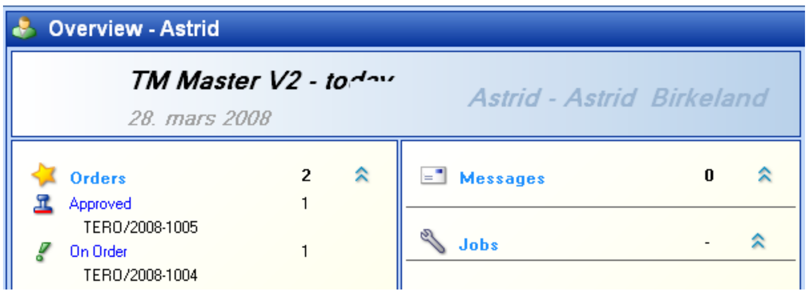
- The order grid is displayed on the overview window below the general status described above, and provides details of the categories listed, the items ordered such as their status, price, supplier, reference, etc.
  Note that the program allows to delete or cancel an order.



- "Account" is a function that can be created with this program for a group of identified expenses such as insurance, equipment, consumable, etc.
- "Print Label" is another function that allows printing labels on any printer compatible with the computer.
- As with the previous module, the user can access a contact list.

- 6 - "My place" is a module that allows the user to control his/her orders, tasks, projects etc.

- "Overview" is a function that gives a general view of the user's orders, tasks, projects etc. The light blue titles in the overview window are also shortcuts to the functions, so by clicking them it is possible to access these functions.



- "Messages" *(see on the right side in the picture above)* is a small e-mail application for the ship. As opposed to an ordinary e-mail application, you can only send messages to users of TM Master v2.
- "Orders" is a function that lists the user's orders.
- "Handover" is a small text editor, similar to Word pad and Microsoft Word, where the user can write important information for the person who is going to relieve him at the end of his duty time.
- "Filter" is a function that allows to organize elements on the most convenient way for the user.
- "v2 Online" is an internet page where the software designer gives information about the development of TM Master v2, such as new features to come, and informs about new upgrades to the software.
- "Preferences" is a function that allows the users to modify the starting mode and grid colours to their convenience.

- 7 - "System" is a module that allows to control users, settings, codes, and logs.

- “Users” is a function that allows the administrator of the software to define a user.
- “User groups” is a function that groups user profiles to ensure that all users in the group have the same access to the system. When a user is defined, the administrator must declare which user group the new user has access to.
- “Setting” is the function that allows organizing how the system works (path through the system, data storing, etc.).
    - To send E mails, the Simple Mail Transfer Protocol (SMTP), which is a communication protocol for electronic mail transmission, must be entered.
    - “Upgrade” is the function that ensures that the software is always the latest version. The update address is where the system finds upgrade files from the web page of the software designer. The system can be setup to periodically check for updates, to do so, the administrator ticks “Check for updates” and gives an interval.
- “Unit groups” is a function that allows the user to create groups of vessels to limit his view in certain modules if there are a lot of vessels.
- “Replication” allows the user to find information about the files that are replicated between the vessel and office. Replication interval is how often replication is carried out. The software manages the replication and keeps an overview of the next file it is expecting. The service then sends a request to the other system to resend the file once more. If the data has still not been received after the re-request time out, it sends an error message to system administrators.
- “Multi-sign” is a function that allows to setup with the company policy for multi-signing. It is possible to allow multi-sign jobs based on the components critical category or by the maintenance job priority.
- "Order settings" allows to manage what is allowed when creating an order:
    - Account and supplier can be a mandatory field that must be filled out when creating an order.
    - If direct orders are allowed, the “Direct orders allowed” must be ticked, otherwise, the system always creates a requisition when the orders are being approved.
- “Codes” is a function that allows creating new codes.
- “Log” is a module that shows all system messages, both system errors and messages about the replication between the vessel and the office.

- 8 - “Tools” is a module that allows to perform database cleaning, reports, codes, and data imports & exports.

- “Company Cleaning” is a tool that allows the user to validate (approve) contacts in the contacts list.
- “Job cleaning” is a tool to merge similar standard jobs. This operation can be done even though other users are working on the system. The changes will be distributed to all the vessels of the fleet.
- “Reports” module, allows the user to make aesthetic changes to the reports in the system, such as add the company logo, use other fonts, and move the different fields in the report.
- “Import & Exports” is a program that allows to import and export files and documents. This module can cause harm to the system if the user is not 100% sure of the source.

- 9 - “Contact” is a module that allows access to the list of contacts from within most of the different modules of the software.

- 10 - “Chat” uses the real time communication system “instant messenger” to send short messages to other stations of the company. Real time means that as the user types the message it appears on the other person’s screen immediately.

4.4.4.3 - To summarize

"TM Master V2" provides applications for managing a fleet of vessels while DiveCert is primarily designed for diving systems. This difference between the two software is the reason they have been presented.
Note that a lot of similar products to "TM Master V2", such as an example "K-fleet maintenance" from Kongsberg, are proposed. Also, note that DiveCert is currently the only software based on the IMCA guidelines designed to manage dive systems on the market.
The selection of the software to be used will depend on the management system, the size of the company, and the number of dive systems that are integrated into boats. Other things a company may consider are whether it is preferable managing its diving systems separately or with the other components of its ships, and which software the personnel in charge prefers.
Of course, the price of the software is an additional element of selection. However, considering that the consequences of documents improperly stored and examinations and tests not performed on time will be quickly more expensive than the value of the software, the price should not be the first criterion. Opposite of that, a software suite the technicians are comfortable to work with is a criterion of selection that should have priority.

4.5 - IMCA audit

4.5.1 - Purpose of the DESIGN documents

The International Maritime Organization (IMO) says in the International Safety Management Code (ISM) that the examination, testing, and maintenance of systems used at sea is mandatory *(see in* *point 4.4.1**)*.
IMCA *(International Marine Contractor Association)* has developed the Diving Equipment Systems Inspection Guidance Note (DESIGN) that must be followed by IMCA members, and the companies working for IOGP *(International association of Oil and Gas Producers)* members and a lot of independent clients. Also, a lot of competent bodies have adopted these documents that are among the most accurate guidelines for the audit and maintenance of a diving system and can be downloaded at this address: https://www.imca-int.com/divisions/diving/publications/guidance/

4.5.1.1 - Aim and legal status of IMCA DESIGN documents

DESIGN documents aim to provide comprehensive reference sources regarding the equipment and layout that are required for a safe diving operation, plus the examination, test, and certification requirements necessary to at least meet acceptable industry practices. They also identify how inspection and testing should be carried out safely and efficiently. Note that recommendations in areas where there is a delicate balance between commercial considerations and safety implications are included. However, safety must never be compromised for any reason.

DESIGN documents are intended to assist the following people:

- Manufacturers and suppliers of diving plant and equipment.
- Diving contractors commissioning new build diving systems.
- Personnel involved in diving operations.
- Vessel owners and marine crews involved with diving operations.
- Staff involved in the maintenance, repair, test or certification of plant and equipment.
- Client and contractor representatives.
- Diving system auditors.
- All personnel involved in quality assurance (QA) and safety.

DESIGN documents apply anywhere in the world being:

- Outside the territorial waters of most countries (normally 12 miles or 19.25 kilometres from shore).
- Inside territorial waters where offshore diving, normally in support of the oil & gas or renewable/alternative energy industries, is being carried out.

Five IMCA DESIGN documents have been published:

- IMCA D 023: DESIGN for surface orientated (air) diving systems.
- IMCA D 024: DESIGN for saturation (bell) diving systems.
- IMCA D 037: DESIGN for surface supplied mixed gas diving systems.
- IMCA D 040: DESIGN for mobile/portable surface supplied systems.
- IMCA D 053: DESIGN for the Hyperbaric Reception Facility (HRF) forming part of a Hyperbaric Evacuation System (HES).

IMCA DESIGN documents have no direct legal status but many courts, in the absence of specific local regulations, would accept that a company carrying out diving operations in line with the recommendations of these documents was using safe and accepted practices.
Note that valid DESIGN documents are required by most clients to start the diving operations.

IMCA says: *"Any company which wishes to do so is free to carry out its operations in ways which do not comply with the recommendations in this document but in the event of an accident or incident it may be asked to demonstrate that the methods or practices that it used were at least as safe as if it had followed the advice of this document"*.
For this reason, audits using DESIGN documents must be regularly performed, and that the equipment audited must comply with the recommendations that are explained in these documents.

DESIGN documents should be used in conjunction with IMCA D 018 *"Code of practice on the initial and periodic examination, testing and certification of diving plant and equipment"*. Cross-references to this code are provided where appropriate.

IMCA says: *"A number of countries in the world have national regulations that apply to offshore diving operations taking place within waters controlled by that country. In such cases, national regulations must take precedence over this document, and the contents of this document should be used only where they do not conflict with the relevant national regulations"*. For this reason, when other codes or standards are required by the client or the administration, evaluation to make sure that the system complies with these codes and standards must be performed. If the system is not compliant, actions must be undertaken to meet the laws and rules requested.
Nevertheless, a lot of companies use IMCA DESIGN documents as the basis for their audit activities. For this reason, audits using the IMCA DESIGN document must also be performed. The result of these audits should be kept for the internal purpose, or published in a separate report if the client or the administration does not recognize it.

4.5.1.2 - Competent persons

The dive system must be audited by a recognised Diving System Assurance Auditor. Details regarding the competency of the auditor are indicated in the information note IMCA D 07/13 and the guidance IMCA D 011 “Annual audit of diving systems” issued in December 2010 and reviewed in January 2017 that sets up the rules for diving systems auditors that are explained more in the next point. This competent person must have a high level of diving expertise with a detailed knowledge of diving techniques and practices and the environment in which the plant will be used.

Except for those who are qualified auditors, the diving supervisor and the dive technicians are not supposed to carry out “official” audits. However, they have to ensure that the dive system is in good condition and that all the certifications are updated. For this reason, they should be familiar with these processes. These checks have to be performed regularly in accordance with the Planned Maintenance System (PMS) plan and using the relevant DESIGN documents and IMCA D 018 as supports.

IMCA D 018 gives advice on a way in which inspection and testing of diving plant and equipment can be carried out safely and efficiently, and it details that all the examinations must be documented in order to demonstrate when they have been carried out and by whom. As already indicated in point 4.4.3.1, the competent persons in charge of the maintenance of the diving system are defined in four categories depending of the inspection and test to be carried out:

- Category 1: An IMCA or equivalent level diving or life support supervisor duly appointed by the diving contractor: His competency should be limited to external visual examinations and function tests of the equipment he is familiar with, unless he has additional specific training.
- Category 2: A technician, certificated Class I Chief Engineer, or other person, all specialising in such work who may be an employee of an independent company, or an employee of the owner of the equipment (unless specific legal restrictions apply), in which case his/her responsibilities should enable him/her to act independently and in a professional manner.
- Category 3: A classification society or insurance company surveyor, or chief engineer certificated in accordance with IMCA C 002 guidelines and competence tables: Marine Division (Job Category A06) but who may also be an “in- house” chartered engineer or equivalent (unless specific legal restrictions apply), or person of similar standing.
- Category 4: The manufacturer or supplier of the equipment, or a company specialising in such work which has, or has access to, all the necessary testing facilities. That may also be a technician employed by the owner of the equipment provided that he has been fully trained and certified for the specific operation and has access to all necessary equipment and facilities.

4.5.1.3 - Organisation of DESIGN documents

The DESIGN documents are organized to perform a breakdown analysis of the diving system.

- Sections

Each document is divided in “sections” that are the important parts of the system.

- The DESIGN document IMCA D 023 is composed of the following sections:
    - 1 General Safety
    - 2 Dive Control
    - 3 Twinlock Air Chamber
    - 4 Diver Launch and Recovery System
    - 5 Diving Basket
    - 6 Wet Bell
    - 7 Wet Bell Main Umbilical
    - 8 Diver Heating System
    - 9 Divers’ Umbilicals
    - 10 Divers’ Personal Equipment
    - 11 Compressors
    - 12 HP Air and Gas Storage
- The DESIGN document IMCA D 024 is composed of the following sections:
    - 1 General System Safety
    - 2 Dive Control
    - 3 Surface Compression Chamber
    - 4 Bell Launch and Recovery System
    - 5 Diving Bell
    - 6 Life Support Control
    - 7 Main Bell Umbilical
    - 8 Diver Heating System
    - 9 Divers’ Umbilicals

- 10 Divers' Personal Equipment
- 11 Compressors, Pumps, etc.
- 12 High Pressure Gas Storage
- 13 Diver Gas Reclaim
- 14 Chamber Gas Reclaim and Purification
- 15 Hyperbaric Rescue Unit
  - 15.1 General – HES System
  - 15.2 HRU Interface with Dive System
  - 15.3 Hyperbaric Rescue Unit (HRU)
  - 15.4 HRU Launch and Recovery System
- 16 Life Support Package

- The DESIGN document IMCA D 037 is composed of the following sections:
  - 1 General Safety
  - 2 Dive Control
  - 3 Twinlock Chamber
  - 4 Diver Launch and Recovery System
  - 5 Wet Bell
  - 6 Wet Bell Main Umbilical
  - 7 Diver Heating System
  - 8 Divers' Umbilicals
  - 9 Divers' Personal Equipment
  - 10 Compressors
  - 11 HP Air and Gas Storage
- The DESIGN document IMCA D 040 is composed of the following sections:
  - 1 General Safety
  - 2 Small Vessel
  - 3 Control Position
  - 4 Divers' Umbilicals
  - 5 Divers' Personal Equipment
  - 6 High Pressure Air and Gas Storage
- The DESIGN document IMCA D 053 is composed of the following sections:
  - 1 General System Safety
  - 2 HRF Compression Chamber
  - 3 HRU Handling Arrangements and Interfaces
  - 4 HRF Life Support Control
  - 5 Compressors, Pumps, etc.
  - 6 High Pressure Gas Storage

- Items

Each section is divided in "Items" that are the important parts of the section. As an example, the section #2 "dive control" in the DESIGN document IMCA D 024 is composed of twelve items:

- 1 General
- 2 Communications
- 3 Surveillance
- 4 Alarms
- 5 Gas Supplies
- 6 Monitoring
- 7 Gauges
- 8 Pipework and Valves
- 9 Electrics
- 10 Firefighting
- 11 Hot Water Temperature
- 12 Breathing Apparatus

- Description

Each Item is described using "sub-items" that are the important parts of the main item. As an example, the item # 7 "gauges" in the section #2 "dive control" in the DESIGN document IMCA D 024 is composed of twelve sub-items:

- 7.1 General

- 7.2 Gauge Protection
- 7.3 Depth
- 7.4 Unit Marking
- 7.5 Contractor's Tables
- 7.6 Digital Gauges
- 7.7 Gas Supply
- 7.8 Scale Divisions
- 7.9 Unit Marking
- 7.10 Cross-over Valves
- 7.11 Supply Gauge Isolation
- 7.12 Gauge Calibration

- Requirement column

For each sub-item there is a description of what must be checked.

As an example the requirement for the sub-item # 7.1 "general" of the item # 7 "gauges" in the section #2 "dive control" in the DESIGN document IMCA D 024 is as follows:

7	Gauges	
7.1	General	The diving supervisor must have available to him enough suitable gauges so that he is aware of the depth of each diver and of the supply pressures of each main and secondary breathing supply

- Need column

This column identifies the importance given to each requirement. Three letters are used:

A. Signifies that the requirement is necessary and must be met. Only in the most unusual circumstances would a diving system be considered safe to use if a requirement with an A need had not been met.

B. Signifies a requirement which is considered as necessary but there may be other ways of meeting the requirement than the method identified in the 'Requirement' column. It is left up to the discretion of the person completing this document as to whether the requirement is being suitably met.

C. Refers to a requirement which is optional and the absence of which would still allow the diving equipment to be used safely

- Response column

This column is where the person completing the DESIGN document write the comments and observations. It is used to answer any questions asked in the 'Requirement' column.

NOTE: Single words or short phrases such as "acceptable", "suitable", "adequate", "yes", "meets the requirement" or similar should not be used as these provide no useful information to anyone reading the completed document. As a minimum, enough information should be given to allow a person reading the document to understand why the person completing it considers the 'Requirement' for a particular item to have been met.

Equally, where items of plant or equipment have unique serial numbers then these should be inserted in the 'Response' column.

Photographs embedded electronically in the document may assist in cutting down long explanations or clearly illustrating a variation, deviation, non-compliance or non-conformance.

- Certificate Issue Date Column

Where a certificate is required, the date of its issue should be entered in this column. The relevant part of the column is shaded if no certificate is required.

- Additional items and items not required for a system

If there is more than one of the same item on a particular dive system then the section or part of a section should be duplicated and repeated.
This means, for example, that if there are two surface compression chambers then that section would be completed twice, once for each chamber. Similarly if there were, for example, six diving helmets, then the part on diving helmets would be completed six times within the overall section.
This imposes the use of a system for references.

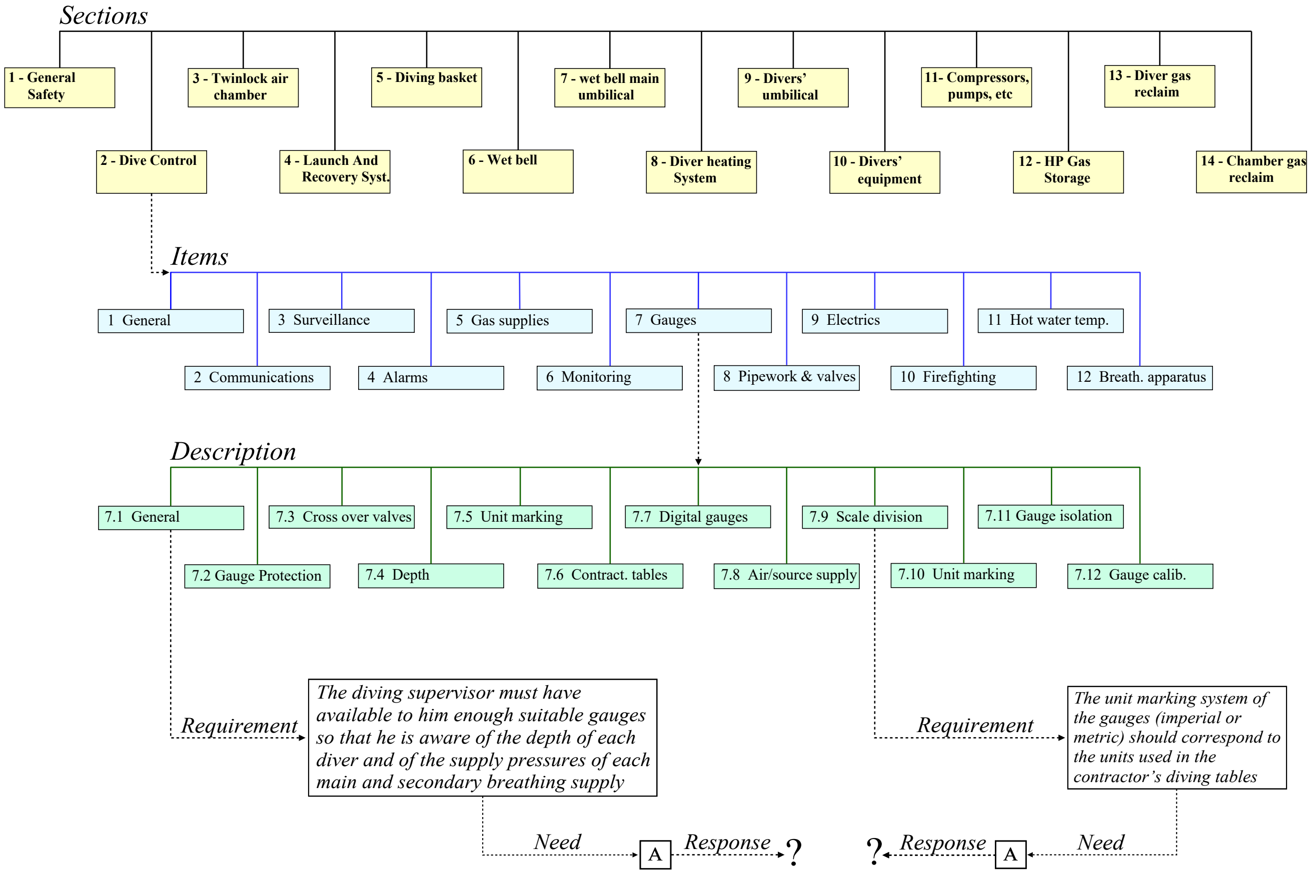
It is recommended that items not required for a particular system are not deleted but rather are marked as "not applicable". This will ensure that the tables in the various sections look similar to a master copy of the blank document, which may make it easier for a subsequent person to check.

- Variation/deviations from requirement

The person completing the DESIGN document should prepare a list identifying any items which do not fully meet the requirements of this document. This will assist in making sure these items are dealt with speedily.

If the item in question has a C in the 'Need' column then variation/deviation does not signify a non-conformance. However if the item is present but is not correct then it should be placed on the variation/deviation list.

The scheme below summarizes the organization of the DESIGN documents as explained on the previous page:



- *Publication formats*

The DESIGN documents are published in PDF *(Portable Document Format)* that can be printed and filled by hand or electronically using an appropriate software. Also, Microsoft Word, and Microsoft Excel formats are available. Note that Microsoft documents can be opened and filled using a compatible office suite.

Important point:
The final report should be published in a protected PDF format that is filled electronically and signed by the auditor.

- *Close Out*

The system cannot be considered in conformance and put in service as long deviations or non-conformances exist.
To assist in subsequent checking of the DESIGN document a list should be available detailing how and when any variations, deviations or non-conformances have been closed out and completed. This list should be part of the document available to any client or other interested parties for checking.
Note that diving companies, and also most clients consider that all non-conformance and deviation that are closed out and completed must be accepted by the auditor who has carried out the audit. This acceptance must be signed and attached to the final report.

- *Records*

The reports must be classified chronologically in a dedicated file and be available:

- They are the history of the diving system and they will be used by the auditor carrying out the next audit to fill the page "Record of inspection" at the beginning of the DESIGN document.
- The records can be used to identify the weaknesses of a system and initiate corrective actions

The DESIGN documents are part of the safety and quality system of the company using them, and can be used to prove that the diving systems and other equipment are safe and maintained appropriately.

4.5.2 - Organize an audit based on IMCA Diving Equipment Systems Inspection Guidance Notes (DESIGN)

IMCA recommends undergoing a comprehensive audit annually and at each mobilization for each diving system. These audits are asked by most clients, which some of them require that some systems are checked by 3rd party auditors. Regarding this point, wise company managers should organize the yearly survey of all diving systems of their company by a competent external body. The advantage of this process is that it removes suspicion against the system owner regarding the sincerity of the inspection performed.

Note that the following issues play critical roles in the quality of DESIGN audit reports:

- Selection and competence of diving system auditors.
- Accuracy, completeness and traceability of information.

- Management and quality control of the DESIGN process.
- Time allowed for auditors to undertake the audit.

The document IMCA D 011 “Annual Auditing of Diving Systems” intends to set out guidance on how the DESIGN process is carried out. It can be downloaded at this address: https://www.imca-int.com/publications/112/guidance-on-auditing-of-diving-systems/

4.5.2.1 - Training of company personnel

As indicated in point 4.5.1.2, diving supervisors and diving technicians are not supposed to carry out “official” audits, but they must ensure that the dive system is in good condition and that all the certifications are updated. Also, because audits are common, it is the duty of the company to ensure that some technicians are certified Diving Systems Auditors. As a result, the training of company personnel involved in IMCA DESIGN audits should be organized as follows:

- Initial and refresher training of personnel must be in place.
- The personnel in charge of the system must be technically competent. Their responsibility is to ensure that the diving system is maintained and certified in compliance with regulations, standards, codes, guidelines and industry good practices using the company’s maintenance system. The qualification requested for diving technicians are indicated in IMCA C 003 and IMCA D 001. In addition to the requirement from IMCA, some clients require additional formations.
- IMCA D 011 says that in addition to their technical qualifications, company personnel should receive formal inductions on the diving system, which should include an explanation of their specific roles and responsibilities:
    - Chief engineers, mechanical and electrical dive system technicians.
    - Offshore construction manager, diving supervisors, divers and tenders.
    - Life support supervisors and technicians.
    - Company assurance auditors.
- DESIGN auditors should:
    - have appropriate operational knowledge of the type of diving system to be audited;
    - be familiar with DESIGN document requirements for the type of system being audited;
    - be familiar with IMCA D 018 – Code of practice on the initial and periodic examination, testing and certification of diving plant and equipment;
    - be familiar with IMCA D 014 – IMCA International code of practice for offshore diving;
    - be familiar with Diving information note IMCA D 10/10 – Competence of auditors, and IMCA D 011 “Annual Auditing of Diving Systems”;
    - be familiar with the company’s quality assurance/control process;
    - comply with the audit terms of reference;
    - recognise the limitations of their competence and when to request specialist assistance as needed;
    - ensure that the DESIGN report is accurate, meaningful and comprehensive;
    - Raise concerns when observing or identifying non-compliance that may affect safety of personnel or the environment;
    - identify and communicate early any potential conflict of interest situations;
    - have undergone formal training in auditing techniques, e.g. certification as recognised by IMCA or similar;
    - have good report writing and communication skills;
    - have the ability to communicate audit findings;
    - be able to take into account/be aware of broader issues, e.g. HSE concerns during the audit;
    - keep a record of all the diving system assurance audits he has been involved in;
    - have undertaken two audits in tandem with a competent auditor before being eligible to carry out an audit unaccompanied;
    - have undertaken three similar diving systems audits before becoming a lead auditor;

The selection of the auditors should be performed using the IMCA document P01 “Dive system auditor”, that can be downloaded at this address: https://www.imca-int.com/core/competence-training/competence/offshore-project-roles/

4.5.2.2 - Training and selection of external personnel intervening on a diving system

The personnel from an external service provider intervening on a diving system has the same responsibilities as the company employees to ensure that the diving system is maintained and certified in compliance with regulations, standards, codes, guidelines and industry good practice.

- They must be technically competent. The qualifications requested are indicated in IMCA C 003 and P 01.
- In addition to their technical qualifications, the diving contractor and their management should make sure that the personnel proposed has received formal inductions on the diving system which should include an explanation of their specific roles and responsibilities. People concerned are:
    - Suppliers of diving system, plant, equipment and components.
    - Certifying authorities, inspection and test houses.
    - Independent third party assurance auditors.

- The Design auditors working for a 3rd party company should be in possession of a Diving Systems Auditing and Assurance (DSAA) certificate and have experience of the systems they audit. Their minimum experience should conform to what is indicated in the previous point.

The process of selection of external auditors should be as those used for choosing a classification society or external members of an FMEA team. Note that there are a lot of service providers that propose diving system auditing, and it is often difficult to see whether they are competent. Also, some clients may not accept some of them. For this reason, it is of utmost importance to ensure that all parties agree to use the services of the selected diving system auditing company. Some classification companies also provide such services, but it is not the case of all of them.
Note that the guidelines indicated in point 4.1.2.3 indicate the process for selecting a service provider. Also, this selection must not be linked to only the reputation of companies, but their ability to provide competent people in the area the diving contractor operates. For this reason, it is important to have the name and experience of the people proposed for an audit job.

4.5.2.3 - Types of audits

- Baseline Audit
The intent of a baseline DESIGN audit is to establish a datum for future reference and should be performed as soon as practicable:
  - After taking delivery of a newly built diving system;
  - Before/after the purchase of an existing diving system;
  - After significant changes to a system;
  - Following mobilisation of a temporary diving system;
  - When contracting a diving system without a baseline system audit;
  - Five years after the previous baseline audit.

Diving contractors with a large inventory of diving systems may find value in identifying a team of auditors to perform baseline audits to ensure continuity of standards across all systems within the company.

- Annual Audit
Annual audit is part of the company process to maintain the DESIGN report as a living document that can be presented at any time for audit and inspection. IMCA D 011 considers that this audit can be made in house. Nevertheless, a lot of clients want this audit performed by an independent 3rd party auditor, which is the safest solution and should always be the rule for the reasons explained previously.

Diving plants and equipment are often operated in remote locations where it is difficult to carry out the required auditing in the appropriate time scales. This may also be the case because of operational reasons where the equipment is in constant use. The audit report would typically be valid for a year, starting from the final day of the audit. However, IMCA says that a diving system with a valid annual audit would not become unsafe at 12 months and 1 day on expiry of the valid audit report.
However, a date of audit has to be decided to ensure that the client does not reject the system, as whether a few weeks can be considered acceptable, several months are not. IMCA D 011 says that if, due to operational circumstances, an annual audit cannot be renewed within the prescribed period then an extension of up to a maximum of 30 days can be issued if the diving or life support supervisor operating the system confirms, in writing, that it is operating satisfactorily and appears in good condition. Where there is one or more qualified equipment technician whose duties include maintaining the system, then they should also all confirm the system is satisfactory before such an extension is issued.

- Six month audit
Six month audits are performed internally by the maintenance and the diving teams. They are based on the fact that visual and function tests are to be made every six month.

- Verification Audit
Prior to accepting a diving system, clients and others assure themselves that the system is fit for purpose. This may be achieved by performing a verification audit.
This form of audit may be achieved by verifying the diving system certification is valid and observing diving system equipment function checks, especially on the winches. DESIGN verification audits may, at the client's discretion, be undertaken by independent third party auditors.

- Theme Audit
Theme audits may be undertaken in response to a diving industry related incident or other concern. These audits will generally have specific terms of reference outlining scope, lines of communication and reporting.

- Every day audit
Pre-dive checks must be performed every shift change during the diving operations. It is not a DESIGN audit, nevertheless, the check list should be built according to the recommendations from the auditing documents. Diving company manuals should explain how the check lists must be performed and any defect reported.

4.5.2.4 - Audit team

IMCA D 011 says:
A risk assessment should be carried out to identify the number of personnel and specialist disciplines required to undertake the full DESIGN audit or to verify the final report.

IMCA D 011 gives the following options:
- depending on the complexity of the system, the following appropriately qualified personnel may be involved:
    - lead auditor
    - lifting and winch specialist
    - hydraulic specialist
    - mechanical and/or electrical diving system technicians
    - classification and flag state experts
    - dive supervisors
    - life support supervisors;
- An appropriately qualified auditor, experienced and knowledgeable in the diving technique and diving system being assessed, may review and comment on the DESIGN report.
- An appropriately qualified internal or external independent third party auditor/s.

Note that when a 3rd party auditor performs the audit, the people carrying on the inspection are from the company of the auditor. However, the diving operator should give them support, and technicians should be ready to assist the auditors when required.

4.5.2.5 - Planning and Assumptions

IMCA says that the estimated audit durations are based upon the assumption that:
- All documentation relevant to the diving system is immediately available and is clear, concise, accurate and legible. For this reason, documents are presented in an appropriate auditable sequence with current in-date documents separate from historical documents.
- There is immediate access to personnel responsible for maintaining the DESIGN documentation to address queries.
- In addition to what IMCA says, the system must be organized for inspection, so the auditors can easily access it and do not lose time waiting for someone to open some areas they need to check. For this reason a technician should be nominated to accompany the auditors and facilitate their inspection.
- A drawing showing where the elements referenced are situated must be ready for use. As built diving schematic diagrams should be kept updated to reflect any significant changes to the diving system and, where appropriate, should be approved by the relevant certifying authority.
  This point is not indicated by IMCA, but it is important for the planning of the job.

The table below indicates the minimum durations given by IMCA. However, it is common that auditing teams need more time, and that these given timings are multiplied by two.

Guidance	Assumptions	Estimated audit duration
IMCA D 023 – DESIGN for surface orientated (air) diving systems	- Containerised twin lock decompression chamber and three diver panel. - Two diver deployment baskets/wet bells, clump weights, man-riding winches. - Main umbilicals. - Compressors. - Gas storage. - Hot water system. - Diving equipment. - Comprehensive, clear and concise diving system documentation portfolio.	2 - 4 man days including report
IMCA D 024 – DESIGN for saturation (bell) diving systems	- Single bell. Single chamber plus transfer lock. - Bell deployment and recovery system. - Main bell umbilical. - Hyperbaric rescue system. - Dive and saturation control rooms/panels. - Diver's heating system. - Compressors. - Gas storage. - Gas reclaim. - Diving equipment. - Comprehensive, clear and concise diving system documentation portfolio. - Emergency exercise information.	3 - 6 man days including report

Guidance	Assumptions	Estimated audit duration
IMCA D 037 – DESIGN for surface supplied mixed gas diving systems	- Containerised twin lock decompression chamber and three diver panel. - Two diver deployment baskets/wet bells, clump weights, man-riding winches. - Main umbilicals. - Compressors. - Gas storage. - Hot water system. - Diving equipment. - Comprehensive, clear and concise diving system documentation portfolio.	2 - 4 man days including report
IMCA D 040 – DESIGN for mobile/portable surface supplied diving systems	- Mobile/portable two diver panel with HP air cylinders. - Surface crafts. - Control position. - Deployment davit/s. - Deck decompression chamber (DDC). - Compressors. - Gas storage. - Diving equipment. - Comprehensive, clear and concise diving system documentation portfolio.	1 - 2 man days including report
IMCA D 053 – DESIGN for the hyperbaric reception facility (HRF) forming part of a hyperbaric evacuation system (HES)	- Single chamber plus transfer lock. - Hyperbaric rescue unit (HRU) handling system. - Saturation control room/panels. - Compressors. - Gas storage. - Gas reclaim. - Comprehensive, clear and concise diving system documentation portfolio. - Emergency exercise information.	2-3 man days including report

- In complement to what is said on the previous page, IMCA D 011 also says that the following variations may extend or reduce estimated audit durations include:
  - size and complexity of the diving system;
  - use of audit team size and disciplines to spread the audit workload;
  - access to diving system documentation onshore which may reduce audit duration at site;
  - whether it is the diving system's baseline DESIGN audit;
  - whether the diving system has arrived from working in a different global region;
  - if the diving system has a DESIGN report from another global region applying different engineering/test criteria;
  - if the diving system has been inoperable for an extended period of time;
  - if the diving system has been assembled from several other diving systems;
  - the audit may be being carried out at the same time as the diving system is coming out of dry-dock, being mobilised or undergoing certification or commissioning tests;
  - any limitations or restrictions to access to key personnel to assist sourcing information or deal with concerns;
  - the diving system may be working offshore and access restricted, delayed or protracted;
  - chambers, hyperbaric chamber and/or bell may be under pressure and inaccessible to auditor;
  - diving system or parts may not be equipped ready for audit;
  - diving system documentation portfolio may not be readily available for review onshore or at site;
  - previous annual DESIGN documentation may not be completed correctly;
  - certificates may be missing, incorrectly filed or incorrectly completed;
  - circumstances may not allow function testing or exercising plant, e.g. planned maintenance, hyperbaric rescue system deployment, etc;

4.5.2.6 - Non-conformances reports

IMCA D 011 says that non-conformances identified during audits should be reported to the on-site contractor's management as soon as reasonably practicable to allow close out actions to commence.
Non-conformity points are usually logged and highlighted at the beginning of the report or on a non-conformances report tracking register with suggested corrective actions. The date, name, signature of the auditor, and the stamp of the company in charge of the audit should be visible on the final document sent to the diving contractor.
Non-conformities must be closed up to authorize the diving system to operate. It is recommended that the acceptance of the resolution of the non-conformances is made by the auditor who made the report.

It is also said that a risk assessment should be carried out to evaluate and rank the non-conformances. From this risk assessment, a "common sense" approach may be used to allow a diving system to operate with some non-conformity points category A or B if relevant control measures can be implemented. However, the decision to allow a diving system to work on his oilfield comes only from the senior client representative, who is the only person who can decide whether the contractor can start the operations or not. Note that the risk assessment and decisions taken must be recorded.

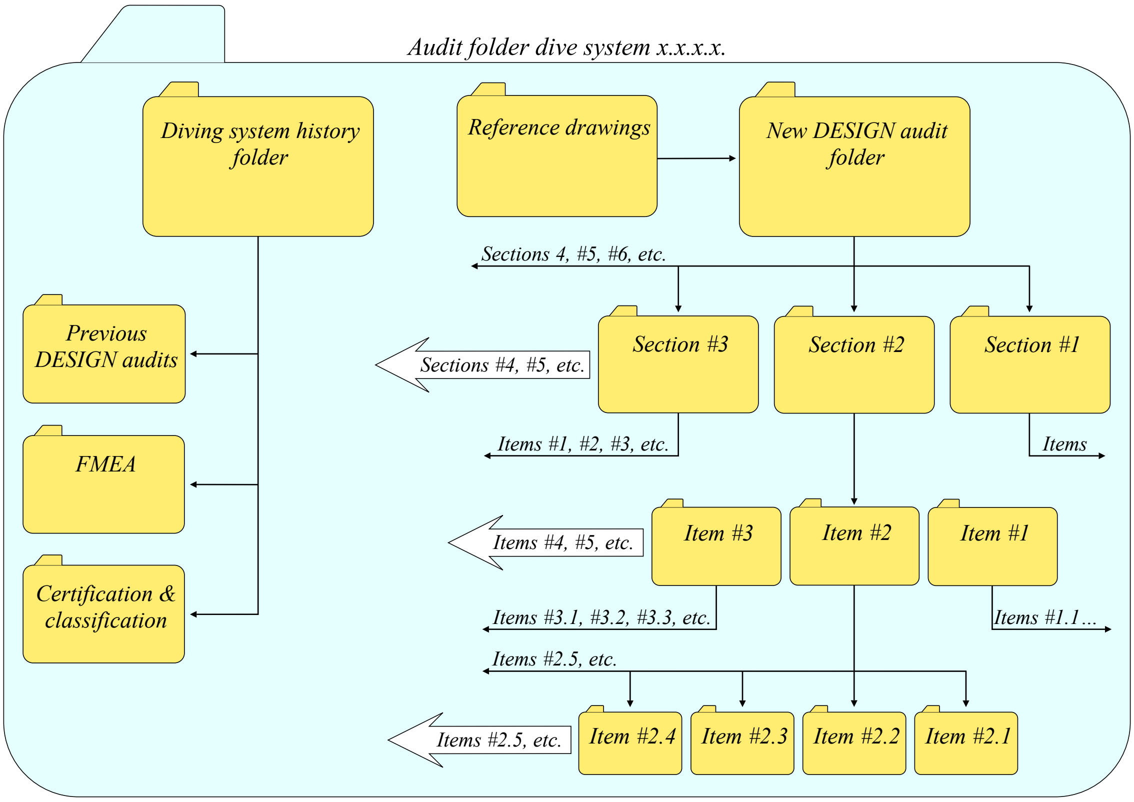
IMCA also indicates that when a disagreement occurs on the audit findings between the auditors and the diving contractor that cannot be resolved on-site, such problems are usually addressed internally by senior management within the organizations with further dialogue and resolution. However, such a discussion has its limits and must never go to a point where the safety of the divers is degraded. Also, as above, the decision to accept an audit with some litigious points is from the senior client representative who can reject the report if he considers that there are unacceptable non-conformities, and may ask for another inspection by a different auditor. In this case, the contractor or the auditing company may lose their reputation.

4.5.2.7 - Complementary guidelines for the organization of audits

As indicated previously, a lot of clients want the IMCA audits performed by an independent auditor. Despite the recommendations from IMCA, a lot of companies still have difficulties organizing for such inspections, and numerous non-conformances that could be avoided are recorded, which result that the dive system cannot be returned to service immediately and gives a bad picture of the company to its client.
It must be highlighted that the quality system of the contractors is a criterion clients take into account for the selection of their contractors. So an audit with too many non-conformances is an indicator that there are breaches in the management system of the diving contractor, which may result that this contractor is rejected from the list of companies agreed by the client. For this reason, it is of utmost importance that the audit report indicates that the system is in peak condition and appropriately maintained.

1. A folder where all the documents are to be collected should be created with sub-folders:
    - A sub-folder that groups the documents that have been used for the certification and the classification of the diving system, the Failure Mode Effect Analysis (FMEA). The previous audits should also be classified in this sub-folder.
    - Another sub-folder that groups all the test and maintenance performed on the diving system should also be created. Note that as indicated in the DESIGN documents, the sea fastening calculation and inspections of portable systems must be included.
    - As the auditors usually require the original certificates, they must be classified the same way as electronic documents and kept ready for the audit.
2. The schemes/drawings of the elements constituting the dive system should be established, taking into account the following:
    - These schemes/drawings can be those made by the manufacturer or by a competent person category 2 or 3. However, the person in charge must ensure that the drawings/schemes are easy to read.
    - Modifications that have been made must be precisely indicated on the scheme.
3. The sections, items, and sub-items should be identified on the schemes/drawings.
    - Each item is precisely located to be easy to find. If necessary photos are added.
    - A reference number or code is given to each item.
    - Acronyms, symbols, or code that are used on the schemes/drawings should be listed in a glossary.
    - Items that are represented on the schemes/drawings should be listed with their identification code, and the path to follow to find them on the drawing.
4. Function tests and inspection certificates of the diving system must be appropriately classified. using the structure of the DESIGN document explained in point 4.5.1.3.
    - The sections are organised and listed, taking in account that the system may have several similar sections. As an example there may be several chambers and compressors.
    - A folder should be created for each section.
    - The items and sub-items that are in these sections should be classified, taking in account that the section is composed of many items and that each item has a function despite some of these items are similar.
    - A sub-folder should be created for each item and sub-item
      The "examination, testing, certification & maintenance" sheets (or equivalent) of the sub-items in the planned maintenance system should be collected with their certificates, and classified in a sub folder, making sure that they are in a chronological order and that the last certificates are on the top of the list.

- The same classification should be done with the original (paper) certificates. Specific office furniture should be used for this purpose. All the original documents should be in the same classier.
- Note that the file names should be as short as possible because Operating Systems such as Windows limit the paths to stored documents to 260 characters. As a result, a certificate with a too-long name and that is reachable through a cascade of too many folders may not be opened by the system.
- When they are several identical elements, each element must be classified in a dedicated sub-folder where its examination and test certificates are classified. As an example, there must be a folder for each gauge, each flexible hose, etc. Thus it is recommended to have dedicated certificates for each item. However, it often happens that organizations performing tests emit only one document for several pieces of the same nature that have been tested in the same period. Manufacturers also issue such “grouped” certificates. In this case, the serial number of the items tested must be listed in the document. To make the audit clear and comfortable, there should be a copy of the “grouped” certificate with the reference number of the item highlighted for each tested article.
- The drawing below shows the way the folders described above can be organized. Note that the most important is to create a classification system that groups all the information of the dive system, and that allows finding quickly every certificate.



5. Perform an internal audit
   This audit allows the technicians to be familiar with the system and the IMCA DESIGN procedures. Also, it will enable finding non-conformances that have not been seen, and whether the system of classification works satisfactorily. It can be done at the same time as updating the Planned Maintenance System.
   - The team audit the system using the appropriate DESIGN document to establish the first status and creating the first list of non-conformances. Also, the team evaluates the classification system in place and propose improvements.
   - Then, the team closes-out the non-conformances listed and update the Planned Maintenance system and ensure that the system is ready to be audited by the Diving System Auditor & Assurance (DSAA).
6. Organize the 3rd party audit and close-outs
   When the problems seen during the internal audit are closed out, the file indicated above can be sent to the 3rd party auditing company so that the inspectors can prepare for the inspection. Also, the team should organize to assist the Diving System Auditors. For this reason, the people involved should:
   - prepare the diving system for inspection, as previously indicated.
   - give explanations regarding the dive system and the Planned Maintenance System (PMS) in force.
   - supply the certificates when asked by the DSAA. Regarding this point, the team must always ensure that the auditor is not struggling to find them.
   - help the DSAA to find the elements indicated in the drawings, and to fill the DESIGN document if required.
   - note the remarks and recommendations of the auditor.
   - close-out the non-conformances as soon as possible (If possible during the audit).
   - ensure that the close-outs are accepted and signed by the Diving System Assurance Auditor (DSAA).

4.5.3 - Ensure of updated certifications

The Diving Equipment Systems Inspection Guidance Note (DESIGN) D 023, D 037, and D 040 must be used as support by the supervisors and the diving technicians to check the diving system regularly with particular attention to the dates of certifications indicated in these documents and listed below.

Note:
The categories of competent persons are those listed in *point 3.5.1.2**.*
The numbers in brackets (; ;) indicate the categories of competent persons and are specified only when only some categories are allowed to test an item … As an example : (2;4) = only n° 2 and 4 are allowed to undertake the test or examination indicated.

IMCA - Diving Equipment Systems Inspection Guidance Note (DESIGN) D 023 - Certifications list

Section	Item # & Description	Visual external + function test , calibration or for lifting appliances: Load test 1.25 SWL	Visual internal + external + gas leak test at max. working pressure or for lifting appliances: Wire destruction test	Internal + external+ leak test 1,5 max. working pressure or for lifting appliances: Load test 1.5 SWL	Other
General safety	1.1 - Classification (If classified)				
General safety	4.5 - Sea Fastening (Design)				At system installation
General safety	4.6 - Sea Fastening				At system installation
General safety	7.6 - Electrical Power	6 months			
General safety	9.3 - Medical kit DMAC 15	6 months (Medic)			
Dive control	2.13 - Communications	6 months (1;2;4)			
Dive control	6.3 - Analysers	6 months (1;2;4)			
Dive control	7.12 - Gauges (calibration)	6 months			
Dive control	8.8 - Pipe works & valves	6 months	2 years	When new	
Dive control	8.12 - Relief valves	6 months	2 ½ years		
Dive control	Oxygen cleaning pipe works and regulators	6 months (2,3,4)	6 month is a minimum: The frequency of oxygen cleaning must be organised according to the working conditions		
Dive control	9.3 Electrics	6 months			
Dive control	10.2 & 10.3 - Portable fire fighting system	6 months			Manufacturer specifications
Dive control	10.2 & 10.4 - fixed fire fighting system	Visual: 6 months Test: 12 months			Manufacturer specifications
Dive control	10.6 - Automatic fire detection	12 months			
Dive control	12.3 to 12.5 - Emergency breathing apparatus	6 months (1;2;4)	2 ½ years (3;4)	5 years (3;4)	
Chamber	1.6 - Communication	6 months (1;2;4)			
Chamber	2.7 & 2.7 - Pressure vessel	6 months	2 ½ years		
Chamber	3.5 to 3.9 - Viewports	6 months	2 ½ years	5 years (3;4)	10 year old max.
Chamber	4.2 & 4.3 Portable fire fighting	6 months			
Chamber	10.2 & 10.4 - fixed fire fighting system	Visual: 6 months Test: 12 months			
Chamber	10.6 - Automatic fire detection	12 months			

Section	Item # & Description	Visual external + function test, calibration or for lifting appliances: Load test 1.25 SWL	Visual internal + external + gas leak test at max. working pressure or for lifting appliances: Wire destruction test	Internal + external+ leak test 1,5 max. working pressure or for lifting appliances: Load test 1.5 SWL	Other
Chamber (external)	5.6 - Electrical penetrators certification				Permanent cert. (3;4)
Chamber (external)	5.16 & 5.17 Medical lock pipework	6 months	2 years		
Chamber (external)	5.19 - Pressure relief valves	6 months (1;2;4)	2 ½ years (2;4)		
Chamber (external)	5.21 - Electrical testing	6 months (2;3;4)			
Chamber (external)	5.23 & 5.24 - Valves & pipe works	6 months	2 years		
Chamber (internal)	6.13 - Communication	6 months (1;2;3)			
Chamber (internal)	6.14 - BIBS	6 months (1;2;4)			
Chamber (internal)	6.22 - Sanitary system (if installed)	6 months			
Chamber (internal)	6. 28 - Fire fighting	6 months			
Chamber (internal)	6.30 - Gauge calibration	6 months (2;3;4)			
Chamber (internal)	6.32 - Scrubber	6 months			
Chamber (internal)	6.35 & 6.36 - Valves & pipe works	6 months	2 years		
Chamber (internal)	6.37 - Electrical equip. and cables	6 months (2;3;4			
Chamber (control panel)	7.12 & 7.13 - Pipe works, valves , regulators	6 months	2 years		
Chamber (control panel)	7.15 - Gauges calibration	6 months (2;3;4)			
Chamber (control panel)	7.17 - Analysers	6 month (1;2;4)			
Chamber (control panel)	7.19 & 7.20 - relief valves	6 months (1;2;4)	2 ½ years (2;4)		
Chamber (control panel)	8.4 & 8.5 - BA sets	6 months (1;2;4)	2 ½ years (3;4)	5 years (3;4)	
LARS	2.13 & 2.14 - Main winch testing	6 months		12 months (2;3;4) (+ dynamic 1.25 SWL)	12 months (2;3;4) (NDE critical areas)
LARS	3.3 - Lubrication main wire (by pressure)				6 months
LARS	3.5 to 3.7 - Main wire testing	6 months	12 months	12 months	
LARS	4.1 - 2nd lifting system: Basket/bell recovery demo.				12 months
LARS	4.17 & 4.18 - 2nd recovery winch testing	6 months		12 months (2;3;4) (+ dynamic 1.25 SWL)	12 months (2;3;4) (NDE critical areas)
LARS	4.21 - Lubrication secondary wire (by pressure)				6 months
LARS	4.23 to 4.25 - secondary wire testing	6 months	12 months	12 months	
LARS	6.7 - Hydraulic system test.	6 months (2;3;4)			
LARS	6.8 - Intercooler	6 months (2;3;4)			
LARS	6.10 - Hydraulic oil analysis or replacement				12 months (2;3;4)
LARS	Relief valve (Hydraulic)	6 months	2 ½ years		

Section	Item # & Description	Visual external + function test, calibration or for lifting appliances: Load test 1.25 SWL	Visual internal + external + gas leak test at max. working pressure or for lifting appliances: Wire destruction test	Internal + external+ leak test 1,5 max. working pressure or for lifting appliances: Load test 1.5 SWL	Other
LARS	7.6 & 7.7 - Pneumatic hose	6 months	2 years		
LARS	8.7 - Electric winch: Electrical testing	6 months (2;3;4)			
LARS	9.2 - Communication	6 months (1;2;4)			
LARS	10.2 & 10.3 - Overall testing of LARS	6 months (2;3;4)		12 months (2;3;4) (+ dynamic 1.25 SWL)	12 months (2;3;4) (NDE critical areas)
LARS	11.3 & 11.4 - Portable fire fighting system	6 months			Manufacturer specifications
LARS	11.3 & 11.5 - fixed fire fighting system	Visual: 6 months Test: 12 months			Manufacturer specifications
LARS	11.7 - Automatic fire detection	12 months			
LARS	13.3 - Breathing apparatus	6 months (1;2;4)	2 ½ years (3;4)	5 years (3;4)	
LARS	7.6 & 7.7 - Pneumatic hose	6 months	2 years		
LARS	8.7 - Electric winch: Electrical testing	6 months (2;3;4)			
LARS	9.2 - Communication	6 months (1;2;4)			
LARS	10.2 & 10.3 - Overall testing of LARS	6 months (2;3;4)		12 months (2;3;4) (+ dynamic 1.25 SWL)	12 months (2;3;4) (NDE critical areas)
LARS	11.3 & 11.4 - Portable fire fighting system	6 months			Manufacturer specifications
LARS	11.3 & 11.5 - fixed fire fighting system	Visual: 6 months Test: 12 months			Manufacturer specifications
LARS	11.7 - Automatic fire detection	12 months			
LARS	13.3 - Breathing apparatus	6 months (1;2;4)	2 ½ years (3;4)	5 years (3;4)	
Diving basket	1.3 Documentation showing the designed SWL	Note: Only for basket manufactured after 1 January 2014			Permanent
Diving basket	1.3 & 1.14 - Load test	6 months		6 months (2;3;4)	
Diving basket	2.6 to 2.8 - Emergency cylinder	6 months	2 years (3;4)	4 years (3;4)	
Diving basket	2.9 - Pressure gauge emergency cylinder	6 months			
Diving basket	2.11 & 2.12 - Pipework	6 months	2 years		
Diving basket	2.13 & 2.14 - Hoses	6 months	2 years		
Diving basket	2.16 & 2.17 - Relief valve regulator	6 months (1;2;4)	2 ½ years (2;4)		
Diver heating system	5.3 & 5.4 - Portable fire fighting system	6 months			Manufacturer specifications
Diver heating system	5.3 & 5.5 - fixed fire fighting system	Visual: 6 months Test: 12 months			Manufacturer specifications
Diver heating system	5.7 - Automatic fire detection	12 months			
Diver heating system	6.1 - Hot water system	6 months			
Diver heating system	6.3 & 6.4 - Pipework	6 months	2 years		

Section	Item # & Description	Visual external + function test, calibration or for lifting appliances: Load test 1.25 SWL	Visual internal + external + gas leak test at max. working pressure or for lifting appliances: Wire destruction test	Internal + external+ leak test 1,5 max. working pressure or for lifting appliances: Load test 1.5 SWL	Other
Diver heating system	6.5 - Gauges	6 months			
Diver heating system	6.6 - Electrical	6 months (2;3;4)			
Diver heating system	6.7 to 6.9 - Pressure vessels	6 months	15 months (3;4)	5 years (3;4)	
Diver heating system	6.11 & 6.12 - Relief valves	6 months	2 ½ years (2;3;4)		
Divers umbilical	3.1 - Electrical components	6 months (2,3,4)			
Divers umbilical	3.2 - Hose components	6 months	2 years	Hydro test When 1st installed	
Divers umbilical	Oxygen cleaning	6 months (2,3,4)	6 month is a minimum: The frequency of oxygen cleaning must be organised according to the working conditions		
Divers personnel equipment	1.7 - Helmet	6 months (1,2,4)	**Note:** Inspection and test 12 month according to manufacturer recommendations		12 months
Divers personnel equipment	2.5 to 2.7 - Bail outs	6 months (2;4)	2 years (3;4)	4 years (3;4)	
Divers personnel equipment	2.8 to 2.10 - Composite bail outs	6 months (2;4)	2 years (3;4)		5 years (hydraulic proof pressure test)
Divers personnel equipment	3.6 - Whips & connectors	6 months	2 years		
Divers personnel equipment	3.8 - Indicating gauges	6 months			
Divers personnel equipment	3.9 to 3.11 - Pipework	6 months	2 years		
Divers personnel equipment	Oxygen cleaning all equipment	6 months (2,3,4)	6 month is a minimum: The frequency of oxygen cleaning must be organised according to the working conditions		
Compressors	3.3. & 3.4 - Portable fire fighting system	6 months			Manufacturer specifications
Compressors	3.3. & 3.5 - fixed fire fighting system	Visual: 6 months Test: 12 months			Manufacturer specifications
Compressors	3.6 - Automatic fire detection	12 months			
Compressors	4.3 - Test automatic stop safety device	6 month (1;2;4)			
Compressors	4.5 - Explosion protection air compressors if $O_2 \geq 25\%$	6 month (1;2;4)			
Compressors	4.7 - Analysers	6 month (1;2;4)			
Compressors	4.8 - Relief valve	6 months (1;2;4)	2 ½ years (2;4)		
Compressors	57 to 59 - Pipework	6 months	2 years	When 1st installed (3;4)	
Compressors	6.2 & 6.3 - Receivers	6 months (2;3;4)	2 ½ years (2;3;4)		
Compressors	7.2 - Electrical testing	6 months (2;3;4)			
Compressors	8.1 - Operational testing	6 months			
Compressors	8.2 - Delivery rate	6 months			
HP and gas storage	2.1 to 2.3 - Cylinders	6 months	2 ½ years (3;4)	5 years (3;4)	

Section	Description	Visual external + function test, calibration Or for lifting appliances: Load test 1.25 SWL	Visual internal + external + gas leak test at max. working pressure Or for lifting appliances: Wire destruction test	Internal + external+ leak test 1,5 max. working pressure Or for lifting appliances: Load test 1.5 SWL	Other
HP and gas storage	2.4 to 2.7 - Pipework & valves (with internal cleanliness)	6 months	2 years	When 1st installed (3;4)	
HP and air storage	2.8 & 2.9 - Lifting equipment (slings, quads…)	6 months (2;3;4)		12 months (2;3;4)	
HP and air storage	2.10 - Relief valves	6 months (1;2;4)	2 ½ years (2;4)		
HP and air storage	3.3. & 3.4 - Portable fire fighting system	6 months			Manufacturer specifications
HP and air storage	3.3. , 3.5 & 3.6 - fixed fire fighting system	Visual: 6 months Test: 12 months			Manufacturer specifications
HP and air storage	3.7 - Automatic fire detection	12 months			

IMCA - Diving Equipment Systems Inspection Guidance Note (DESIGN) D 037 - Certifications list

Section	Item # & Description	Visual external + function test, calibration or for lifting appliances: Load test 1.25 SWL	Visual internal + external + gas leak test at max. working pressure or for lifting appliances: Wire destruction test	Internal + external+ leak test 1,5 max. working pressure or for lifting appliances: Load test 1.5 SWL	Other
Dive control	Portable fire fighting system	6 months			Manufacturer specifications
Dive control	Fixed fire fighting system	Visual: 6 months Test: 12 months			Manufacturer specifications
Dive control	Automatic fire detection	12 months			
Dive control	1st aid	6 months			
Dive control	Emergency breathing apparatus	6 months (1;2;4)	2 ½ years (3;4)	5 years (3;4)	
Dive control	Communications	6 months (1;2;4)			
Dive control	Analysers	6 months (1;2;4)			
Dive control	Gauges	6 months			
Dive control	Valves and pipe works	6 months	2 year		
Dive control	Oxygen cleaning pipe works and regulators	6 months (2,3,4)	6 month is a minimum: The frequency of oxygen cleaning must be organised according to the working conditions		
Dive control	Electrical equipments	6 months (1;2;4)			
Dive control	Relief valves	6 months	2 ½ years		
Chamber general	Communication	6 months (1;2;4)			
Chamber general	Fire fighting	6 months			
Chamber general	1st aid	6 months			
Chamber external	Pressure hull	2 months	2 ½ years	5 years (3;4)	
Chamber external	Viewports	6 months	2 ½ years	5 years (3;4)	10 year old max.
Chamber external	Light and cables	6 months (2;3;4)			

Section	Item # & Description	Visual external + function test, calibration or for lifting appliances: Load test 1.25 SWL	Visual internal + external + gas leak test at max. working pressure or for lifting appliances: Wire destruction test	Internal + external+ leak test 1,5 max. working pressure or for lifting appliances: Load test 1.5 SWL	Other
Chamber external	Pressure relief valves	6 months (1;2;4)	2 ½ years (2;4)		
Chamber external	Valves & pipe works	6 months	2 years		
Chamber internal	Viewports	6 months			
Chamber internal	Valves & pipe works	6 months	2 years		
Chamber internal	Communication	6 months (1;2;3)			
Chamber internal	Lights and cables	6 months (2;3;4			
Chamber internal	BIBS	6 months (1;2;4)			
Chamber internal	Sanitary system (if installed)	6 months			
Chamber internal	Fire fighting	6 months			
Chamber internal	Depth gauge	6 months (2;3;4)			
Chamber internal	Scrubber	6 months			
Chamber internal	Heating / cooling system	6 months			
Chamber Control panel	BA sets	6 months (1;2;4)			
Chamber Control panel	Gauges	6 months (2;3;4)			
Chamber Control panel	Analysers	6 month (1;2;4)			
Chamber Control panel	Pipe works, valves , regulators	6 months	2 years		
LARS	Main winch testing	6 months		12 months (2;3;4) (+ dynamic 1.25 SWL)	12 months (2;3;4) (NDE critical areas)
LARS	Lubrication main wire (by pressure)				6 months
LARS	Main wire testing	6 months	12 months	12 months	
LARS	lifting system: Basket/bell recovery demo.				12 months
LARS	2nd recovery winch testing	6 months		12 months (2;3;4) (+ dynamic 1.25 SWL)	12 months (2;3;4) (NDE critical areas)
LARS	Lubrication secondary wire (by pressure)				6 months
LARS	Secondary wire testing	6 months	12 months	12 months	
LARS	Hydraulic system test.	6 months (2;3;4)			
LARS	Intercooler	6 months (2;3;4)			
LARS	Hydraulic oil analysis or replacement				12 months (2;3;4)
LARS	Relief valve (Hydraulic)	6 months	2 ½ years		
LARS	Pneumatic hose	6 months	2 years		

Section	Item # & Description	Visual external + function test, calibration or for lifting appliances: Load test 1.25 SWL	Visual internal + external + gas leak test at max. working pressure or for lifting appliances: Wire destruction test	Internal + external+ leak test 1,5 max. working pressure or for lifting appliances: Load test 1.5 SWL	Other
LARS	Electric winch: Electrical testing	6 months (2;3;4)			
LARS	Communication	6 months (1;2;4)			
LARS	Overall testing of LARS	6 months (2;3;4)		12 months (2;3;4) (+ dynamic 1.25 SWL)	12 months (2;3;4) (NDE critical areas)
LARS	Portable fire fighting system	6 months			Manufacturer specifications
LARS	Fixed fire fighting system	Visual: 6 months Test: 12 months			Manufacturer specifications
LARS	Automatic fire detection	12 months			
LARS	Breathing apparatus	6 months (1;2;4)	2 ½ years (3;4)	5 years (3;4)	
Wet bell general	Structure and lift points (visual examination)	6 months (2;3;4)			
Wet bell general	Load test + MPI of lifting points	12 months (2;3;4)			
Wet bell general	Buoyancy test			When new & during load tests (3;4)	
Wet bell gas cylinders	Cylinder	6 months	2 years (3;4)	4 years (3;4)	
Wet bell outfitting	Gauges	6 months		When installed (3;4)	
Wet bell outfitting	Pipework	6 months	2 years (3;4)	When installed (3;4)	
Wet bell outfitting	Relief valve	6 months (1,2,4)	2 ½ years (3;4)		Manufacturer set. 1st inst. (2;3;4)
Wet bell outfitting	Electricals	6 months (2;3;4)			Manufacturer set. 1st inst. (3;4)
Wet bell Main umbilical	Hose components	6 months	2 years	When installed (3;4)	
Wet bell Main umbilical	electrical components	6 months			
Wet bell Spare umbilical	Hose components	6 months	2 years	When installed (3;4)	
Wet bell Spare umbilical	electrical components	6 months			
Diving basket	1.3 Documentation showing the designed SWL	Note: Only for basket manufactured after 1 January 2014			Permanent
Diving basket	1.3 & 1.14 - Load test	6 months		6 months (2;3;4)	
Diving basket	2.6 to 2.8 - Emergency cylinder	6 months	2 years (3;4)	4 years (3;4)	
Diving basket	2.9 - Pressure gauge emergency cylinder	6 months			
Diving basket	2.11 & 2.12 - Pipework	6 months	2 years		
Diving basket	2.13 & 2.14 - Hoses	6 months	2 years		
Diving basket	2.16 & 2.17 - Relief valve regulator	6 months (1;2;4)	2 ½ years (2;4)		
Hot water system	Portable fire fighting system	6 months			Manufacturer specifications

Section	Item # & Description	Visual external + function test, calibration or for lifting appliances: Load test 1.25 SWL	Visual internal + external + gas leak test at max. working pressure or for lifting appliances: Wire destruction test	Internal + external+ leak test 1,5 max. working pressure or for lifting appliances: Load test 1.5 SWL	Other
Hot water system	Fixed fire fighting system	Visual: 6 months Test: 12 months			Manufacturer specifications
Hot water system	Automatic fire detection	12 months			
Hot water system	Hot water system	6 months			
Hot water system	Pipework	6 months	2 years		
Hot water system	Gauges	6 months			
Hot water system	Electrical	6 months (2;3;4)			
Hot water system	Pressure vessels	6 months	15 months (3;4)	5 years (3;4)	
Hot water system	Relief valves	6 months	2 ½ years (2;3;4)		
Divers umbilicals	Electrical components	6 months (2,3,4)			
Divers umbilicals	Pressure Function test	6 months	2 years	Hydro test When 1st installed	
Divers personnel equipment	Helmet	6 months (1,2,4)	**Note:** Inspection and test 12 month or according to manufacturer recommendations		12 months
Divers personnel equipment	Bail outs	6 months (2;4)	2 years (3;4)	4 years (3;4)	
Divers personnel equipment	Composite bail outs	6 months (2;4)	2 years (3;4)		5 years (hydraulic proof pressure test)
Divers personnel equipment	Whips & connectors	6 months	2 years		
Divers personnel equipment	Indicating gauges	6 months			
Divers personnel equipment	Pipework	6 months	2 years		
Compressors	Portable fire fighting system	6 months			Manufacturer specifications
Compressors	Fixed fire fighting system	Visual: 6 months Test: 12 months			Manufacturer specifications
Compressors	Automatic fire detection	12 months			
Compressors	Test automatic stop safety device	6 month (1;2;4)			
Compressors	Explosion protection air compressors if $O_2 \geq 25\%$	6 month (1;2;4)			
Compressors	Analysers	6 month (1;2;4)			
Compressors	Relief valve	6 months (1;2;4)	2 ½ years (2;4)		
Compressors	Pipework	6 months	2 years	When 1st installed (3;4)	
Compressors	Receivers	6 months (2;3;4)	2 ½ years (2;3;4)		
Compressors	Electrical testing	6 months (2;3;4)			
Compressors	Operational testing	6 months			
Compressors	Delivery rate	6 months			

Section	Description	Visual external + function test , calibration Or for lifting appliances: Load test 1.25 SWL	Visual internal + external + gas leak test at max. Working pressure Or for lifting appliances: Wire destruction test	Internal + external+ leak test 1,5 max. working pressure Or for lifting appliances: Load test 1.5 SWL	Other
Compressors	Gas purity	6 months (1;2;4)			
HP and gas storage	Cylinders	6 months	2 ½ years (3;4)	5 years (3;4)	
HP and gas storage	Pipework & valves (with internal cleanliness)	6 months	2 years	When 1st installed (3;4)	
HP and air storage	Lifting equipment (slings, quads…)	6 months (2;3;4)		12 months (2;3;4)	
HP and air storage	Relief valves	6 months (1;2;4)	2 ½ years (2;4)		
HP and air storage	Portable fire fighting system	6 months			Manufacturer specifications
HP and air storage	Fixed fire fighting system	Visual: 6 months Test: 12 months			Manufacturer specifications
HP and air storage	Automatic fire detection	12 months			
General safety	Classification (If classified)				
General safety	Sea Fastening (Design)				At system installation
General safety	Sea Fastening (welds)				At system installation
General safety	Electrical Power	6 months			
General safety	Hydraulicl Power	6 months			
General safety	9.3 - Medical kit DMAC 15	6 months (Medic)			

IMCA - Diving Equipment Systems Inspection Guidance Note (DESIGN) D 040 - Certifications list

Section	Item # & Description	Visual external + function test, calibration or for lifting appliances: Load test 1.25 SWL	Visual internal + external + gas leak test at max. working pressure or for lifting appliances: Wire destruction test	Internal + external+ leak test 1,5 max. working pressure or for lifting appliances: Load test 1.5 SWL	Other
General safety	1.1 - Classification				Permanent
General safety	4.5 - Sea Fastening (Design)				At Installation
General safety	4.6 - Sea Fastening (Installation)				At installation
General safety	6.1 - Marine audit IMCA M 189 small diving vessel				Before mobilization
General safety	7.3 - 1st aid kit DMAC 15.3	6 months (1,2,3)			
General safety	7.6 - Oxygen set in the small vessel	6 months	2 ½ years (4; 4)		Visual internal + test max working pressure: 5 years
Small vessel	3.5 - Emergency electrical power	6 months			
Control position	2.8 - Test communications	6 months			
Control position	4.3 - Analyser	6 months			

Section	Item # & Description	Visual external + function test, calibration or for lifting appliances: Load test 1.25 SWL	Visual internal + external + gas leak test at max. working pressure or for lifting appliances: Wire destruction test	Internal + external+ leak test 1,5 max. working pressure or for lifting appliances: Load test 1.5 SWL	Other
Control position	5.12 - Gauges calibration	6 month (2;3;4)			
Control position	6.8 - Valves & Pipework	6 months	2 years		
Control position	6.11 - Relief valves	6 months	2 ½ years (2; 3; 4)		
Control position	7.4 - Electrical testing	6 months			
Control position	8.1 - Breathing apparatus	6 months	2 ½ years	5 years (leak test at max working pressure)	
Diver's umbilical	3.1 - Electrical components	6 months			
Diver's umbilical	3.2 - Hose components	6 months	2 years (2; 3; 4)		
Diver's personal equipment	2.7 - Helmets	6 months			Manufacturer's recommendations : 12 months
Diver's personal equipment	3.5 - Bail out (steel)	6 months	2 years (3; 4)	4 years (3; 4)	
Diver's personal equipment	3.8 - Bail out (composite)	6 months	2 years (3; 4)	5 years (3; 4) (Hydro test to the pressure marked on cylinder)	
Diver's personal equipment	4.6 - Whips and connectors	6 months	2 years		
Diver's personal equipment	4.8 - Gauge	6 months			
Diver's personal equipment	4.9 - Pipework	6 months	2 years		
Diver's personal equipment	4.13 - Relief valve testing	6 months (1;2;4)	2 ½ years (2;4)		
Diver's personal equipment	5.3 - Harness				Discarded after 5 years in service
Diver's personal equipment	5.3 - Harness				Discarded after 10 years after fabrication
Gas storage	2.1 - Cylinders (Steel)	6 months	2 years (3; 4)	4 years (3; 4)	
Gas storage	2.4 - Cylinder (composite)	6 months	12 months	5 years (3; 4) (Hydro test to the pressure marked on cylinder)	
Gas storage	2.7 - Pipework testing	6 months	2 ½ years	When new	Internal cleanliness
Gas storage	2.11 - Relief valves	6 months	2 ½ years (2; 3; 4)		
Chamber	1.6 - Communication	6 months (1;2;4)			
Chamber	2.7 & 2.7 - Pressure vessel	6 months	2 ½ years		
Chamber	3.5 to 3.9 - Viewports	6 months	2 ½ years	5 years (3;4)	10 year old max.
Chamber	4.2 & 4.3 Portable fire fighting	6 months			

Section	Item # & Description	Visual external + function test, calibration or for lifting appliances: Load test 1.25 SWL	Visual internal + external + gas leak test at max. working pressure or for lifting appliances: Wire destruction test	Internal + external+ leak test 1,5 max. working pressure or for lifting appliances: Load test 1.5 SWL	Other
Chamber	10.2 & 10.4 - fixed fire fighting system	Visual: 6 months Test: 12 months			
Chamber	10.6 - Automatic fire detection	12 months			
Chamber (external)	5.6 - Electrical penetrators certification				Permanent cert. (3;4)
Chamber (external)	5.16 & 5.17 Medical lock pipework	6 months	2 years		
Chamber (external)	5.19 - Pressure relief valves	6 months (1;2;4)	2 ½ years (2;4)		
Chamber (external)	5.21 - Electrical testing	6 months (2;3;4)			
Chamber (external)	5.23 & 5.24 - Valves & pipe works	6 months	2 years		
Chamber (internal)	6.13 - Communication	6 months (1;2;3)			
Chamber (internal)	6.14 - BIBS	6 months (1;2;4)			
Chamber (internal)	6.22 - Sanitary system (if installed)	6 months			
Chamber (internal)	6. 28 - Fire fighting	6 months			
Chamber (internal)	6.30 - Gauge calibration	6 months (2;3;4)			
Chamber (internal)	6.32 - Scrubber	6 months			
Chamber (internal)	6.35 & 6.36 - Valves & pipe works	6 months	2 years		
Chamber (internal)	6.37 - Electrical equip. and cables	6 months (2;3;4			
Chamber (control panel)	7.12 & 7.13 - Pipe works, valves , regulators	6 months	2 years		
Chamber (control panel)	7.15 - Gauges calibration	6 months (2;3;4)			
Chamber (control panel)	7.17 - Analysers	6 month (1;2;4)			
Chamber (control panel)	7.19 & 7.20 - relief valves	6 months (1;2;4)	2 ½ years (2;4)		
Chamber (control panel)	8.4 & 8.5 - BA sets	6 months (1;2;4)	2 ½ years (3;4)	5 years (3;4)	
Compressors	3.3. & 3.4 - Portable fire fighting system	6 months			Manufacturer specifications
Compressors	3.3. & 3.5 - fixed fire fighting system	Visual: 6 months Test: 12 months			Manufacturer specifications
Compressors	3.6 - Automatic fire detection	12 months			
Compressors	4.3 - Test automatic stop safety device	6 month (1;2;4)			
Compressors	4.5 - Explosion protection air compressors if $O_2 \geq 25\%$	6 month (1;2;4)			
Compressors	4.7 - Analysers	6 month (1;2;4)			
Compressors	4.8 - Relief valve	6 months (1;2;4)	2 ½ years (2;4)		
Compressors	57 to 59 - Pipework	6 months	2 years	When 1st installed (3;4)	

Section	Item # & Description	Visual external + function test, calibration or for lifting appliances: Load test 1.25 SWL	Visual internal + external + gas leak test at max. working pressure or for lifting appliances: Wire destruction test	Internal + external+ leak test 1,5 max. working pressure or for lifting appliances: Load test 1.5 SWL	Other
Compressors	6.2 & 6.3 - Receivers	6 months (2;3;4)	2 ½ years (2;3;4)		
Compressors	7.2 - Electrical testing	6 months (2;3;4)			
Compressors	8.1 - Operational testing	6 months			
Compressors	8.2 - Delivery rate	6 months			
Compressors	8.3 - Gas purity	6 months (1;2;4)			
HP and gas storage	2.1 to 2.3 - Cylinders	6 months	2 ½ years (3;4)	5 years (3;4)	
HP and gas storage	2.4 to 2.7 - Pipework & valves (with internal cleanliness)	6 months	2 years	When 1st installed (3;4)	
HP and air storage	2.8 & 2.9 - Lifting equipment (slings, quads…)	6 months (2;3;4)		12 months (2;3;4)	
HP and air storage	2.10 - Relief valves	6 months (1;2;4)	2 ½ years (2;4)		
HP and air storage	3.3. & 3.4 - Portable fire fighting system	6 months			Manufacturer specifications
HP and air storage	3.3. , 3.5 & 3.6 - fixed fire fighting system	Visual: 6 months Test: 12 months			Manufacturer specifications
HP and air storage	3.7 - Automatic fire detection	12 months			

5 - Weather and currents

Among reported diving incidents/accidents, a lot were due to adverse environmental conditions not sufficiently anticipated. This is the reason why the supervisor must be sure that everything is under control on this side. For that, a minimum knowledge and good common sense is necessary.

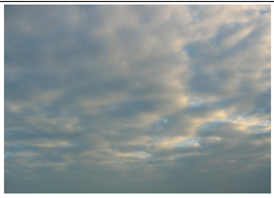
5.1 - Observe and report the weather

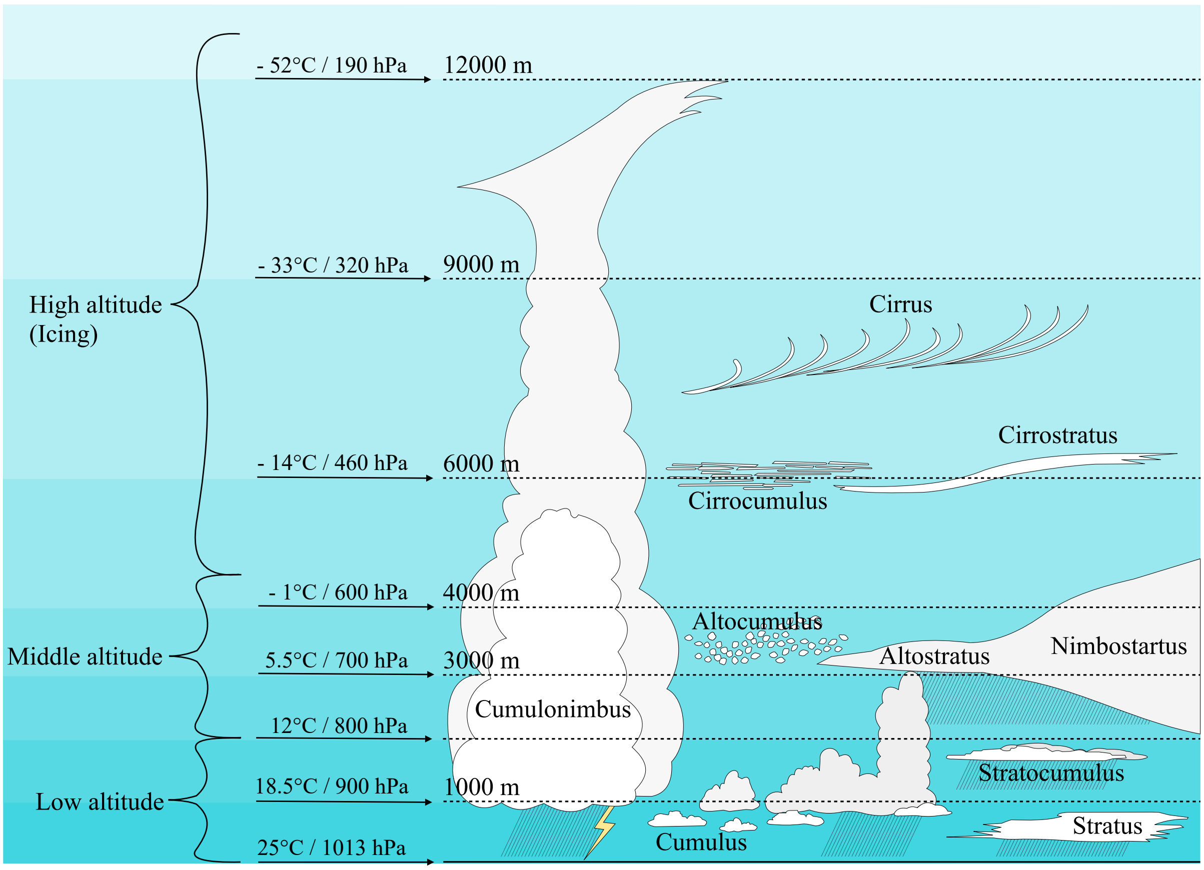
The weather prediction techniques have widely progressed with the development of means of calculation, communications and observation, particularly the space industry. Nevertheless, despite the obvious progress, experience sometimes shows some huge differences with the reality on location. That is why it is important to be able to observe and report clearly what is really happening on site. For that, the means of observation and the classifications developed in the old times are still valid tools.

5.1.1 - Clouds

In addition to the barometer, and the observation of the sea, the "reading" of the clouds is a reliable means of weather prediction.

Altitude	Name	Description
4000 to 12000 m	Cirrus	Cirrus clouds are formed when water vapor undergoes deposition at high altitudes. Random, isolated cirrus do not have any particular significance, but a large number of cirrus clouds can be a sign of an approaching frontal system or upper air disturbance. When cirrus clouds precede a cold front, squall line or multi-cellular thunderstorm, it is because they have been blown off the top of the cumulonimbus, and the next to arrive are the cumulonimbus clouds. In the tropics, a veil of white cirrus can be seen about 1 and a half days prior the passage of a cyclone. 
4000 to 6000 m	Cirrostratus	As a warm front approaches, cirrus clouds tend to thicken into cirrostratus. When sunlight or moonlight passes through the hexagonal-shaped ice crystals of cirrostratus clouds, the light is dispersed or refracted in such a way that a ring or halo may form. Cirrostratus may thicken and lower into altostratus, stratus, and even nimbostratus. 
3000 to 6000 m	Cirrocumulus	Cirrocumulus clouds are layered clouds which commonly appear in regular, rippling patterns or in rows of clouds with clear areas in between. Like other members of the cumuliform category, they are formed via convective processes. Significant growth of these patches indicates high-altitude instability and can signal the approach of poorer weather. 
2000 to 6000 m	Altocumulus	They are characterized by globular masses or rolls in layers or patches. They are larger and darker than cirrocumulus and smaller than stratocumulus. Altocumulus are commonly found between the warm and cold fronts in a depression, often hidden by lower clouds. Towering altocumulus, frequently signals the development of thunderstorms later in the day, as it shows instability and convection in the middle levels of the troposphere. 
2000 to 4000 m	Altostratus	An altostratus is formed by the lifting of a large mostly, stable air mass that causes invisible water vapour to condense into clouds. It can produce light precipitation. If the precipitation increases in persistence and intensity, the altostratus cloud may thicken into nimbostratus. 
2000 to 4000 m	Nimbostratus	Nimbostratus clouds belong to the Low Cloud group. They are dark grey with a ragged base. Nimbostratus clouds are associated with continuous rain (or snow). Sometimes they cover the whole sky, and you can't see the edges of the cloud. 

Altitude	Name	Description
2000 to 2400 m	Stratocumulus	They are large dark, rounded clouds, usually in groups, lines, or waves. Larger than the altocumulus, and at a lower altitude. When they produce precipitation, it is only light rain (or snow). However, these clouds are often seen at either the front or tail end of worse weather, so they may indicate storms to come. They are also often seen underneath the cirrostratus and altostratus sheets that often precede a warm front. 
1000 to 3000 m	Cumulus	They are low-level clouds that can have noticeable vertical development and clearly defined edges. They are "cotton-like" in appearance, and generally have flat bases. Cumulus clouds may appear by themselves, in lines, or in clusters. They can be associated with good or bad weather.   Cumulus humilis clouds (photo on the right) are associated with fair weather. Cumulus congestus clouds (Photo on the left) are often precursors of other types of clouds such as cumulonimbus, and usually associated with bad weather. Their tops look like cauliflower heads and mean that light to heavy showers can occur.
Surface to 2000 m	Stratus	These clouds belong to the Low Cloud group which form when a sheet of warm, moist air lifts off the ground and depressurises, or when the ambient air temperature decreases, increasing the relative humidity. They can also form from stratocumulus. They are uniform grey in colour and can cover most or all of the sky, and look like a fog that doesn't reach the ground. They can persist for days in anticyclone conditions. 
1000 to 12000 m	Cumulonimbus	Cumulonimbus clouds belong to the Clouds with Vertical Growth group. They are generally known as thunderstorm clouds. A cumulonimbus cloud can grow up to 12 km high. At this height, high winds will flatten the top of the cloud out into an anvil-like shape. Cumulonimbus clouds are associated with heavy rain, (snow & hail), lightning, and tornadoes. Cumulonimbus progress from overdeveloped cumulus congestus clouds and may further develop as part of a supercell. 



Note: To be more realistic with the tropical areas, the temperatures are calculated for 25 degrees at the surface instead of 15 degrees commonly used for the Standard Atmosphere.

5.1.2 - Beaufort scale

Invented by Admiral Beaufort (1774 - 1857), it is an empirical system of measure based on the observation of the sea state and the wind speed: This system allows to identify the condition of the sea with reduced tools.

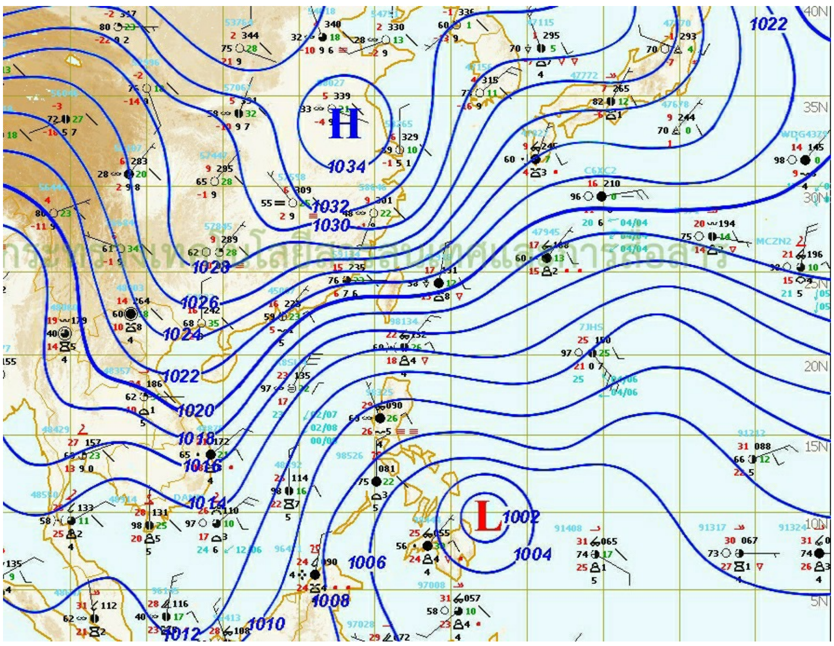
Force (level)	Wind speed (kts)	Waves height	Description	Visual effect
0	0	0	Calm	Sea like a mirror
1	1	0.1	Light air	Ripples with the appearance of scales are formed, but without foam crests
2	4	0.2	Light breeze	Small wavelets, still short but more pronounced; crests have a glassy appearance and do not break
3	7	0.6	Gentle breeze	Large wavelets; crests begin to break; foam of glassy appearance; perhaps scattered white horses
4	11	1	Moderate breeze	Small waves, becoming longer; fairly frequent white horses
5	17	1.8	Fresh breeze	Moderate waves, taking a more pronounced long form; many white horses are formed
6	22	3	Strong breeze	Large waves begin to form; the white foam crests are extensive everywhere
7	28	4	Near gale	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind
8	34	5.5	Gale	Moderately high waves of greater length; edges of crests begin to break into spindrift; foam
9	41	7	Strong gale	High waves; dense streaks of foam along the direction of the wind; crests of waves begin to topple.
10	46	9	Storm	Very high waves with long overhanging crests; the surface of the sea takes a white appearance; visibility affected
11	56	11	Violent storm	Exceptionally high waves; the sea is completely covered with long white patches of foam; visibility affected
12	64	14 & +	Hurricane	The air is filled with foam and spray; sea completely white with driving spray; visibility seriously affected

5.1.3 - Barometer

A barometer is still used by the forecasters to measure the short term changes. There is a barometer on any boat, and regular records can be helpful to predict the tendency, and also cross check with the indications of the weather maps.

The normal atmospheric pressure at sea level is 760 mm of mercury (also called Torr) which is corresponding to 1013 hecto-Pascal (noted hPa).

- The pressures below 1013 hPa are considered as low. They are indicated on the weather maps by a “L”.
- The pressures Above 1013 hPa are considered high pressure and they are indicated on the map using a “H”.
- Notice that some forecasters call the low pressure zones “depression” and the high pressure zone “Anticyclone”. In this case, they are noted using a “D” in place of “L” and an “A” in place of “H”.
- The levels of pressures recorded are indicated on the weather maps using blue or black lines.



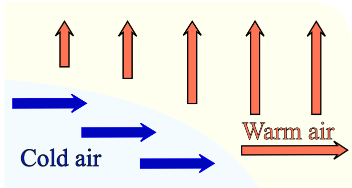
5.2 - Weather system

5.2.1 - Global system

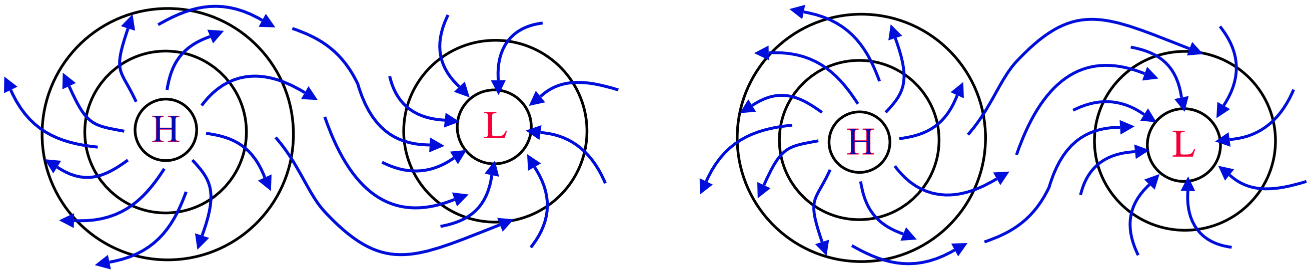
The weather systems are driven by the heat received from the sun at the Earth's surface. Because roughly spherical, with an orientation and a distance from the sun which change during the year, the distribution of heat on earth is not uniform, and varies during the year (it is what we call the seasons). Also, oceans and land absorb heat in different ways. Over oceans, the air temperature remains relatively stable for two reasons: water has a relatively high heat capacity, and because both conduction and convection will equilibrate a hot or cold surface with deeper water. In contrast, dirt, sand, and rocks have lower heat capacities, and they can only transmit heat into the Earth by conduction and not by convection. Therefore, bodies of water stay at a more even temperature, while land temperatures are more variable.

The heat at the surface of land or the sea is transmitted to the atmosphere and creates what is called “air masses”. An air mass is often defined as a widespread body of air that is approximately homogeneous in its horizontal extent, particularly with reference to temperature and moisture distribution; in addition, the vertical temperature and moisture variations are approximately the same over its horizontal extent. The stagnation or long-continued motion of air over a source region permits the vertical temperature and moisture distribution of the air to reach relative equilibrium with the underlying surface: For example, polar air masses are cold and equatorial air masses warm. Air masses over land are usually dry and those above the ocean are moist.

Because the hot air masses are warmer, they expand, and areas of low pressure develop. Meanwhile, the air masses which remain at lower temperatures retain higher pressures. These differences in pressure cause air movements.

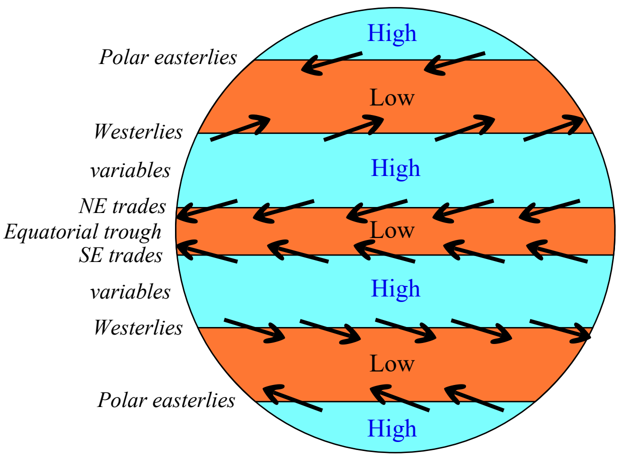


Air naturally flows from high to low pressure; but the “coriolis force” due to the rotation of the Earth, deflect the flow. As a result, in the North Hemisphere, the air from an anticyclone (high pressure) flows clockwise, slightly outwards across the isobars at an angle of about 18°–20°, and blows anticlockwise slightly inwards across the isobars, at an angle of about 10°–20° when approaching a depression. In the South Hemisphere, the circulations are reversed with air diverging in an anticlockwise flow around an anticyclone and converging in a clockwise circulation around a depression. These angles across the isobar are due to the frictions with the environment.



North Hemisphere *South Hemisphere*

Over surfaces free of obstruction, this system should create pressure belts with associated preferential winds, but in reality these belts are disturbed by the land masses. The description of the system is as follows:



- Equatorial trough

The “Equatorial Trough” or “Doldrums” is a low pressure belt of small gradients. It moves N and S seasonally outside the equatorial latitudes, particularly in the vicinity of large land masses. These areas where the Trade Winds from the two hemispheres converge are marked by lines or zones of massive cumulonimbus clouds and associated heavy downpours, thunderstorms and squalls, and are also named the “Inter-tropical Convergence Zone”. The weather to be expected in the Doldrums is variable light or calm winds alternating with squalls and thunder showers, but there are also stable periods of fine weather. The conditions are generally degraded when the Trade Winds are strong. This zone is often the birthplace of disturbances which can develop and intensify to become violent tropical storms.

- Trade winds
These winds blow from the sub-tropical oceanic anticyclones (HP) of the N and S Hemispheres towards the "Equatorial Trough". The general direction is NE in the N Hemisphere; SE in the S Hemisphere. They blow persistently over all major oceans of the world, except the North Indian Ocean and the China Seas where the monsoon winds predominate. The zones where they blow follow the migration of the Equatorial trough. Their average speed is between 7 to 16 knots with a maximum strength of 20 knots in the spring. The weather in these zones is generally favourable with clear sky or only small clouds. Mist, fog and impaired visibility can be encountered due to cold ocean currents or dust carried by the wind. The clouds and rain increase towards the "Equatorial Trough" and also near the Westerlies in summer.

Variables:
"Variable" are the zones covered by the oceanic anticyclones between the "Trade Winds" and the "Westerlies". The winds of these areas are light with fair weather and small amounts of rain.

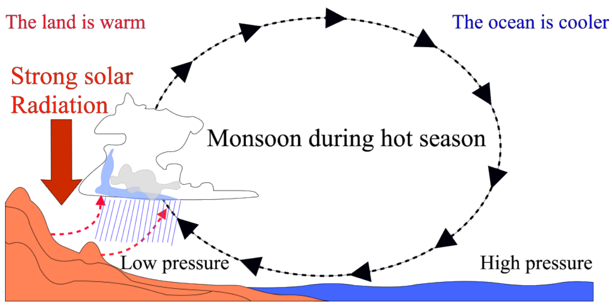
- Westerlies
They are the areas between 30 and 60 degrees latitude with prevailing winds blowing from the high pressure area in the horse latitude towards the poles from the west to the east. Because there are continual passages of depressions across these zones, the winds vary in direction and strength but they are predominantly from the southwest in the Northern Hemisphere and from the Northwest in the Southern Hemisphere. Gales are frequent, especially in winter, and particularly in the 40° of the South Hemisphere (Roaring Forties). Due to these conditions, the weather changes rapidly and fine weather is seldom prolonged.

- Polar Easterlies
These prevailing winds are generally from the east. Gales are common in winter often accompanying snow or ice rains . Cloudy sky and fog is frequent in summer. These areas are difficult to access or unreachable by boat due to the amount of ice.

5.2.2- Seasonal system: The monsoon

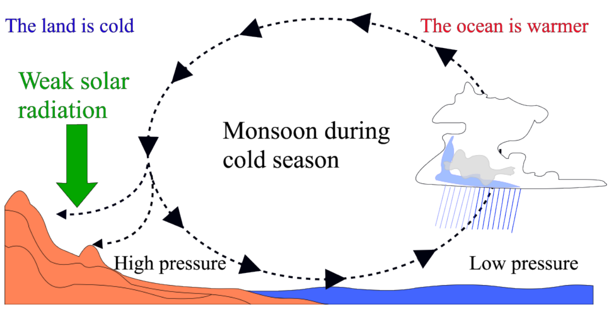
Monsoons are large-scale sea breezes which occur when the temperature on land is significantly warmer or cooler than the temperature of the ocean. "Monsoon" is traditionally defined as a seasonal reversing winds accompanied by corresponding changes in precipitation, and usually refers to the rainy phase, but technically there is also a dry phase.

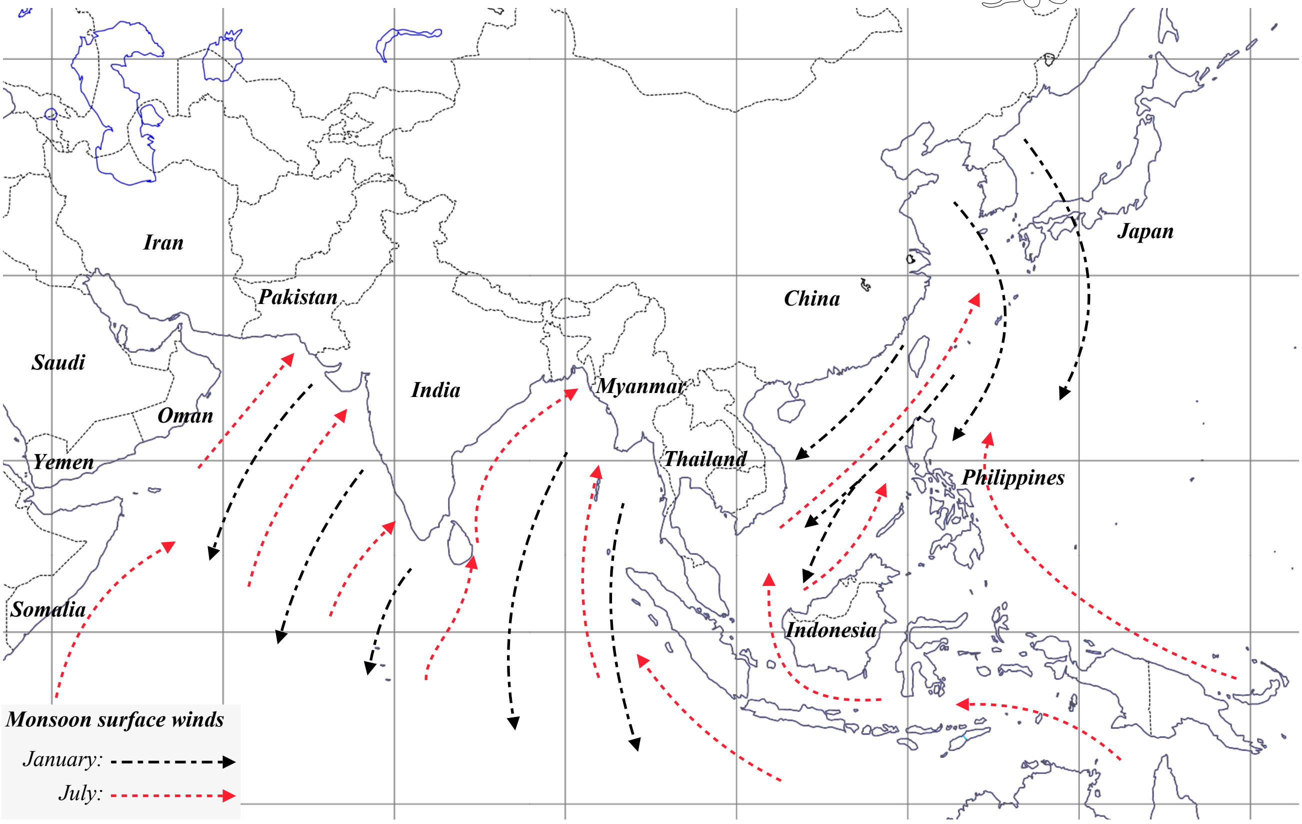
- Hot season
During the warmer months, the sunlight heats the surfaces of both land and oceans, but land temperatures rise more quickly. As the land's surface becomes warmer, the air above it expands and an area of low pressure develops. Meanwhile, the ocean remains at a lower temperature than the land, and the air above it retains a higher pressure. This difference in pressure causes sea breezes to blow from the ocean to the land, bringing moist air inland. This moist air rises to a higher altitude over land and then it flows back toward the ocean (thus completing the cycle). However, when the air rises, and while it is still over the land, the air cools. This decreases the air's ability to hold water, and this causes precipitation over the land. This is why summer monsoons cause so much rain over land.



As result, in the North, the pressure over Asia falls with lowest pressure near the West Himalayas. The anticlock-wise circulation gives persistent Southwest Monsoon winds from May to September or October over the North Indian Ocean and South China Sea, and South Southwest or South winds over the West Pacific Ocean. Winds are generally fresh to strong and raise considerable seas. Warm humid air gives much cloud and rain on windward coasts and islands.

- Cold season
In the colder months, the cycle is reversed. The land cools faster than the oceans and the air over the land has higher pressure than air over the ocean. This causes the air over the land to flow to the ocean. When humid air rises over the ocean, it cools, and this causes precipitation.
As result, in the North, an intense anticyclone (high pressure zone) develops over the cold Asian continent and from around October or November to March a persistent North-east Monsoon wind blows over the North Indian Ocean and South China Sea; over the West Pacific Ocean the wind is North Northeast. The winds are generally moderate to fresh but can reach gale force locally as surges of cold air move South and particularly where funneling effects occurs (Taiwan Strait, Palk Strait, for example).



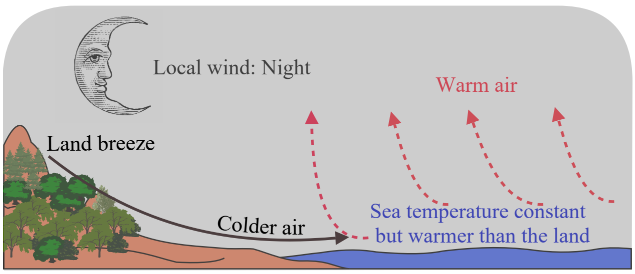


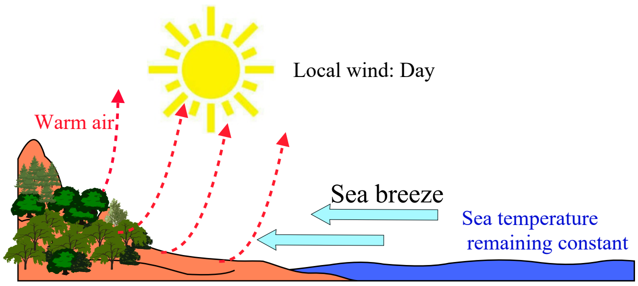
5.2.3 - Local system: Land and sea breeze

The cause of these breezes is the unequal heating and cooling of the land and sea. By day, the sun rapidly raises the temperature of the land surface whereas the sea temperature remains virtually constant. Air in contact with the land expands and rises, and air from the sea flows in to take its place producing an onshore wind known as a "sea breeze". By night, the land rapidly loses heat by radiation and becomes colder than the adjacent sea; air over the land is chilled and flows out to sea to displace the warmer air over the sea and produces the offshore wind known as a "land breeze". Sea breezes usually set in during the forenoon and reach maximum strength, about force 4 (occasionally 5 or 6) in mid-afternoon. They die away around sunset. Land breezes set in late in the evening and fade shortly after sunrise; they are usually weaker and less well marked than sea breezes. The following factors favour development of land and sea breezes:

- Clear or partly cloudy skies;
- Calm conditions or light variable winds;
- Desert or dry barren coast as opposed to forests or swamps;
- High ground near the coast.

In windy conditions, the effect of a land or sea breeze may be to modify the prevailing wind by reinforcing, opposing or causing a change in direction.





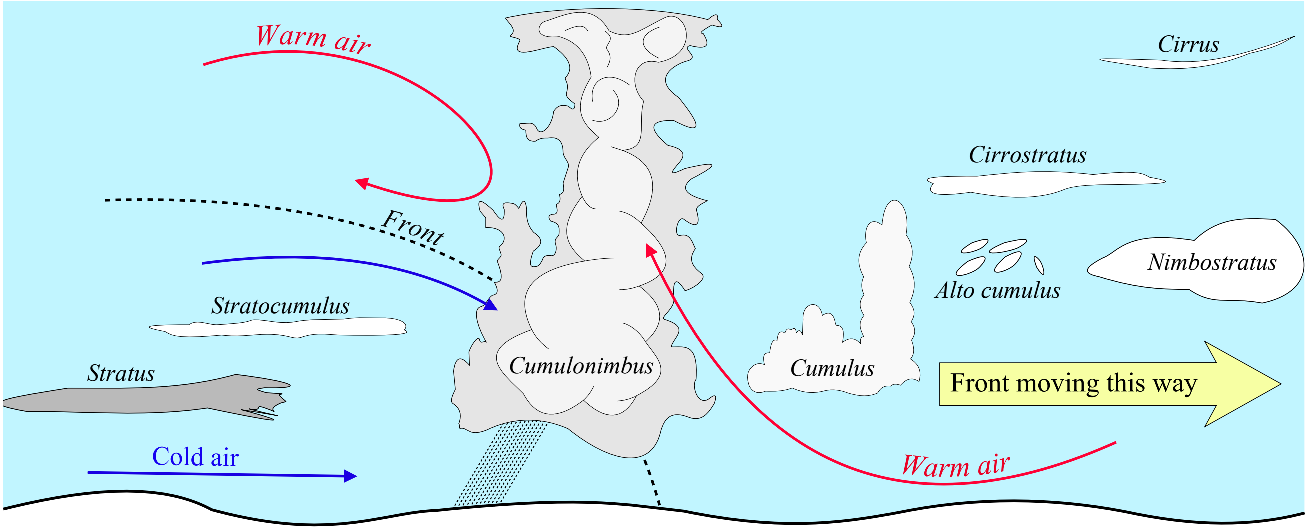
5.3 - Weather perturbations

5.3.1 - Weather front

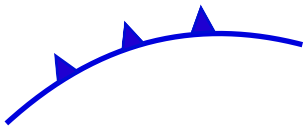
A weather front is a boundary separating two masses of air of different densities, and humidity. It is the principal cause of meteorological phenomena.

- Cold weather front

A cold weather front is due to a cold air mass replacing a warmer air mass. The air behind a cold front is colder and drier than the air in front. Cold fronts generally move from west to east. A cold front approaching is commonly generating strong winds with a sudden drop in temperature and heavy rain. Lifted warm air ahead of the front produces cumulus or cumulonimbus clouds and thunderstorms, often preceded by cirrus, cirrostratus then altostratus and altocumulus. Atmospheric pressure changes from falling to rising at the front. After a cold front moves through an area it may be noticed that the temperature is cooler, the rain has stopped, and the cumulus clouds are replaced by stratus and stratocumulus clouds or clear skies. Because of the greater density of air in their wake, cold fronts and cold occlusions move faster than warm fronts and warm occlusions.

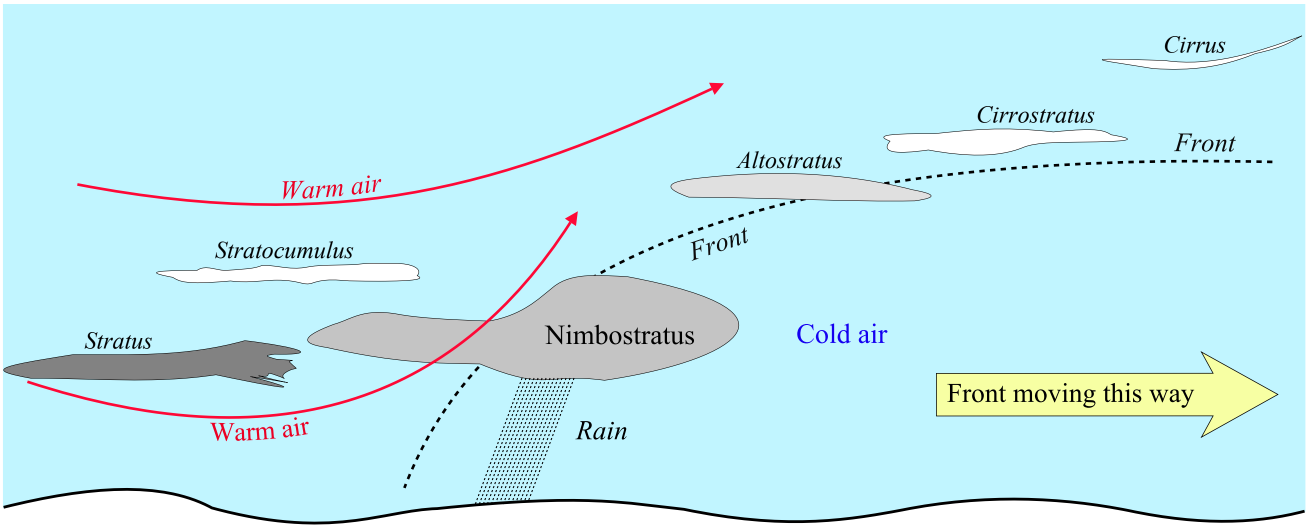


On a weather forecast map, a cold front is represented by a solid line with blue triangles along the front pointing towards the warmer air and in the direction of movement.

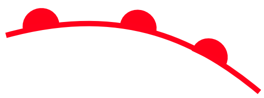


- Warm front

A warm weather front is defined as a warm air mass replacing a cold air mass. Warm fronts usually move from southwest to northeast and the air behind a warm front is warmer and moister than the air ahead of it. When a warm front passes, the air becomes noticeably warmer and more humid than it was before. High clouds like cirrus, cirrostratus, and middle clouds like altostratus are ahead of a warm front. These clouds form in the warm air that is high above the cool air. As the front passes over an area, the clouds become lower and rain and sometimes fog is likely. There can be thunderstorms around the warm front if the air is unstable. The weather usually clears with scattered stratus and stratocumulus. If the warm front is part of a depression, there is often a sheet of altostratus.



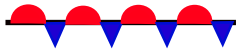
On a weather forecast map, a warm front is represented by a solid line with red semicircles pointing towards the colder air and in the direction of movement.



- Stationary front

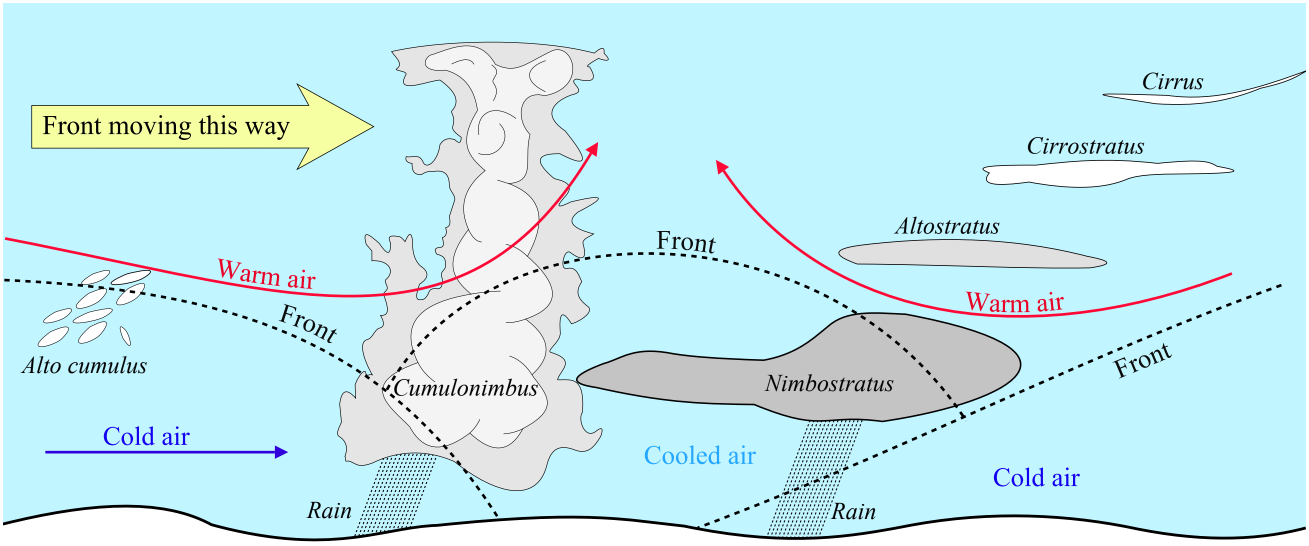
A stationary front forms when a cold front or warm front stops moving. This happens when two masses of air are pushing against each other but neither is powerful enough to move the other. Winds blowing parallel to the front instead of perpendicular can help it stay in place. Stationary fronts may stay put for days. If the wind direction changes the front will start moving again, becoming either a cold or warm front, or the front may break apart.
Because a stationary front marks the boundary between two air masses, there are often differences in air temperature and wind on opposite sides of it. The weather is often cloudy along a stationary front and rain often falls, especially if the front is in an area of low atmospheric pressure. Over time, the density contrast across the frontal boundary vanishes. This is most common over the open oceans. The temperature of the ocean surface is usually the same on both sides of the frontal boundary and modifies the air masses on either side of it to correspond to its own temperature.

On a weather map, a stationary front is shown as alternating red semicircles and blue triangles like in the map on the right. The blue triangles point in one direction and the red semicircles point in the opposite direction.

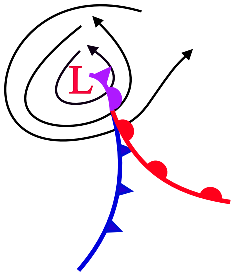


- Occluded front

Sometimes a cold front follows right behind a warm front. A warm air mass pushes into a colder air mass (the warm front) and then another cold air mass pushes into the warm air mass (the cold front). Because cold fronts move faster, the cold front is likely to overtake the warm front. Occluded fronts usually form around areas of low atmospheric pressure.
There is often precipitation along an occluded front from cumulonimbus or nimbostratus clouds with more severe weather than the weather found in a cold front. Wind changes direction as the front passes, and the temperature changes too. The temperature may warm or cool. After the front passes, the sky is usually clearer and the air is drier.



On a weather map, an occluded front looks like a purple line with triangles and semicircles along it pointing in the direction that the front is moving. It ends at a low pressure area shown with a large 'L' on the map, and at the other end connects to cold and warm fronts. (See on the right)



5.3.2 - Wind gust & squall

Wind gust is a sudden, brief increase in speed of the wind which reaches at least 16 knots, and the variation in wind speed between the peaks and lulls is at least 9 knots. The duration of a gust is usually less than 20 seconds.
A squall is a sudden, sharp increase in wind speed of 15 knots with a minimum speed of 21 knots which is usually associated with active weather, such as rain showers and thunderstorms.

5.3.3 - Thunderstorm

Thunderstorms are dangerous phenomena which form when very warm, moist air rises into cold air. As this humid air rises, water vapour condenses, forming huge cumulonimbus clouds.

There are two main types of thunderstorms: ordinary and severe.

- Ordinary thunderstorms last about one hour. The precipitation associated with these storms includes rain. With ordinary thunderstorms, cumulonimbus clouds can grow up to 12 kilometers high.
- Severe thunderstorms is a term designating a thunderstorm that has reached a predetermined level of severity. They are generally large, and capable of producing baseball-size hail (25 mm Ø and above), strong winds (at least 93 km/h) , intense rain (> 50 mm / hr, or 75 mm for 3 hrs), flash floods, and tornadoes. Severe thunderstorms can last several hours and can grow 18 kilometers high. These phenomenon can occur from any type of storm cell. However, three common forms of thunderstorms are the most frequently involved in severe weather:
  - "Multicell" thunderstorms, which are clusters of storms that may then evolve into one
  - "Supercell" which are large thunderstorms, also referred to as rotating thunderstorms
  - "Squall lines" are lines of thunderstorms that can form along or ahead of a cold front

- Thunderstorm formation

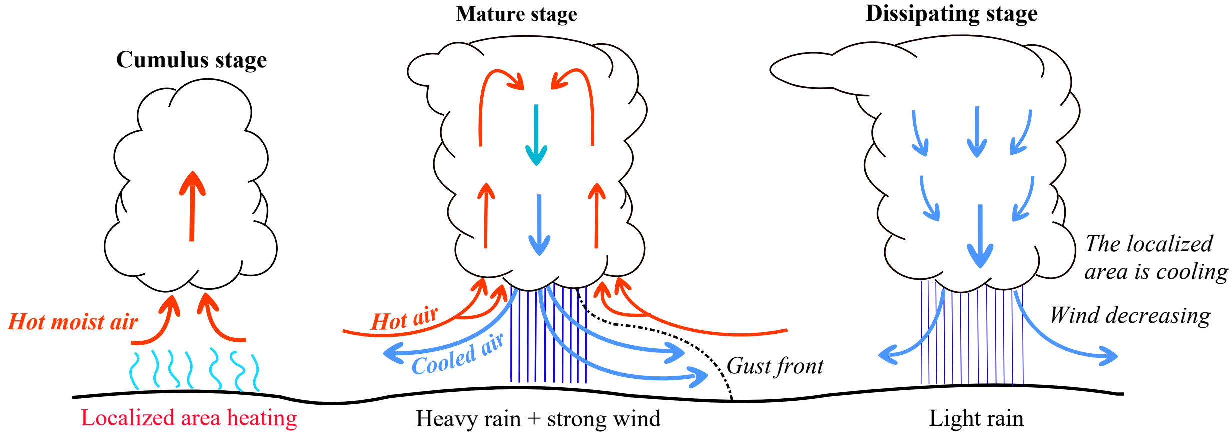
Most thunderstorms develop from a cycle that has three stages: the cumulus stage, mature stage, and dissipating stage.

Cumulus Stage
The sun heats the Earth's surface during the day. The heat on the surface warms the air around it. Since warm air is lighter than cool air, it starts to rise (known as an updraft). If the air is moist, then the warm air condenses into a cumulus

cloud. The cloud will continue to grow as long as warm air below it continues to rise.

Mature Stage:
When the cumulus cloud becomes very large, the water in it becomes large and heavy. Raindrops start to fall through the cloud when the rising air can no longer hold them up. Meanwhile, cool dry air starts to enter the cloud. Because cool air is heavier than warm air, it starts to descend in the cloud (known as a downdraft). The downdraft pulls the heavy water downward, making rain.
This cloud has become a cumulonimbus cloud because it has an updraft, a downdraft, and rain. Thunder and lightning start to occur, as well as heavy rain. The cumulonimbus is now a thunderstorm cell.

Dissipating Stage:
After about 30 minutes, the thunderstorm begins to dissipate. This occurs when the downdrafts in the cloud begins to dominate over the updraft. Since warm moist air can no longer rise, cloud droplets can no longer form. The storm dies out with light rain as the cloud disappears from bottom to top.
The whole process takes about one hour for an ordinary thunderstorm. Supercell thunderstorms are much larger, more powerful, and last for several hours.



Lightning:
Lightning is a giant spark. A single stroke of lightning can heat the air around it to 30,000 degrees Celsius. This extreme heating causes the air to expand at an explosive rate. The expansion creates a shock wave that turns into a booming sound wave known as thunder.

5.3.4 - Tropical cyclones

"Cyclone" is the scientific name referring to hurricane, typhoon, tropical storm, cyclonic storm, and tropical depression. It is a rapidly-rotating storm system characterized by a low-pressure centre, strong winds, and a spiral arrangement of thunderstorms that produce heavy rain. Depending on its location and strength, they are usually characterized by inward spiraling winds that rotate anti-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere of the Earth.
Tropical cyclones typically form over large bodies of relatively warm water. They derive their energy from the evaporation of water from the ocean surface, which ultimately recondenses into clouds and rain when moist air rises and cools to saturation. In fact, the process is similar to thunderstorms.
The first indicator of cyclone development is the appearance of a cluster of thunderstorms over the sea. There are six main requirements to develop a tropical cyclone:

- Sufficiently warm sea surface temperatures
- Atmospheric instability
- High humidity in the lower to middle levels of the troposphere (Troposphere = Surface to 17- 20 km above)
- Enough "Coriolis force" to develop a low pressure centre
- A preexisting low level disturbance
- A low vertical wind shear

With strong cyclones, the Coriolis force initiated by the rotation of Earth causes the resulting low-level winds to spiral anticlockwise in the Northern Hemisphere, and clockwise in the Southern Hemisphere.
The cyclones are classified into 3 main groups based on the intensity:

- Tropical depression
It is an organized system of clouds and thunderstorms with a defined, closed surface circulation and maximum sustained winds of less than 34 knots (63 km/h). It has no eye and does not typically have the organization or the spiral shape of more powerful storms. However, it is a low-pressure system, hence the name "depression".

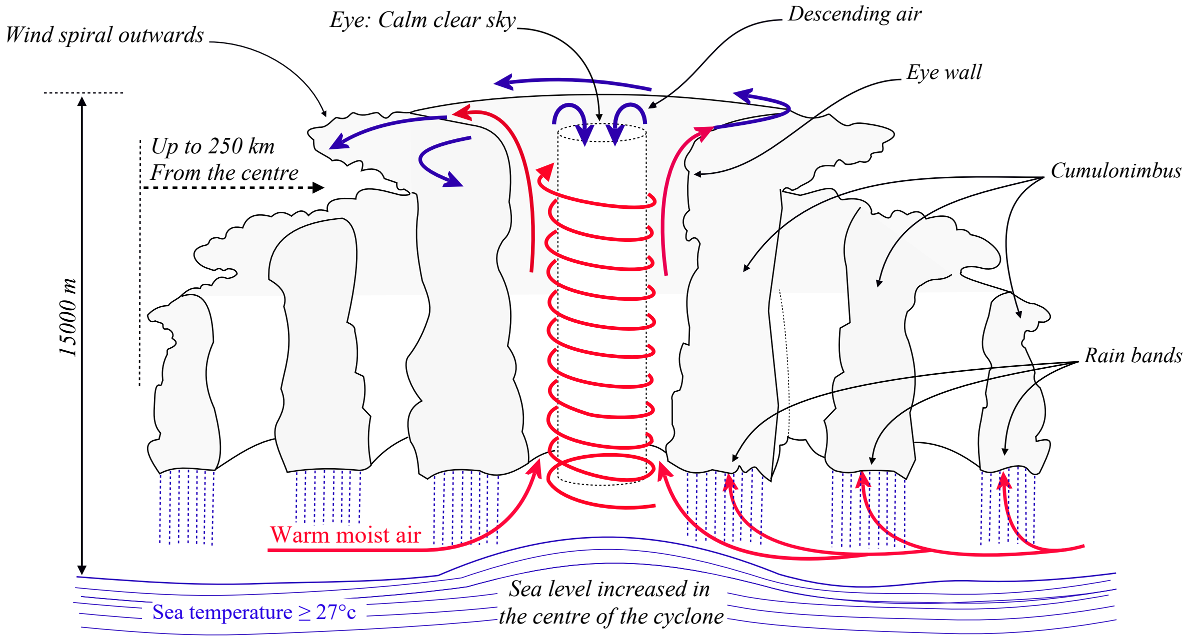
- Tropical storm
It is an organized system of strong thunderstorms with a defined surface circulation and maximum sustained winds between 34 knots (63 km/h) and 64 knots (118 km/h). At this point, the distinctive cyclonic shape starts to develop, although an eye is not usually present.

- Tropical cyclone or hurricane (also called typhoon)

Tropical cyclones are typically between 100 and 4000 km in diameter. A cyclone is considered a "hurricane" when the wind speed reaches 119 km/h (64.3 knots). A cyclone of this intensity tends to develop an eye, visible from satellite, which is an area of relative calm and lowest atmospheric pressure at the centre of circulation. Surrounding the eye is the eye-wall, an area about 16 to 80 kilometres wide in which the strongest thunderstorms and winds circulate around the storm's centre. Maximum sustained winds in the strongest tropical cyclones are about 165 knots/h (314 km/h).

A "tropical cyclone" or "hurricane" works like a large heat engine: The fuel is moisture from warm ocean water. The moisture is converted to heat in the thunderstorms that form. Spiral rain bands that surround the tropical cyclone's core help feed the circulation more heat energy. As air nears the centre, it rises rapidly and condenses into clouds and rain. The condensation releases tremendous amounts of heat into the atmosphere. The result is lower surface pressure and strengthening winds.

In this way, the tropical cyclone's engine refuels itself, concentrating its power in a donut-shaped area, called the eye wall, surrounding the centre. The eye wall typically contains the strongest surface winds. Sinking air at the centre clears the tropical cyclone of clouds and forms the "eye." Falling surface pressure can occur only if air mass is removed from the circulation centre. This is accomplished by wind flowing away from the circulation in the upper atmosphere.



Based on wind speeds and damages caused on shore, hurricanes are categorised from 1 to 5 on "Saffir-Simpson" scale. This scale can be used offshore to evaluate the potential damages to a boat and a dive system.

Category 1: Winds 119-153 km/hr**.** Storm surge generally 1.2-1.5 m (4-5 feet) above normal. No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Some damage to poorly constructed signs, and some coastal road flooding and minor pier damage

Category 2: Winds 154-177 km/hr. Storm surge generally 1.8-2.4 m (6-8 feet) above normal. Some roofing material, door, and window damage of buildings. Considerable damage to shrubbery and trees, with some trees blown down. Considerable damage to mobile homes, poorly constructed signs, and piers. Coastal and low-lying escape routes flood 2-4 hours before arrival of the hurricane center.

Category 3: Winds 178-209 km/h. Storm surge generally 2.7-3.6 m (9-12 ft) above normal. Some structural damage to small residences and utility buildings, with a minor amount of curtain wall (non-load-bearing exterior wall) failures. Damage to shrubbery and trees, with foliage blown off trees, and large trees blown down. Mobile homes and poorly constructed signs are destroyed. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the centre of the hurricane. Flooding near the coast destroys smaller structures, with larger structures damaged by battering from floating debris.

Category 4: Winds 210-249 km/hr (131-155 mph). Storm surge generally 3.9-5.5 m (13-18 feet) above normal. More extensive curtain wall failures, with some complete roof structure failures on small residences. Shrubs, trees, and all signs are blown down. Complete destruction of mobile homes. Extensive damage to doors and windows. Low-lying escape routes may be cut by rising water 3-5 hours before arrival of the centre of the hurricane. Major damage to lower floors of structures near the shore. Terrain lower than 10 feet above sea level may be flooded

Category 5: Winds greater than 249 km/hr (155 mph). Storm surge generally greater than 5.5 m (18 feet) above normal. Complete roof failure on many residences and industrial buildings. Some complete building failures, with small utility buildings blown over or away. All shrubs, trees, and signs blown down. Complete destruction of mobile homes. Severe and extensive window and door damage. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the centre of the hurricane. Major damage to lower floors of all structures located less than 4.5 m (15 feet) above sea level and within 460 m (500 yards) of the shoreline.

- *Precursor signs offshore:*

British Admiralty says the following: The following signs may be evidence of a storm in the locality; the first of these observations is a very reliable indication of the proximity of a storm within 20° or so of the equator. It should be borne in mind, however, that very little warning of the approach of an intense storm of small diameter may be expected.

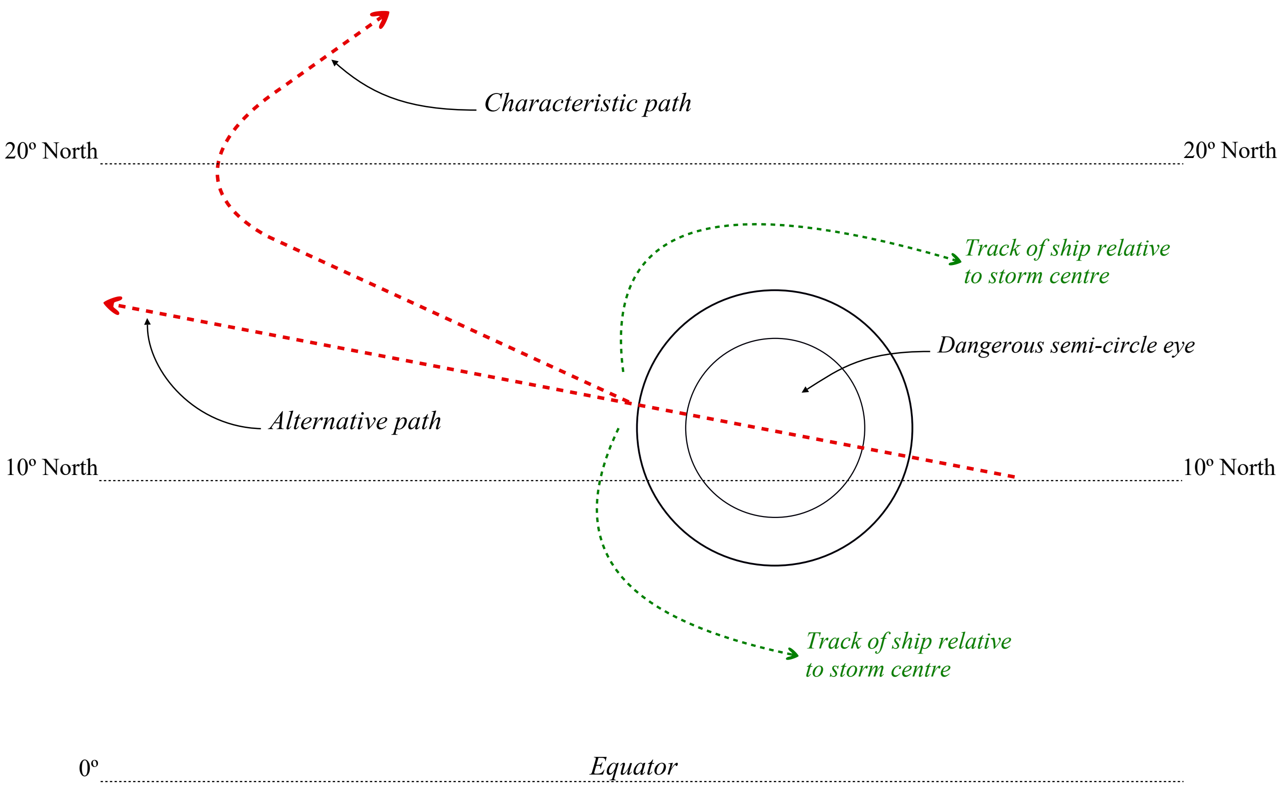
- If a corrected barometer reading is 3 hpa or more below the mean for the time of year, as shown in the climatic atlas or appropriate volume of *Admiralty Sailing Directions*, suspicion should be aroused and action taken to meet any development. The barometer reading must be corrected not only for height, latitude, temperature and index error (if mercurial) but also for diurnal variation which is given in climatic atlases or appropriate volumes of *Admiralty Sailing Directions*. If the corrected reading is 5 hPa or more below normal it is time to consider avoiding action for there can be little doubt that a tropical storm is in the vicinity. Because of the importance of pressure readings, it is wise to take hourly barometric readings in areas affected by tropical storms;
- An appreciable change in the direction or strength of the wind;
- A long low swell is sometimes evident, proceeding from the approximate bearing of the centre of the storm. This indication may be apparent before the barometer begins to fall;
- Extensive cirrus clouds followed, as the storm approaches, by altostratus and then broken cumulus or scud.
- Radar may give warning of a storm within about 100 miles. By the time the exact position of the storm is given by radar, the ship is likely to be already experiencing high seas and strong to gale force winds. It may be in time, however, to enable the ship to avoid the eye and its vicinity where the worst conditions exist.

- *Path of the storm:*

British admiralty also says: To decide the best course of action if a storm is suspected in the vicinity, the following knowledge is necessary:

  - The bearing of the centre of the storm.
  - The path of the storm.

- If an observer faces the wind, the centre of the storm will be from 100° to 125° on his right hand side in the N hemisphere when the storm is about 200 miles away, when the barometer has fallen about 5 hPa and the wind has increased to about force 6. As a rule, the nearer he/she is to the centre the more nearly does the angle approach 90°. The path of the storm may be approximately determined by taking two such bearings separated by an interval of 2–3 hours, allowance being made for the movement of the ship during the interval. It can generally be assumed that the storm is not traveling towards the equator and, if in a lower latitude than 20°, its path is most unlikely to have an E component. On the rare occasions when the storm is following an unusual path it is likely to be moving slowly.
- The diagram below shows typical paths of tropical storms and illustrates the terms dangerous and navigable semicircle. The former lies on the side of the path towards the usual direction of recurvature, the right hand semicircle in the N and the left hand semicircle in the S Hemisphere. The advance quadrant of the dangerous semicircle is known as the dangerous quadrant as this quadrant lies ahead of the centre. The navigable semicircle is that which lies on the other side of the path. A ship situated within this semicircle will tend to be blown away from the storm centre and recurvature of the storm will increase her distance from the centre.



In the North Hemisphere (See previous page)

a) If the wind is backing, the ship will be in the dangerous semi circle. The ship should proceed with all available speed with the wind 10 degrees - 45 degrees depending on speed on the port bow. As the wind backs the ship should alter course to port thereby tracing a course relative to the storm as shown in the diagram on the previous page

b) If the wind remains steady in direction or nearly steady so that the vessel should be in the path of the storm or very nearly in its path. She should bring the wind well on to the port quarter and proceed with all available speed. When well within the navigable semicircle act as at (c) below.

c) If the is wind backing the ship is in the navigable semicircle. The ship should bring the wind on the starboard quarter and proceed with all available speed turning to port as the wind backs to follow a track as shown in the diagram.

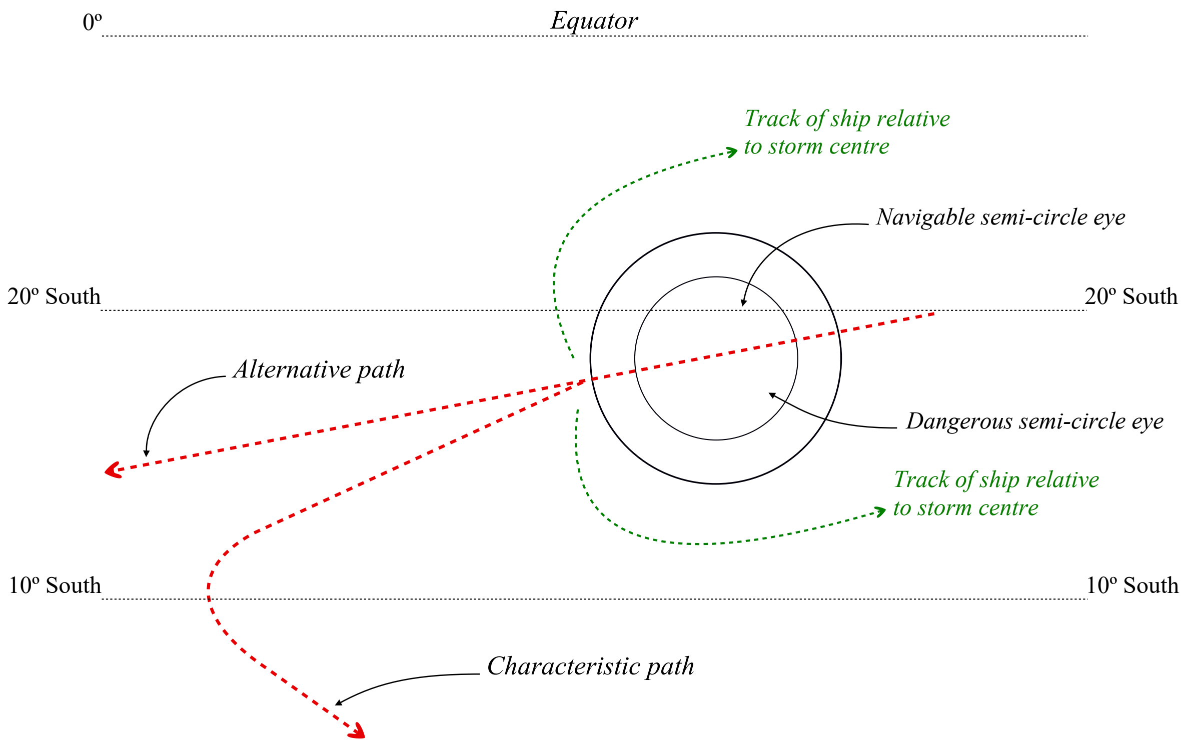
In the South Hemisphere (see below)

a) If the wind backing, the ship must be in the dangerous semicircle. The ship should proceed with all available speed with the wind 10 degrees – 45 degrees, depending on speed, on the port bow. As the wind backs, the ship should alter course to port thereby tracing a course relative to the storm as shown in diagram below.

b) If the wind remains steady in direction, or nearly steady, so that the vessel should be in the path of the storm or very nearly in its path, she should bring the wind well on to the port quarter and proceed with all available speed. When well within the navigable semicircle act as at (*c*) below.

c) If the wind veers, the ship is in the navigable semicircle. The ship should bring the wind on to the port quarter and proceed with all available speed turning to starboard as the wind veers to follow a track as shown in the diagram.

If there is insufficient room to run when in the navigable semicircle and it is not practicable to seek shelter, the ship should heave-to with the wind on her starboard bow in the N hemisphere or on her port bow in the S hemisphere.



- In the harbour

British admiralty also says that when a tropical storm approaches it is preferable to put to sea if this can be done in time to avoid the worst of the storm. A tropical storm in a harbour or anchorage is an unpleasant and hazardous experience especially if there are other ships. Even if berthed alongside or if special moorings are used, a ship may be far from secure.

As an example of what is said above, it is common to find ships that were alongside jetties or moored in a harbor pushed ashore or sunk after a hurricane reached their location.

- Weakening the cyclones

Cyclones and Hurricanes diminish rather quickly when moving over cooler water that can't supply warm moist tropical air, or over land, again cutting off the source of warm, moist air.

The cyclones can also collapse if they are moving into an area where strong winds high in the atmosphere disperse latent heat, reducing the warm temperatures aloft and raising the surface pressure.

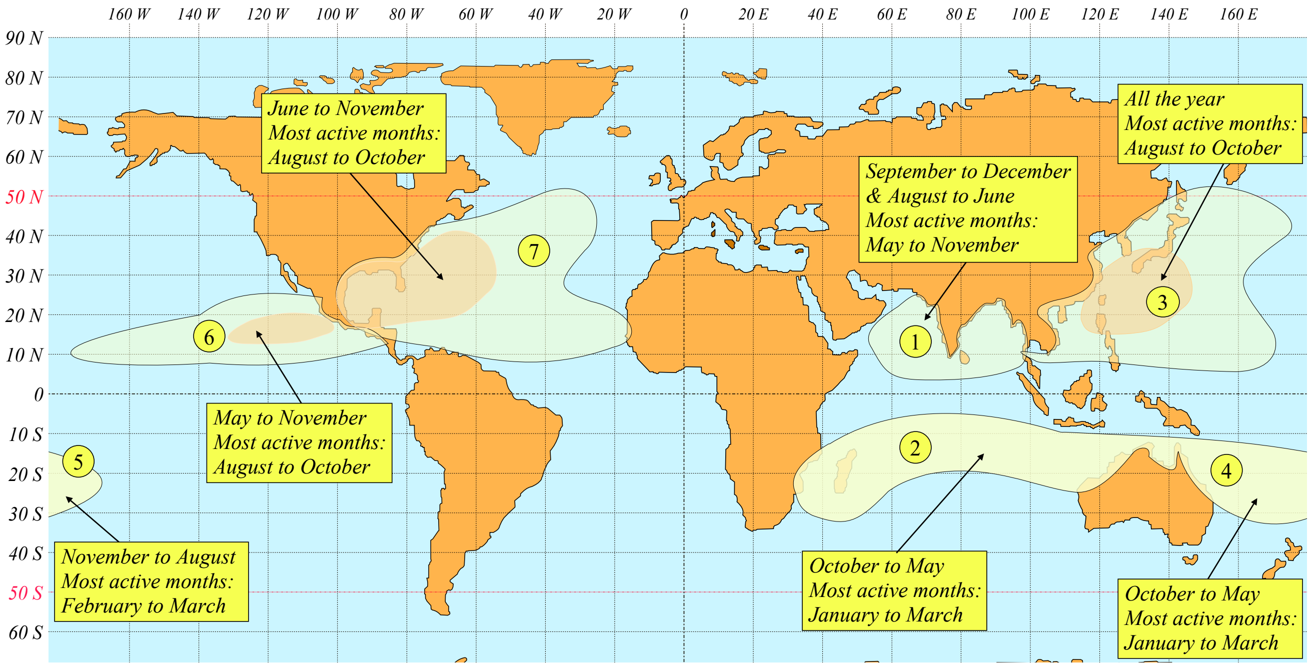
- Main zones where cyclones are likely to happen

A cyclone may develop where all the conditions listed previously can be met.

Areas where Cyclones have favourable conditions to develop are in the Inter-Tropical Convergence Zone. As explained in point 5.2.1, the trade winds from the two hemispheres converge in these zones where cumulonimbus clouds associated with heavy downpours, thunderstorms and squalls are frequently encountered.
There are no cyclones at the equator. For example, there are almost no cyclones in French Guyana, Singapore, or even near the Indian Ocean coast of Africa such as Somalia, Kenya, the northern Tanzania or Zanzibar.
Also, the necessarily warm seas explains why tropical storms are not found in South Atlantic ocean that is under the influence of cold ocean currents. For the same reason, there are no cyclones near the coasts of Chile and Peru, because the "upwelling" phenomenon replaces the warm surface waters of the ocean by wind-driven cold waters from the South Pole and from the very deep depths of the pacific ocean.

In the Northern hemisphere, the summer period is between June and September. However cyclones can develop from June to November.
In the Southern hemisphere, the summer is between December and March, but the cyclonic season extends from November to April or May.

The map and the table below show the main areas where cyclones have been recorded and their average frequency.



Areas where cyclones are likely to be encountered

Areas of high cyclonic frequencies *(> 20/year)*

Number	Situation	Cyclonic period(s)	Most active period(s)	Number of tropical storms / year	Number of hurricanes / year
1	North of Indian Ocean	September to December & August to June	May and November	5	2
2	Southwest of Indian Ocean	October to May	January to March	10	6
3	Northwest of Pacific Ocean	All year	August to October	24	16
4	Southeast Australia	October to May	January to March	6	8
5	South Pacific	November to August	February to March	8	8
6	Northeast and Central Pacific	May to November	August to October	16	8
7	North Atlantic	June to November	August to October	15	7

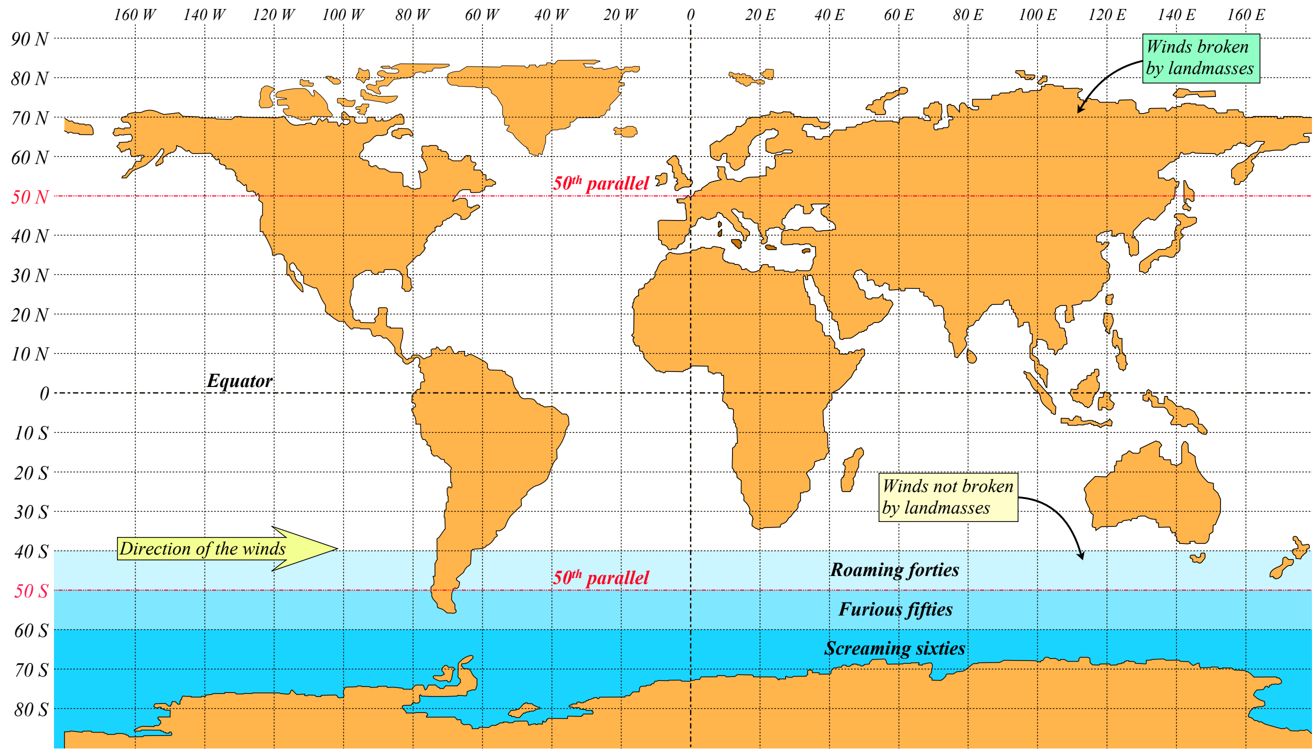
5.3.5 - Polar vortices and their effects

Polar vortices are persistent, large-scale cyclones, circling the North and South poles. The bases of the polar vortices are located in the middle and upper troposphere and extend into the stratosphere. They surround areas of high atmospheric

pressure that are around the poles.
The cold temperatures in the polar regions cause air masses to descend and create high-pressure zones. These air masses of polar origin meet and clash with those of tropical or subtropical origin in convergence zones as the extremely cold and dry air masses do not mix with the warmer moist maritime air masses. Storms with high wind speeds routinely form in these high-temperature gradient regions. The higher the temperature gradient is, the higher the wind speeds will develop. Generally it happens in areas around the 50th parallels of latitude.
Polar vortices are strong in winter and weaken in summer due to their dependence upon the temperature differential between the equator and the poles. The air in a polar vortex circulates counter-clockwise in the Northern hemisphere, and clockwise in the Southern hemisphere.

Polar vortices have an influence on Westerlies that increase in strength when the polar vortices are strong. In the south hemisphere, they are at the origin of the "Roaring Forties", "Furious Fifties"' and "Screaming Sixties".
The "Roaring Forties" are strong westerly winds found between the latitudes of 40 and 50 degrees. These almost continuous winds are powerful as they are not broken by landmasses except for the extremity of the South American continent and New Zealand.
The "Furious Fifties" that are between the latitudes of 50 and 60 degrees and the "Screaming Sixties" that are below 60 degrees latitude are subject to incessant storms and hurricanes with waves that can be over 15 m in height. Icebergs are common in these latitudes.

It must be noticed that some offshore facilities are situated in such areas where the working conditions are much difficult and hazardous.

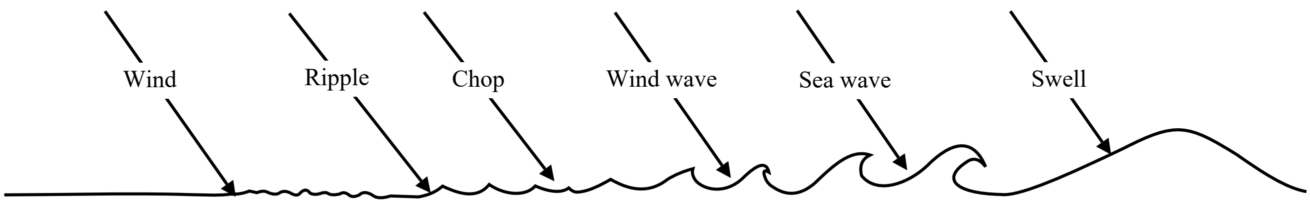


5.4 - Waves and swell

5.4.1 - Waves

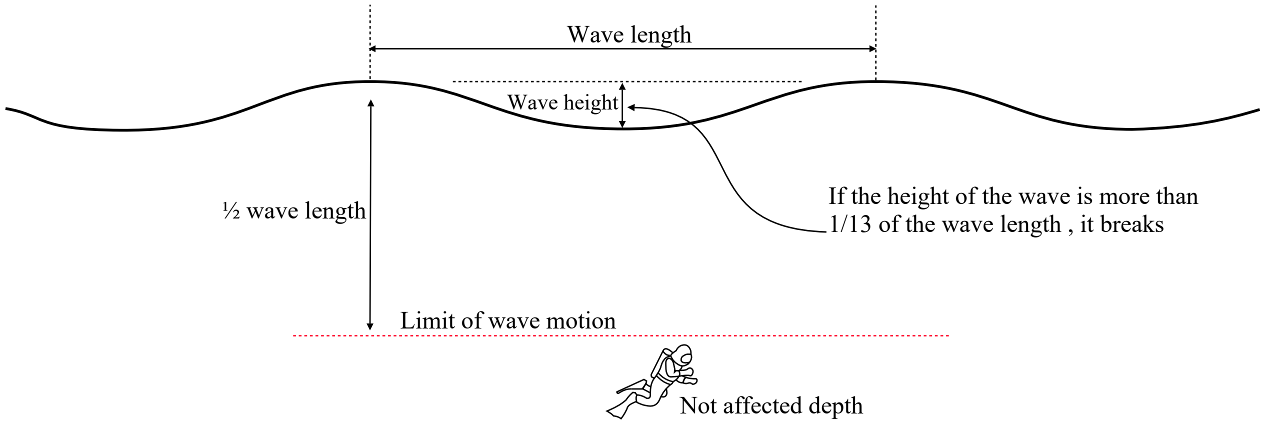
Almost all waves at sea are caused by wind, though some may be caused by other forces of nature such as volcanic explosions, earthquakes or even icebergs calving. The area where waves are formed by wind is known as the generating area, and "sea waves" is the name given to the waves formed in it.

The height of the sea waves depends on how long the wind has been blowing, the fetch, the currents and the wind strength. The Beaufort Wind Scale gives a guide to probable wave heights in the open sea, remote from land, when the wind has been blowing for some time.



Wave generation

The dimensions of a wave are its height, from crest to trough, its wavelength, the distance between crests and the depth to which its movement can be felt. Wavelength is always much greater than height, and if the ratio of height to wavelength becomes greater than about 1:13 the wave breaks. If the wave moves into shallow water, it will slow down, but the wave height increases rapidly. It will start to break when the water depth is equal to about half its wavelength.



The distance that the waves will travel depends on their wavelength. Long wavelengths travel furthest, and it is common to experience a long wavelength swell generated by a wind many miles away.
Under normal conditions, the wave pattern is a combination of one or more wave trains. A local wind, for example, may generate waves on top of a remotely produced swell. The interference between the wave trains can produce considerable variation in wave height.

5.4.2 - Swell

Swell is the wave motion caused by a meteorological disturbance, which persists after the disturbance has died down or moved away.
Swell often travels for considerable distances out of its generating area, maintaining a constant direction as long as it remains in deep water. As the swell travels away from its generating area, its height decreases though its length and speed remain constant, giving rise to the long low regular undulations so characteristic of swell.
The measurement of swell is no easy task. Two or even three swells from different generating areas, are often present and these may be partially obscured by the sea waves also present. For this reason a confused swell is often reported.

Sea state

code	Description	Height in metres
0	Calm - glassy	0
1	Calm - rippled	0.1
2	Smooth wavelets	0.1 - 0.5
3	Slight	0.5 - 1.25
4	Moderate	1.25 - 2.5
5	Rough	2.5 - 4
6	Very rough	4 - 6
7	High	6 - 9
8	Very high	9 - 14
9	Phenomenal	over 14

Swell waves

Swell length	
Description	**Metres**
Short	0 - 100
Average	100 - 200
Long	Over 200
Swell height	
Description	**Metres**
Low	0 - 2
Moderate	2 - 4
Heavy	Over 4

5.4.3 - Rogue waves

Rogue waves also called "extreme storm waves", are waves which height can be up to 26 m, and perhaps above, and quickly break after their formation. They are very unpredictable and come unexpectedly from directions other than those of prevailing winds and waves. Such waves are responsible for the sinking of several vessels, which some of them were more than 250 m long. When the rogue wave has collapsed, the sea returns to its previous condition.

Because these waves are rare, scientists continue to investigate how and when they form. However, two theories have been emitted:

1. Some scientists think that such waves may result from the addition of different waves that travel at different speeds and have their peaks occasionally overlapping, producing an exceptional mass of water that erects as a wall up to the heights indicated before for several minutes.
2. Another theory is that waves may interact with one another, transferring energy between them. These interactions may result in a similar effect as above.

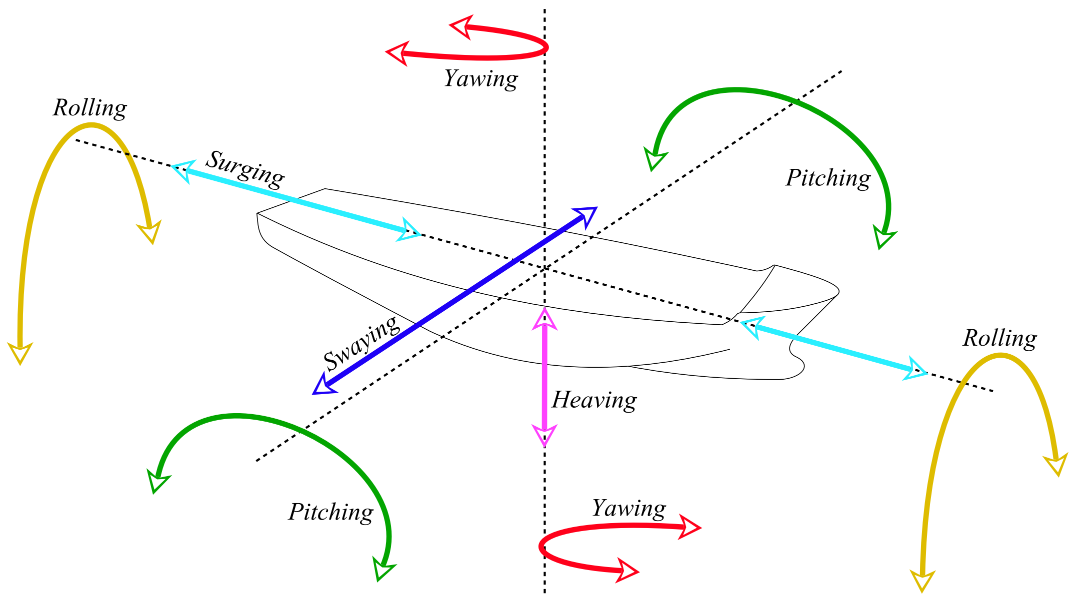
5.5 - Effects of waves and swell

5.5.1 - Effects on the vessel

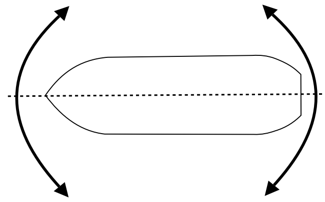
The weather conditions are likely to exert a combination of forces upon a ship and its cargo over a prolonged period. Such forces may arise from pitching, rolling, heaving, surging, yawing or swaying or a combination of any two or more.
The acceleration values depend on the shapes of the vessel, its beam, the position of the centre of gravity and centre of buoyancy and similar parameters which determine the behavior of ships at sea.

The ship's movement may be divided into three types of linear motion and three types of rotational motion.

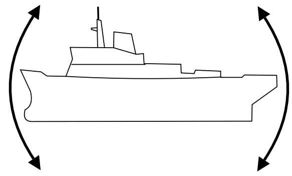
Linear motion	Rotational motion
Surging is motion along the longitudinal axis.	Rolling is motion around the longitudinal axis.
Swaying is motion along the transverse axis.	Pitching is motion around the transverse axis.
Heaving is motion along the vertical axis.	Yawing is motion around the vertical axis.



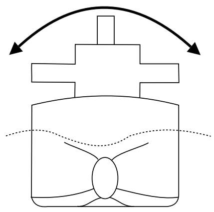
5.5.1.1 - *Rotational motions*



Yawing:
Yawing involves rotation of the ship around its vertical axis. This occurs due to the impossibility of steering a ship on an absolutely straight course. Depending upon sea conditions and rudder deflection, the ship will swing around its projected course. Yawing normally does not happen on a moored barge or 4 point mooring. It has direct effect on a DP vessel heading, but normally, this movement is controlled by the system. Because under control, this movement normally does not affect the diving operation. It also has no effect on the systems installed on deck during the cruising periods.

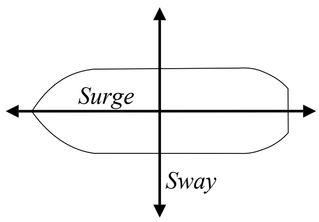


Pitching:
The ship is lifted at the bow and lowered at the stern and vice versa. Pitching angles vary with the length of the vessel. In relatively long vessels, they are usually less than 5°, but it can be considerably more on small units.
When diving from the stern, which is often the case from supply vessels, these movements create hazardous situations due to the rapid oscillation up and down of the basket/bell, the waves breaking on decks, and the uncontrolled movements during the launching and recovering. In addition the constrains applied to the launch and recovery system can quickly affect its condition.

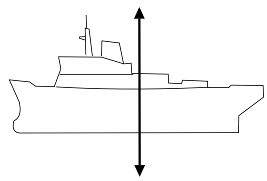


Rolling:
Rolling involves side-to-side movement of the vessel. The rolling period is defined as the time taken for a full rolling oscillation from the horizontal to the left, back to horizontal then to the right and then back to horizontal. Rolling angle is measured relative to the horizontal. Just in moderate seas, even very large vessels roll to an angle of 10°. In bad weather, angles of 30° are not unusual. Even the largest ships must be expected to roll to such angles. Stabilizers and other anti-heeling systems may help to damp ship movements. However, not all systems are usable or sufficiently effective in bad weather.
A diving operation undertaken from the side of a vessel affected by rolling is very hazardous. Due to the uncontrolled movements, there is a risk of hitting the hull with the baskets/bell during the launching and recovering. The rolling can also create up and down oscillations, initiating shocks and vibrations which can affect the resistance of the whole launch and recovery system in the same manner as the “pitching” effect . Like for the majority of movements applied to the boat, the sea fastenings of the materials stored on deck will be submitted to strong efforts.

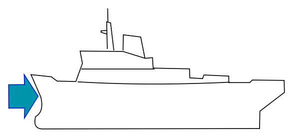
5.5.1.2 - *Linear motions*



Surging and swaying:
The sea's motion pushes the ship forward and backward and side to side. These movements may occur in all possible axis, not merely, for example, horizontally. If a vessel's fore-body is on one side of a wave crest and the after-body is on the other side, the hull may be subjected to considerable torsion forces.
The diving operations undertaken in these conditions are hazardous with the basket/bell banging the hull during the recovering and launching and over-fatigue of the launch and recovery system. On deck, the materials not sufficiently secured can start to move and create additional danger to the personnel.



Heaving:
Heaving involves upward and downward acceleration of a ship along its vertical axis. In very long swells, the vessel moves slowly upwards and downwards and is not affected, but the buoyancy varies a lot if the ship is moving through wave crests and troughs with rapid oscillations. Such constant up and down movements have an effect on the materials stored on deck. During the diving operations, they can create hazards due to the basket /bell coming up and down all the time (ears equilibration & possible injuries when coming in and out and hazardous recovery).

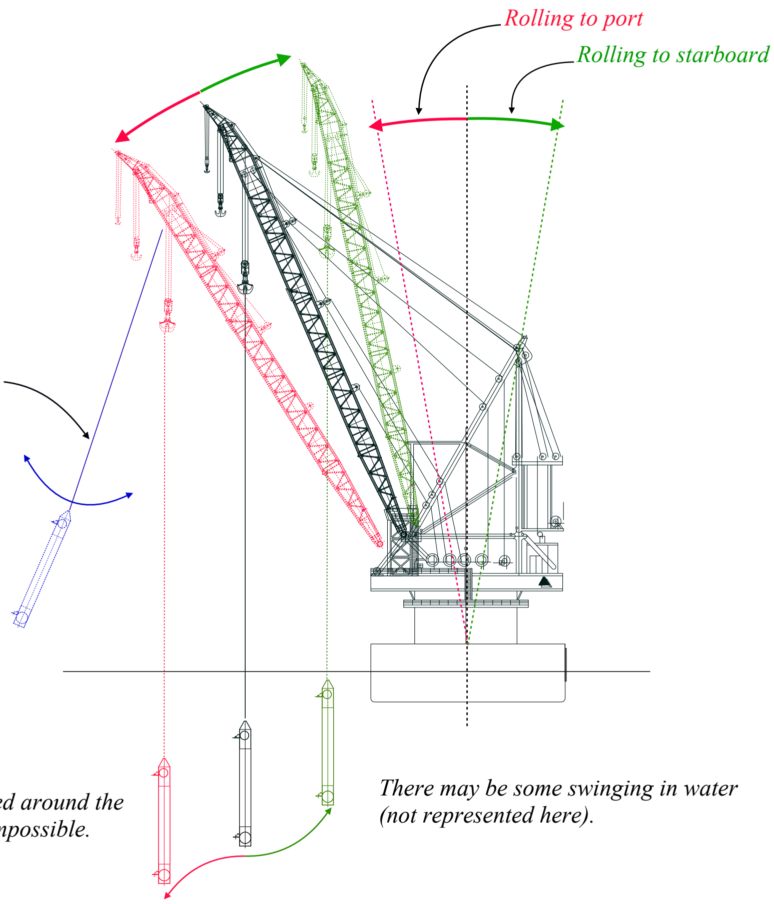


Slamming:
Slamming is not a motion, but the term is used to describe the hydrodynamic impacts which a ship encounters due to the up and down motion of the hull, entry into wave crests and the consequent abrupt immersion of the ship into the sea. This impact creates vibration and stresses to the whole ship and the materials stored in it. Due to their square shapes, barges are very vulnerable to these effects

5.5.2 - Effects on crane operations and systems to control them

5.5.2.1 - Effect on crane operations

In the case of lifting operations by bad sea, the motion of the vessel will be amplified by the boom of the crane, which is often very high. That may result in a load that starts swinging and moving up and down and becomes uncontrollable if the crane and the vessel are not equipped with systems to control these movements.

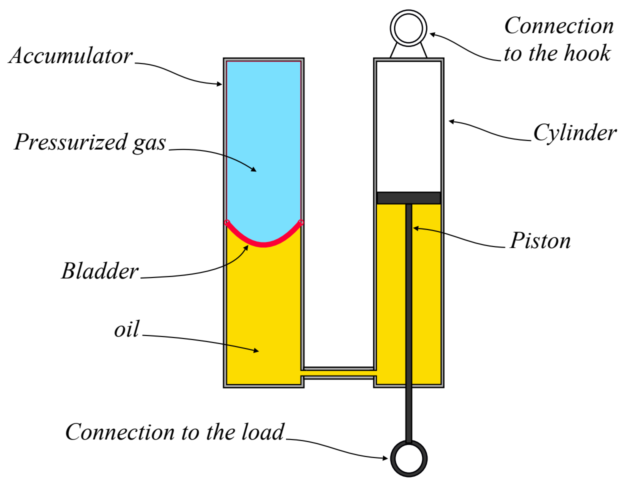


Rolling and pitching effects can be moderated by adjusting the heading of the surface support. However, that can be difficult with anchored vessels due to the constraints resulting from the pre-established anchor positions. Dynamic Positioning vessels offer more possibilities of adjustment, except when they are obliged to work alongside a facility, which is often the case. Also, even though the effects of rolling and pitching can be moderated by adjusting the heading of the vessel, motions such as heaving cannot be under control using such a method. For this reason, modern units are equipped with heave compensation and roll reduction systems.

5.5.2.2 - Heave compensation

Heave Compensation systems are designed to compensate for the vertical vessel movement caused by waves, so the relative distance between the load and seabed or the other vessel is kept constant.
Heave compensation can be divided into two main categories: passive heave compensation (PHC) and active heave compensation (AHC).

Passive Heave Compensation (PHC) requires no input energy to operate. Its principle of work is to accumulate kinetic energy during the vessel movement and then to use this energy to compensate for the change of position between the vessel and the load. Similarly to a shock absorber, it is a reactive device that attempts to isolate the weight from the vessel heave using a compressed gas cushion (usually nitrogen), as shown in the scheme on the side, where the accumulator is charged with pressurized gas set to hold the load at a steady-state on one side of a bladder that separates the gas from the hydraulic oil, which is at the same pressure as the gas and holds the load by pushing on the piston in the cylinder. Note that some systems use a spring in place of the compressed gas.
Passive Heave Compensators are connected between the hook of the crane and the load.

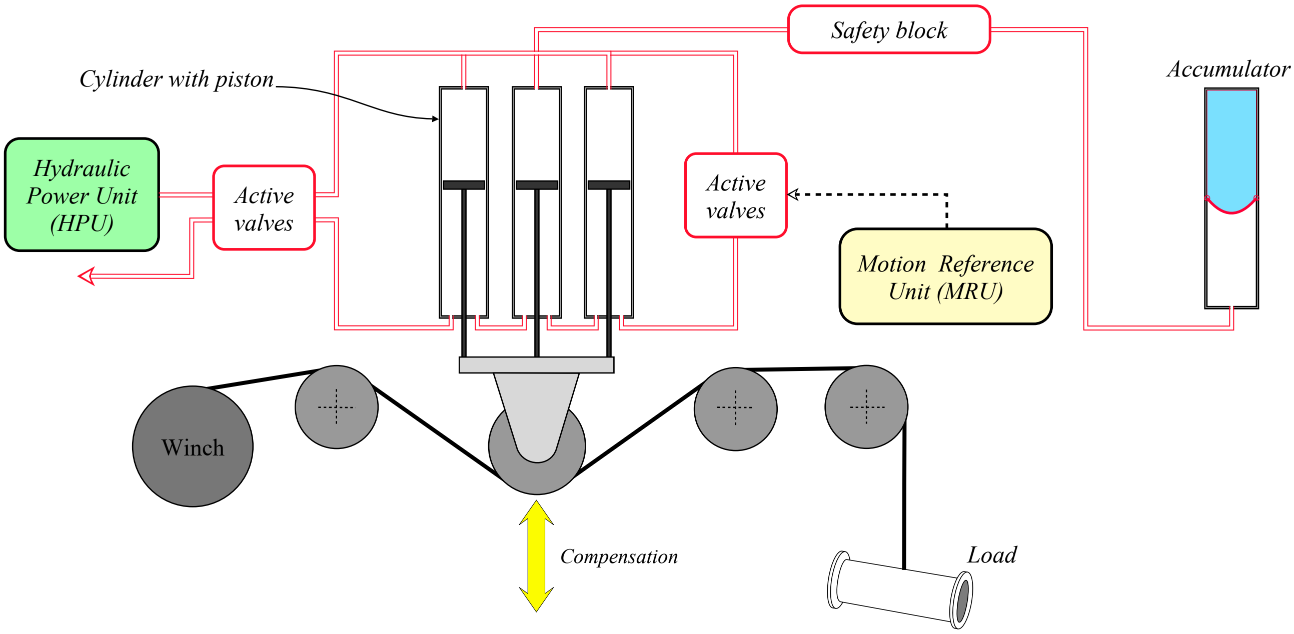


Passive Heave Compensators are often used with lattice boom cranes. Their advantages are that there is no power consumption, they are easy to operate and maintain, and they are relatively cheap.
Their disadvantages are that they require adjustment for the actual load that must have a high resistance to movements, and that they provide a limited range of motion.

Passive Heave Compensation has a limited efficiency, and for this reason, most modern vessels are equipped with Active

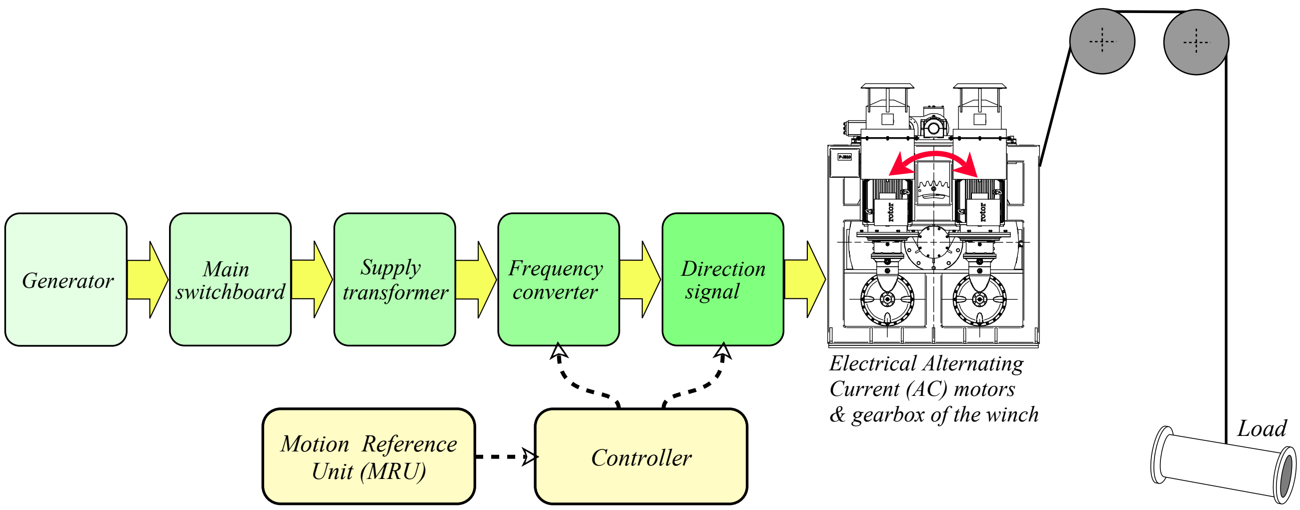
Heave Compensation (AHC) systems.
Active Heave Compensation (AHC) systems utilize a Motion Reference Unit (MRU), which is an inertial measurement unit with multi-axis motion sensors that actively measures all the movements of the vessel. Based on the data collected, a computer calculates the necessary counter motion of the system and controls it in real time. As a result, the length of the cable is permanently adjusted to counteract the vertical movements of the vessel, and there is no variation of the distance of the load from the bottom; thus, its depth is kept constant.
The systems that adjust the length of the cable can be based on hydraulic cylinders, and also rotary hydraulic motors or electric motors that directly move the winch.

Hydraulic cylinder systems are based on pistons that extend and retract according to the direction of the fluid coming from the Hydraulic Power Unit (HPU) through a series of electronically piloted control valves that direct this fluid according to the orders from the Motion Reference Unit (MRU). The cylinders are working independently from the winch, which is usually inactive. They can be installed vertically or horizontally. The function of the accumulator is to maintain a constant pressure in the system.



Rotary hydraulic systems are based on the same principle as hydraulic cylinders. The difference is that the cylinders are replaced by the motor of the winch that acts in one direction or its opposite in function of the direction of the fluid sent from the HPU through the electronically piloted control valves.

Electrically driven heave compensation systems are often used due to their high efficiency as well as the fact that they can be easily fed by the generators of the last generation diesel-electric vessels. Also, it is said that they are more silent than other hydraulic systems. In addition, they do not need an oil reservoir and Hydraulic Power Unit (HPU), which may save some space and attract contractors who do not want to deal with oil replacement and potential leaks.
The advantage of electricity is also that it can act directly to the motor and allows the same torque at a slow speed as that at rapid speed. However, the electricity produced by the generators must be adjusted to the needs of the electric motor of the winch. The scheme below shows an example of a chain of conversion of the electrical current produced by the generator and where the Motion Reference Unit (MRU) intervenes to allow heave compensation.



Definitions:

- *An electric switchboard is a device that directs electricity from one or more sources of supply to several smaller regions of usage. It is an assembly of one or more panels, each of which contains switches that allow electricity* *to be redirected.*

- *A transformer is a device used to change the voltage of an alternating current in one circuit to a different voltage in a second circuit. Transformers consist of a frame-like iron core that has a wire wound around each end. As a current enters the transformer through one of the coils, the magnetic field it produces causes the other coil to pick up the current. If there are more turns on the second coil than on the first coil, the outgoing current will have a higher voltage than the incoming current. This is called a step-up transformer. If there are fewer turns on the second coil than on the first, the outgoing current will have a lower voltage. This is called a step-down transformer.*
- *A frequency converter is a device that converts alternating current (AC) of one frequency to alternating currents of other frequencies. As the speed of an AC motor is dependent on the frequency of the AC power supply changing this frequency allows changing the motor speed. As a result, the rotational speed of the motor can be adjusted using this means instead of using a gearbox, which allows saving energy.*

Active Heave Compensation solves most of the problems that cannot be solved by Passive Heave Compensation, so the distance of the load from the seabed is accurately monitored and stable. That allows increasing the weather window of lifting operations. The major inconveniences of such systems are that they have an elevated demand for power, and the rope wear of cranes equipped with such devices is higher than with classical cranes. Also, they are often complicated, and so are more exposed to breakdowns than passive systems and must be maintained by specialized personnel.

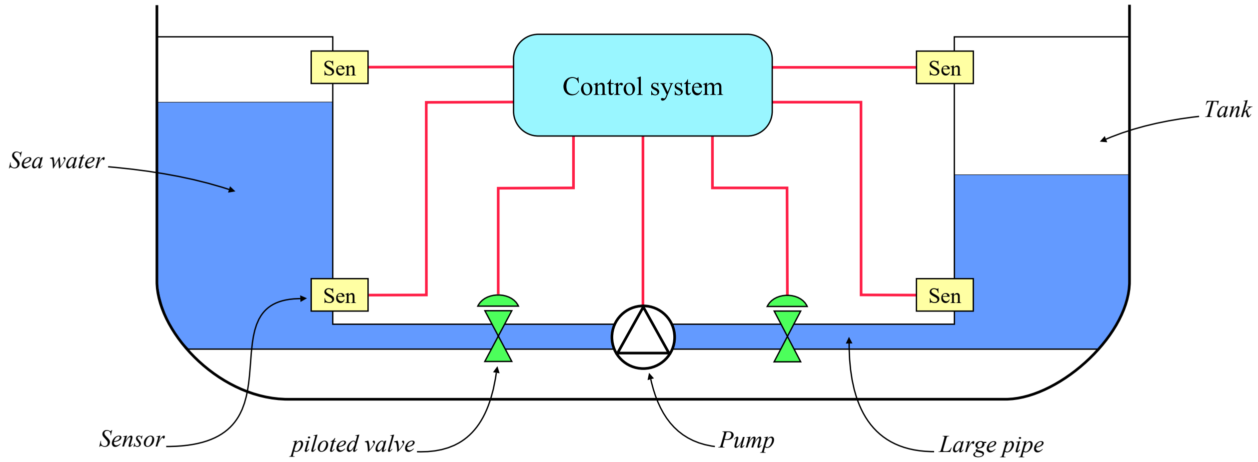
Roll and Pitch compensation:
Active Heave Compensation allows controlling the load vertically on the target but does not control the other movements of the vessel. However, some crane manufacturers have engineered a hydraulically actuated two-directional motion compensation system employing high-speed hydraulic cylinders at the base of the crane.
With the active heave compensation and the two-axis motion compensation system tied into the ship's motion reference unit (a gyro), the system allows full three-axis (x, y, and z) compensation.

5.5.2.3 - Ship stabilization systems

Boats designed for crane operations with heavy loads may have their stability compromised by the cumulated effect of the waves and the weight deployed overboard. Also, heavy and voluminous cargo that may be on deck and unfavourable weather conditions may influence the behaviour of the boat, making her uncomfortable and affecting her safety. For this reason, several systems of stabilization are in place:

- Bilge keels which are plates projecting from the turn of the bilge and extending over the middle half to two-thirds of the ship's length are in place. They create turbulence dampening the motion of the ship and causing a reduction in rolling amplitude. However, they are effective only when the ship is sailing.
- Ballast tanks, which are compartments filled with sea water, are used to provide stability. Also, the water in the ballasts can be pumped out to temporarily reduce the draft of the vessel when required to enter in shallow waters or to maintain the vessel afloat in the case of flooded compartments.
  Note that according to chapter II / rule 8 - "Construction, structure and stability" of SOLAS (International Convention for the Safety of Life at Sea), ballast systems that can be operated during adverse conditions are mandatory with new vessels.
- Anti heeling tanks / anti rolling tanks which can be used as classical ballast tanks are provided to compensate the movements of the cranes. The anti-heeling system automatically detects the angle of the ship and compensates it, which allows the vessels to have continues loading and unloading cargo operation without stopping in between for tilt correction.
  The system consists of ballast tanks which are internally connected to each other by means of pipelines, automatic valves and control systems. When the ship tilts to any of the sides, the heeling sensor sends the signal for a change of ships angle with respect to the ship's upright position to the master control panel. The change of angle is compensated by auto transferring the water from one side to the other side of the ship, maintaining the

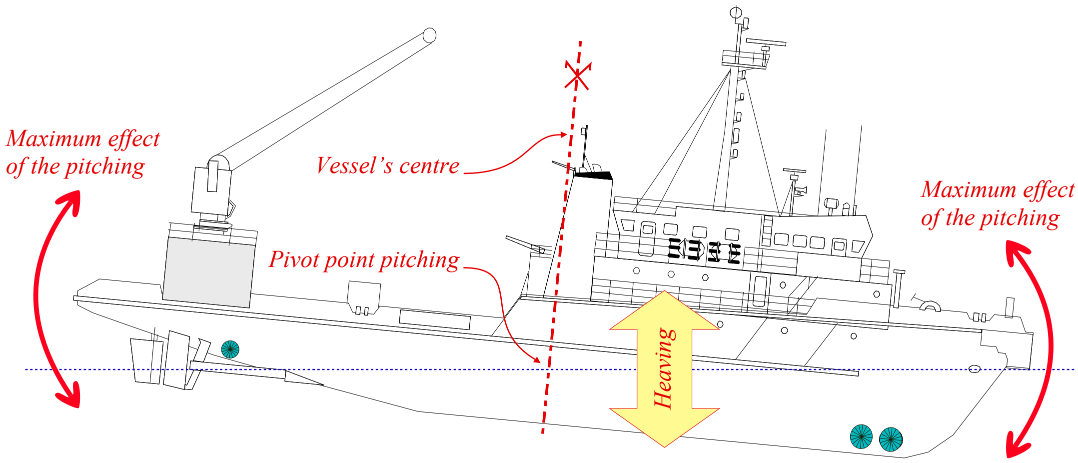
vessel in upright position. The anti heeling system can be used as anti rolling system while the vessel is underway. Similar pumps as those used for ballasting tanks are used to fill and empty these tanks.



5.5.3 - Effects on surface supplied diving operations and the measures to control them

5.5.3.1 - Effect on diving operations

During unfavorable weather conditions, the effects of the movements of the vessel on a basket or a wet bell are similar to those on a load hanged to a crane. Thus, the basket or bell moves up and down and bumps the hull during the launching and recovery, depending on their amplitude. As a result, the launching and recovery can be dangerous for the divers and the personnel operating the system, who can be seriously wounded or ejected to the sea. In addition, the in-water decompression is not performed in optimal conditions, which may result in a decompression illness. Note that in case the deployment of the diver is done from a ladder by such unfavorable weather conditions, the diver can be thrown away by the waves, injured by the up and down movements of the ladder, and not be able to grab it. Also, the movements of the deployment device are amplified if the position of the Launch And Recovery System (LARS) is at the very stern of the vessel, which is frequently the case with diving operations from units tied to platforms.



Another effect is that the elements incorrectly fastened may be torn off from their initial position and become uncontrolled objects acting like battering rams, resulting in injuries or fatalities of the personnel and equipment damages.

5.5.3.2 - Means of control

It must be considered that diving operations from unstable surface support are hazardous and must not be launched. For this reason, the sea condition should be risk assessed, taking into consideration the stability of the surface support used, the exposure of the dive station to the weather, and the available means for the rescue of the divers.
The ship stabilization systems described previously are efficient means of control of the rolling. The use of heave compensation systems similar to those used by cranes is technically possible. Unfortunately, surface-supplied diving systems are usually not provided with such devices, even though they are commonly used with saturation systems. The main reasons are their costs, complexity, and the space necessary to install them. However, several other solutions allow to partially compensate for the problems described above:

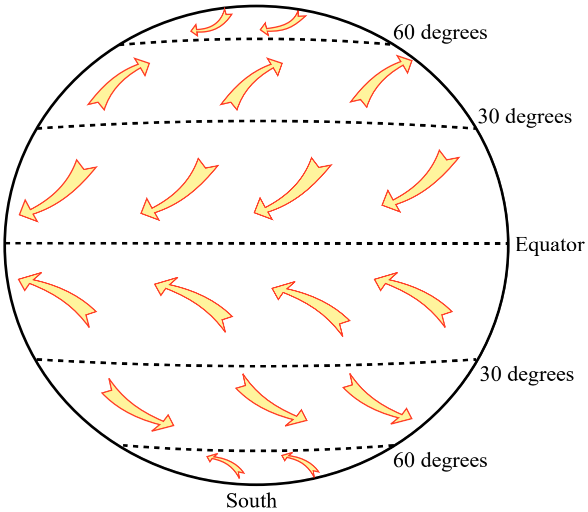
- It is preferable to install the launch and recovery station as close as possible as to the pivot point of the vessel which is not affected by the pitching (see the scheme above).
- A suitable heading of the vessel allows diminishing the rolling and pitching effects. Thus, the ship's position has to be studied during the project preparation. Also, dynamic Positioning vessels can easily modify their orientation, except when working alongside facilities.
- The components of the dive station and tools must be fastened. These fastenings must be calculated and verified.
- Surface decompression procedures must be ready to replace in-water decompression at all times.

5.6 - Ocean currents

The main cause of surface currents in the open ocean is the direct action of the wind on the sea surface and a close correlation accordingly exists between their directions and those of the prevailing winds. It is said that the speed of a wind generated current is usually about 3% of the wind speed. Winds of high constancy blowing over extensive areas of ocean will naturally have a greater effect in producing a current than will variable or local winds. Thus, the Northeast and Southeast Trade Winds of the two hemispheres are the main spring of the mid-latitude surface current circulation.

In the Atlantic and Pacific Oceans, the two Trade Winds drive an immense body of water "W" over a width of some 50° of latitude, broken only by the narrow belt of the E-going Equatorial Counter-current, which is found a few degrees N of the equator in both of these oceans. A similar transport of water to the "W" occurs in the South Indian Ocean driven by the action of the Southeast Trade Wind.

The Trade Winds in both hemispheres are balanced in the higher latitudes by wide belts of variable "W" winds. These produce corresponding belts of predominantly E-going sets in the temperate latitudes of each hemisphere. With these E-going and W-going sets constituting the N and S limbs, there thus arises great continuous circulations of water in each of the major oceans. These cells are centred in about 30°N and S, and extend from about the 10th to at least the 50th parallel in both hemispheres. The direction of the current circulation is clockwise in the N Hemisphere and anti-clockwise in the S Hemisphere.

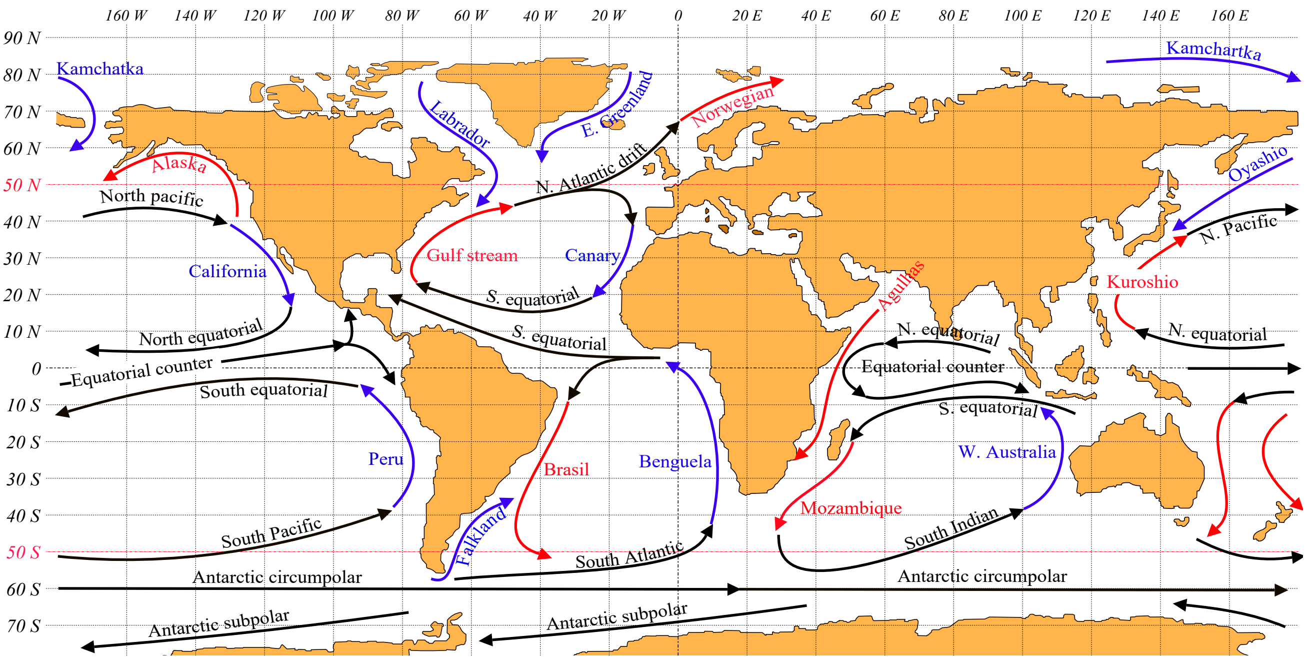


There are also regions of current circulation outside the main gyres, due to various causes, but associated with them or dependent upon them. As an example, part of the North Atlantic Current branches from the main system and flows N of Scotland and N along the coast of Norway. Branching again, part flows past Svalbard into the Arctic Ocean and part enters the Barents Sea.

In the main monsoon regions, the North part of the Indian Ocean, the China Seas and Eastern Archipelago, the current reverses seasonally, flowing in accordance with the monsoon blowing at the time.

The South Atlantic, South Indian and South Pacific Oceans are all open to the Southern Ocean, and the Southern Ocean Current, encircling the globe in an East direction, supplements the South part of the main circulation of each of these three oceans.

Temperatures of the oceanic currents:



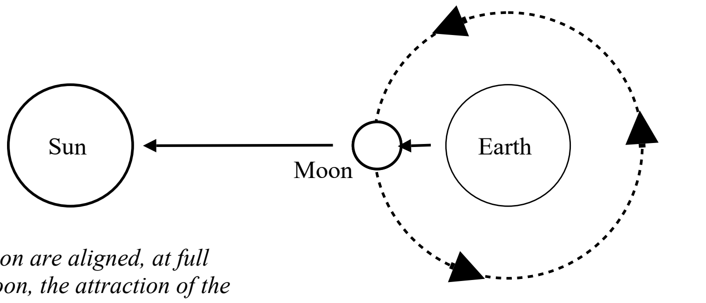
In general, oceanic currents which set continuously E or W acquire temperatures appropriate to the latitude concerned. Currents which set N or S over long distances, however, transport water from higher to lower latitudes, or vice versa. The Gulf Stream, for example, transports water from the Gulf of Mexico to the central part of the North Atlantic Ocean where it gives rise to temperatures well above the latitudinal average. The map on the bottom of the previous page shows the main warm (in red) and cold (in blue) North or South currents, and also the main East or West currents (in black).

5.7 - Tides

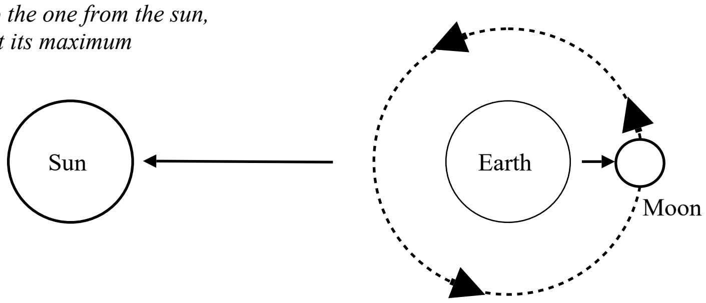
Tides are the rise and fall of sea levels caused by the combined effects of the gravitational forces exerted by the Moon and the Sun and the rotation of the Earth.

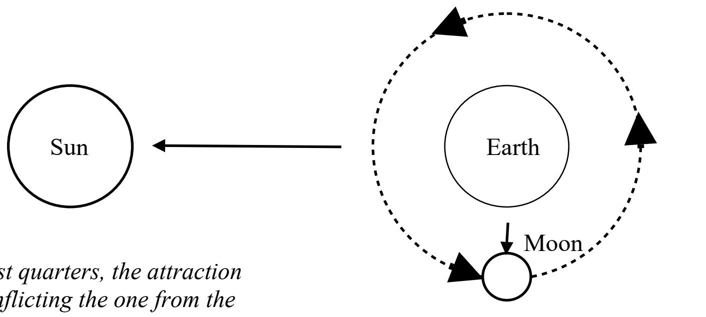
The tidal forces affect the entire earth, but the movement of the solid earth is only centimeters. The atmosphere is much more fluid and compressible, so its surface moves kilometers, in the sense of the contour level of a particular low pressure in the outer atmosphere. Because it is a fluid, the water is also more sensitive to attraction than solid materials and can move up and down several meters, depending of the period of the year.

The peak amplitudes are reached around the spring and autumn equinoxes along the Atlantic coast, or around the summer and winter solstices in some parts of Asia.

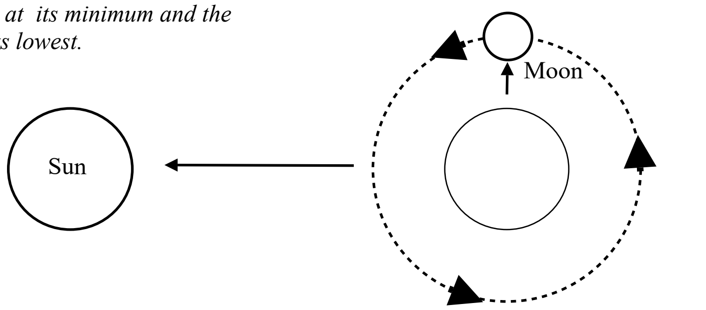


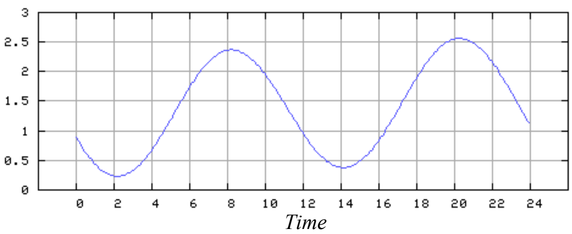
When sun and moon are aligned, at full moon and new moon, the attraction of the moon is adding to the one from the sun, and the effect is at its maximum





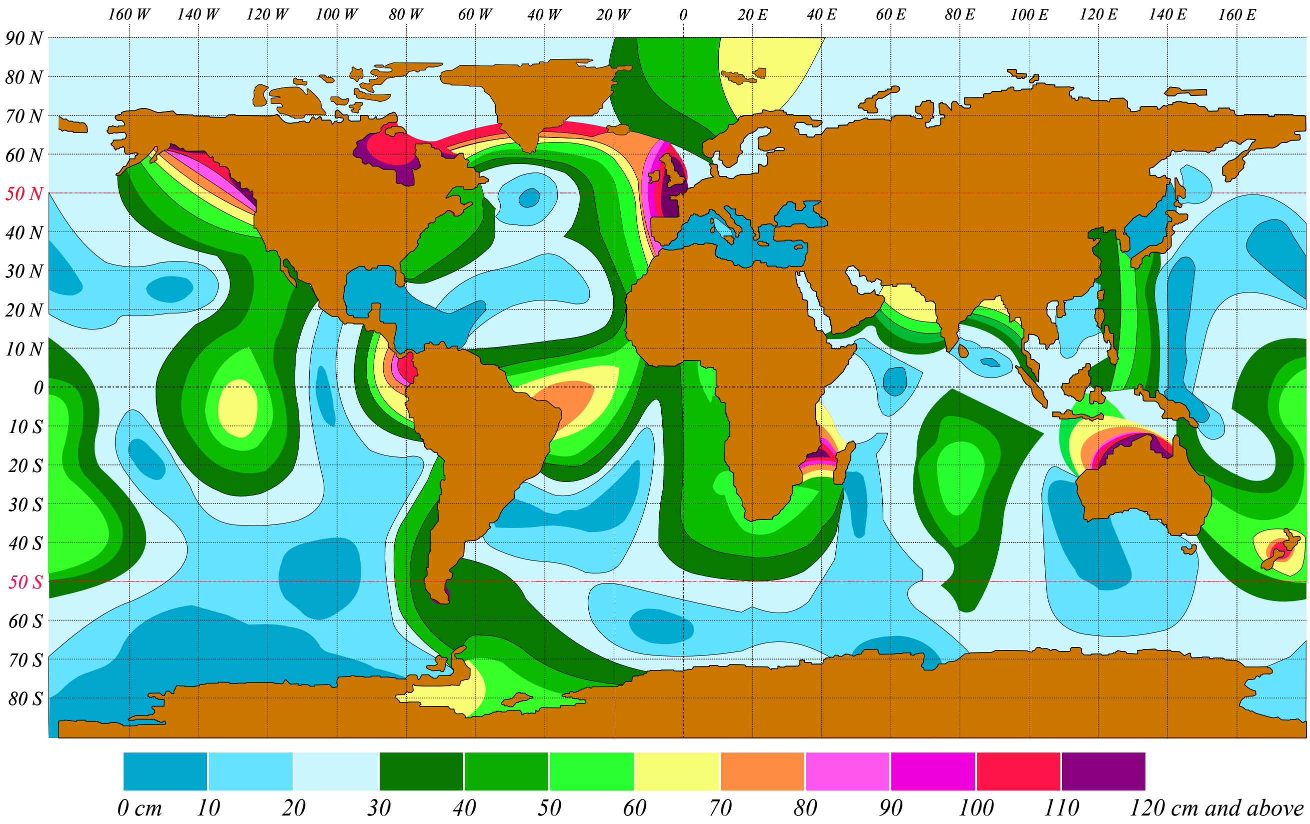
At the first and last quarters, the attraction of the moon is conflicting the one from the sun. The effects is at its minimum and the tidal range is at its lowest.



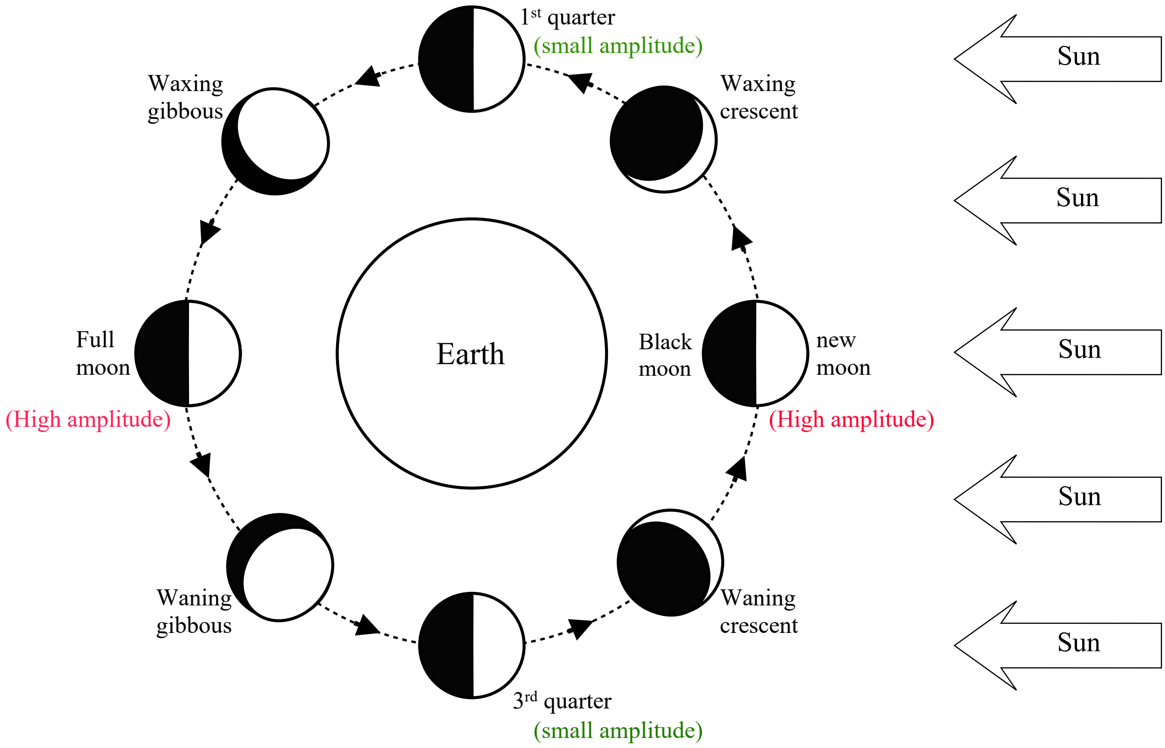


Tides are commonly semi-diurnal (two tidal cycles each day), or diurnal (one tidal cycle per day).
The tidal range is the difference in height between low tide and high tide. It depends on the phase of the moon and the shape of the coastline, so that some bays may have different tidal ranges than the open sea. The times and heights of tides are given in tide tables and can be affected considerably by strong winds.

The map below shows the world tidal amplitudes expressed in centimetres.



The amplitudes of the tides are given on tables, but they can also be evaluated according to the position of the moon :



Tides produce oscillating currents known as tidal streams:
The moment that the tidal current ceases is called "slack water or slack tide". The tide then reverses direction and is said 'to be turning". "Slack water" usually occurs near "high water" and "low water". But, there are locations where the moments of slack tide differ significantly from those of high and low water.

The amplitude of the tide has a direct effect on the speed and the power of the tidal stream: The bigger the range, the faster the tidal stream. Tidal streams can also increase in speed around headlands and in narrow channels. In some estuaries, the tidal streams can cumulate with the current from the river. These currents are often associated with poor visibility caused by sediment carried by the river. Some tide currents can be as fast as 10 knots.
In addition, due to the interferences initiated by the conditions at the location, the currents may run in different directions at different depths. This possible effect is common and has to be anticipated before launching the dive. Major ocean currents may superimpose on these currents, increasing or decreasing the speed and producing turbulence.

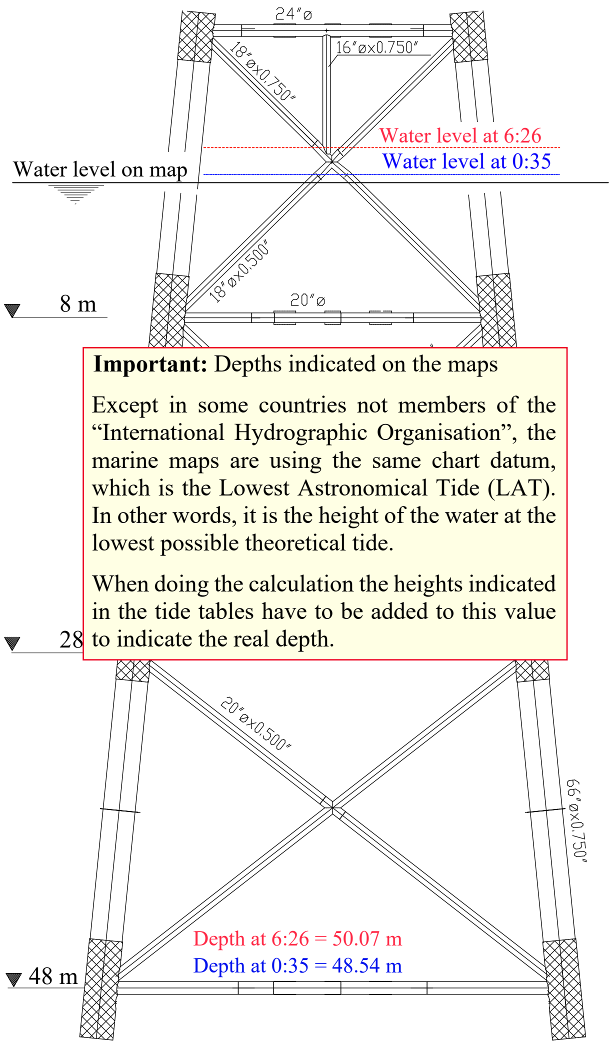
There is "high water" every 12:25 hrs. On average, the tide rises for 6 hours and 12 minutes. This is "the rising, or flood tide". At the top of the flood, the level remains constant for a short period at "high water slack". The "falling or ebb tide" then runs for about 6 hours 12 minutes until low water slack. Then the cycle begins again. In some areas, flood and ebb tides may run for considerably less than six hours.
The twelve's rule is used to calculate the amount of rise or falling. This rule is based on: The range divided by 12 and the duration divided by 6.

Hours	Twelfth of Range
Hour 1	1/12 of range
Hour 2	2/12 of range
Hour 3	3/12 of range
Hour 4	3/12 of range
Hour 5	2/12 of range
Hour 6	1/12 of range

Example: Check the real depth of a platform member indicated at 48 m on the elevation.

The tide table of the day is indicating:

Statement	Time	Height
Low water	0:35	0.4 m
High water	6:26	2.07 m
Low water	12:11	0.45 m
High water	18:30	2.71 m



Important: Depths indicated on the maps

Except in some countries not members of the "International Hydrographic Organisation", the marine maps are using the same chart datum, which is the Lowest Astronomical Tide (LAT). In other words, it is the height of the water at the lowest possible theoretical tide.

When doing the calculation the heights indicated in the tide tables have to be added to this value to indicate the real depth.

1) Flood tide between 0:35 and 6:28

At 0:35, the depth of the brace will be 48 + 0.4 = 48.4 m

At 6:28, the depth of the brace will be 48 + 2.07 = 50.07 m

The range is 50.07 - 48.4 = 1.67 m

1/12 = 1.67 / 12 = 0.139 m (0.14)
2/12 = 0.139 x 2 = 0.278 m (0.28)
3/12 = 0.139 x 3 = 0.417 m (0.42)

Time	hr	1/12	Height
1:34	1st	1/12	48.4 + 0/139 = 48.54 m
2.32	2nd	2/12	48.539 + 0.278 = 48.81 m
3.31	3rd	3/12	48.81 + 0.417 = 49.23 m
4:29	4th	3/12	49.234 + 0.417 = 49.65 m
5:28	5th	2/12	49.651 + 0.278 = 49.93 m
6:26	6th	1/12	49.929 + 0.139 = 50.07 m

2) Ebb tide between 6:28 and 12:11

At 6:26 the depth of the brace will be 48 + 2.07 = 50.07 m

At 12:11 the depth of the brace will be 48 + 0.44 = 48.45 m

The range is 50.07 - 48.45 = 1.62 m

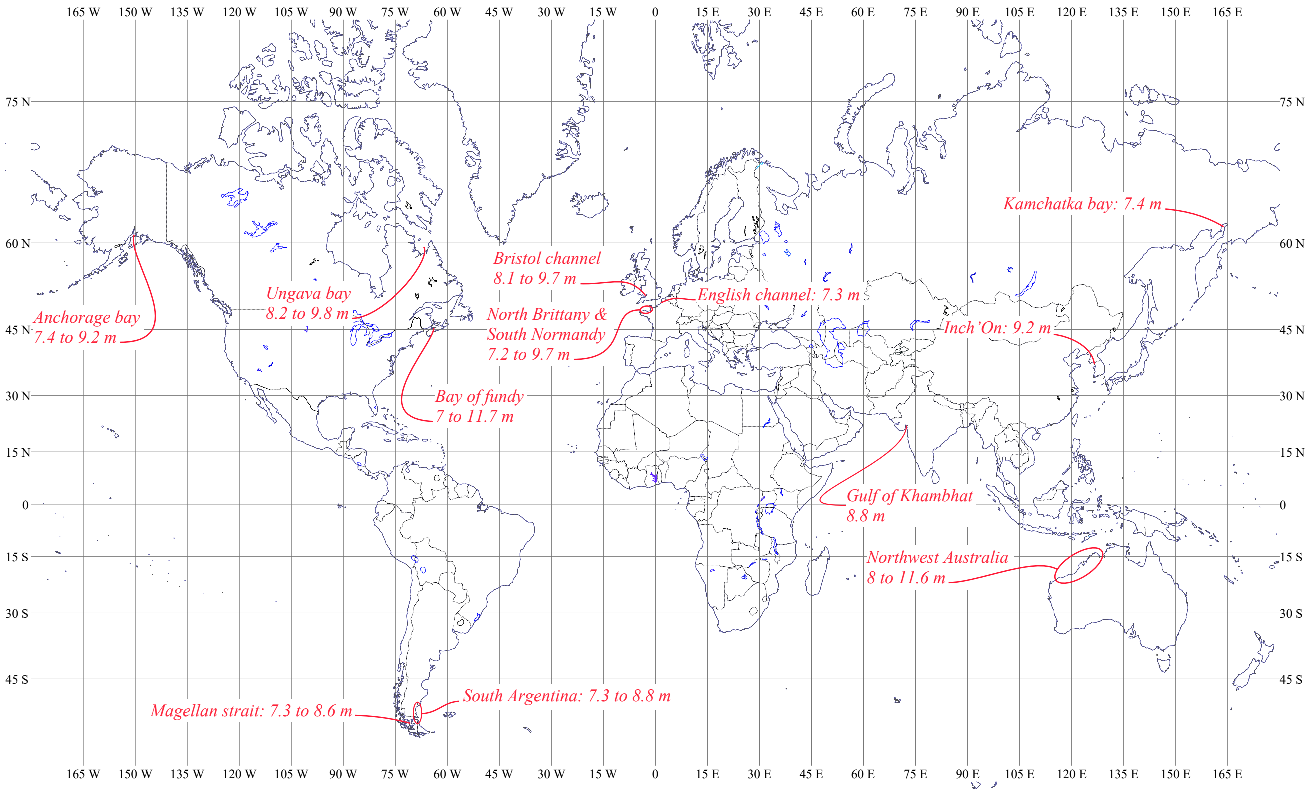
1/12 = 1.62 / 12 = 0.135 m
2/12 = 0.135 x 2 = 0.27 m
3/12 = 0.135 x 3 = 0.405 m (0.42)

Time	hr	1/12	Height
7:24	1st	1/12	50:07 - 0.135 = 49.93 m
8:21	2nd	2/12	49.935 - 0.27 = 49.66 m
9:18	3rd	3/12	49.665 - 0.405 = 49.26 m
10:15	4th	3/12	49.26 - 0.405 = 48.85 m
11:13	5th	2/12	48.855 - 0.27 = 48.58 m
12:11	6th	1/12	48.785 - 0.135 = 48.45 m

Hyperlink Tables of contents

Areas with extreme ranges of tides:
There are a lot of places in the world that have extreme tides such as those indicated in the list below that shows some of the areas where tide ranges are 7 metres and above. These data, that are based on records from the US National Oceanic and Atmosphere Administration (NOAA) and other organizations, do not indicate the exceptional tides.

Location	***Range (metres)***	***Location***	***Range (metres)***
Bay of Fundy - Canada	7 to 11.7 m	South Argentina coast	7.3 to 8.8 m
Northwest Australian coast	8 to 11.6 m	Gulf of Khambhat - India	8.8 m
Ungava bay - Canada	8.2 to 9,8 m	North Brittany and South Normandy coasts - France	7.2 to 9.7 m
Bristol channel - United kingdom	8.1 to 9.7 m	Magellan strait	7.3 to 8.6
Anchorage bay - Alaska - USA	7.4 to 9.2 m	Kamchatka bay Russia (East Siberian coast)	7.4
Inch'On - Korea	9.2 m	English channel, (Cayeux [Fr] & Dover [UK])	7.3 m



There is a belief that says that extreme tides happen in areas above the North and South 45th parallels, which is incorrect, and as it is proved by the map above. Instead, extreme tidal ranges are created by the configurations of the continents and the surrounding coastlines, the prevailing winds, the currents, and other interactions, as indicated in the previous pages. For example, NOAA says that favorable conditions for high ranges of tides in the high latitudes of the northern hemisphere result from the fact that North American, European, and Asian continents are close in these latitudes. Also, a lot of areas where such tidal effects are recorded are bays or locations at the proximity of straits.

High and low tides in Saint Malo - North Brittany - France

5.8 - Effects of underwater currents on divers’ performance and safety

As described previously the underwater currents can have several origins which can conflict or cumulate.

- The seasons have direct effect on the power of tidal currents and the ocean currents.
- The weather perturbations can create fast surface currents, most often from surface to 10 m, but sometimes much deeper. These currents can persist for days following the perturbation. Some surface currents can also establish due to bad weather situated far out in the ocean.
- In some estuaries, the rivers are sometimes conflicting with the tides, creating “tidal bore” effects. Tidal bore is due to the incoming tide forming a wave of water that travels above the river. This effect is quite dangerous because these waves are established very suddenly. Most often, there is not a tidal bore, and the river is merely flowing underneath the rising salt water.
- In case of conflicting currents, it is common to have several currents crossing by layers at different depth. It is also frequent to have cold currents establishing through masses of warm water.

All these elements make the predictions of underwater currents difficult.

IMCA D 067 “The effects of underwater currents on divers’ performance and safety”, that supersedes AODC says:

The effects of currents on divers varies with the individual, the work being done, the diver’s position in the water and the diving method used. Currents produce forces which affect not only divers’ bodies but also their umbilicals, together with any hoses and cables from the surface to equipment and tools the divers may have at the working depth. Currents can also have an adverse effect on diver deployment devices, for example cages, bells and/or bell umbilicals.

As an increasing amount of energy is devoted to combating the effects of current, as well as carrying out productive operations, it follows that the greater the speed of the current, the shorter will be the period during which the diver will be effective before the onset of significant fatigue.

A diver operating from a bell or wet bell is better able to operate in currents than a surface orientated diver since his umbilical is shorter, is deployed in the horizontal plane, and therefore, attracts much less resistance to water movement. Thus, a diver operating down or upstream from a bell has to contend with the effect of the current on his person only and not on his umbilical.

The force exerted on a diver and his equipment by the current is proportional to the water velocity squared. If the velocity doubles, the force increases four times. The table below shows approximate drag forces exerted on the "average" diver in both a vertical and horizontal position.

Current speed (knots)	*Force on the diver standing facing the current (Max. Profile)*		*Force on the diver horizontal facing the current (min. Profile)*	
	lbs	*Kg force*	*lbs*	*Kg force*
0.5	*6*	*3*	*1*	*0.5*
1	*23*	*10*	*4*	*2*
1.5	*52*	*23*	*9*	*4*
2	*92*	*41*	*15*	*7*
2.5	*144*	*65*	*24*	*11*
3	*207*	*94*	*36*	*16*
3.5	*282*	*128*	*47*	*21*
4	*369*	*167*	*61*	*28*
4.5	*467*	*212*	*78*	*35*
5	*567*	*260*	*96*	*44*

Note: 1 kg force = 9.80 newton (measured at Paris) - 1 pound force = 4.45 newton (measured at London)

The possibility to organize an efficient and safe dive when currents are present depends on factors such as:

A) The physical condition of the diver and his experience with strong currents.
B) Whether the standby diver can be deployed to rescue the diver in the event of an emergency.
C) Whether the work is to be performed in mid-water or on the seabed, and requires strong efforts or not.
D) The means of deployment used (bell or a basket), the umbilical deployed's length, buoyancy, and orientation.
E) The influence of the current on the implementation and the recovery of the equipment to be used.
F) The means of prediction and monitoring that are available to control the underwater current changes.
G) The current’s strength and evolution, and if other currents are present at depths above or below.
H) Whether swim-lines, down-lines, means of attachment, and/or an underwater tender are available.
I) Whether the diver can be sheltered by underwater structures or the configuration of the seabed.

Based on the elements above, IMCA has reviewed the previous limitations of AODC 47 for diving operations that may be possible at various current speeds and reduced the exposure of divers to such conditions as displayed below:

	0.0 to 0.7 knots	***0.7 to 1.0 knots***	***1.0 to 1.2 knots***	***1.2 to 1.5 knots***	***1.5 knots and over***
Surface supply in mid water	Normal work	Light work	Special precaution	No diving	No diving
Surface supply on bottom	Normal work	Normal work	Special precaution	No diving	No diving
Bell or wet bell in mid water	Normal work	Light work	Special precaution	No diving	No diving
Bell or wet bell on the bottom	Normal work	Normal work	Special precaution	No diving	No diving

Normal work	*No restrictions*
Light work	*Dives limited to works not requiring strong efforts.*
Special precaution	*Diving in these currents should not be considered a routine operation:* ◦ *Based on the elements indicated previously, the diving supervisor should consult with the divers involved and other people about the feasibility of such an operation.* ◦ *A risk assessment should be performed to ensure that suitable control measures are in place.* ◦ *The team must also consider whether the standby diver can be safely deployed to rescue the diver in the event of an emergency.*
No diving	*Diving operations are normally forbidden beyond 1.2 knots*

The new IMCA limitation of the normal conditions to 1 knot merely follows the limits set up by the industry as a lot of clients have published this maximum limit in their working rules for a very long time.
It is also the rule to ensure that means of prediction *(see in point 5.7 "tides")* and monitoring of the current are in place.

Note that the diving supervisor responsible for the operation is the only person who can order the start of a dive. However, the client representative, the diving superintendent, and the master of the vessel can ask him to abort it if they consider the conditions unsuitable.

5.9 - Water turbidity

4.9.1 Remembering about the visible light in water

Light is an electromagnetic wave oscillation varying in length between 380 and 750 million (manometers). It is apparently white, but through a prism, the white is decomposed into six colours: red, orange, yellow, green, blue and purple. Each of such colours has a wavelength that is specific.

Colour	Min and Max wavelength
Purple	400 - 430 million
Blue	430 - 490 million
Green	490 - 560 million
Yellow	560 - 590 million
Orange	590 - 620 million
Red	620 - 700 million

It is considered that the "hot" colours are those whose wavelength is longer than its 560: yellow, red and orange. Those whose wavelength is shorter are cool colours: blue, green, purple.
The speed of light is 300,000 km/ second. It is the speed at which it enters into the atmosphere and it is not significantly slowed down when it reaches the surface of the sea except during cloudy days.

5.9.1.1 - Reflection of the light

When sunlight reaches the surface of the sea, depending on the angle of incidence, there is a partial reflection back to the atmosphere of a part of the light rays, with the result of a loss of light.
The wider the angle incidence (when the angle of the sun is close to the horizontal of the sea surface), the more reflected rays, therefore, the amount of light that enters the water is small. When the sun is high in the sky, the angle of incidence is smaller (the incident ray will be near the vertical) and, therefore, the loss of light is lower. One can easily deduce that the best time to have underwater natural light are the hours between 11:00 and 15:00 because the sun is at the zenith, and the loss of light by reflection is reduced.

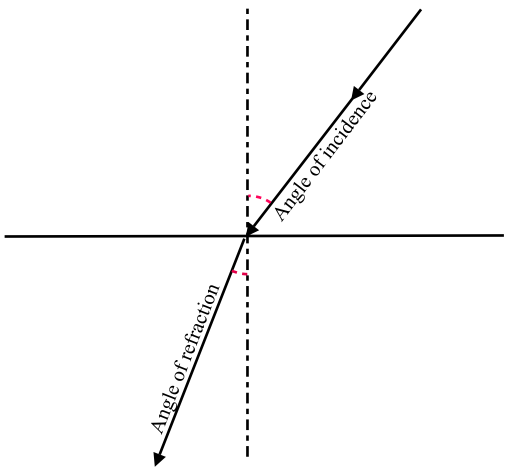
The figures below indicate the loss of light with a clear sky. If the sky is overcast, the light lost in the clouds is about 6% whatever the position of the sun.

Angle of incidence	% of light reflected (lost)
0º	0.02
10º	2.1 %
20º	2.1 %
30º	2.1 %
40º	2.5 %
50º	3.4 %
60º	6 %
70º	13.4 %
80º	38.4 %
90º	100 %

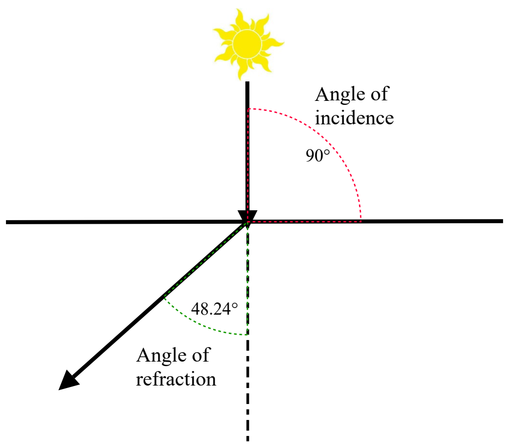
5.9.1.2 - Refraction of the light:

The refraction is the change in direction of a wave due to a change in its transmission medium. The refraction is a constant, and is not really influenced by the weather conditions. For remembering only:

- Refraction law: Sin of the angle of incidence / Sin of the angle of refraction = Constant
- In air: Sin of the angle of incidence / Sin of the angle of refraction = 1 (index of refraction of air)
- In fresh water: Sin of the angle of incidence / Sin of the angle of refraction = 1.33 (index of refraction of fresh water)
- In salt water: Sin of the angle of incidence / Sin of the angle of refraction = 1.34 (index of refraction of salt water)



- Example with an angle of incidence of 90 degrees with sea water:
  - In salt water: Sin of the angle of incidence / Sin of the angle of refraction = 1.34
  - Sin 90° / sin of the angle of refraction
  - Sin 90° = 1 so 1/1.34 = 0.746 = 48.24 degrees



- Effects:
  - 1.333 (index of refraction fresh water) = 4/3
  - An object in the water is seen 1/3 bigger: A fish which appear 1.2 m is in fact 0.8 m long
  - An object appears closer 1/4: an object at 4 m seems to be a 3 m (which often create problems to grab them…)

5.9.2 - Other causes of loss of the light

Other causes of the extinction of light at sea are due to absorption and diffusion in water.

- Absorption
  The water absorbs an amount of light that is proportional to the thickness of the liquid column crossed and the number of particles suspended in it. The first cause is constant, but the second cause varies according to the size, the type and amount of solution.
- Diffuse reflection
  Diffuse reflection is the scattering of light in all directions. There are 2 main causes. The water that normally reflects the light, and the suspended particles composed of mineral salts, sediments, and also varieties of plankton. Because of their irregular shapes, these particles deviate the trajectory of the light, and when crossed by it, they refract it in every direction. This light is then reflected to the particles that were not initially crossed by the initial light, with the same effect. The intensity of the light and the contrast are affected. The well known effect is foggy pictures on the video.
  Because the absorption and diffusion increase with depth, there is a decrease in light intensity which is related to the depth and also a phenomenon of modification of the colours:

Depth	% of sun light
0 m	100 %
1 m	40 %
5 m	25 %
10 m	14 %
20 m	7 %
30 m	3 %
40 m	1.5 %
50 m	0.7 %
60 m	0.25 %
90 m	0.17 %

Depth	Effect on colours
5 m	Red not visible
15 m	Orange not visible
30 m	Yellow not visible
35 m	Blue and green are the most visible
55 m	Purple and indigo are the most visible

The absorption and diffuse reflection are more intense in the vicinity of the coasts and river mouths than open sea due to a greater number of particles in suspension and the direct influence of heavy rains on the rivers and of the bad weather to the shallow sea floors.

That creates situations where the diver is constrained to work in reduced visibility or in the darkness, which creates additional risk, because the hazards are difficult to identify in these conditions. Also, some untrained divers can become anxious in these conditions.

5.10 - precautions

It is the responsibility of employers and their representatives to take care of the health and safety of the people they employ. “Health and Safety at Work etc Act 1974 (1974 c 37)” precise page 3 / point 2 /”general duties”:

(1) It shall be the duty of every employer to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all his/her employees.

(2) Without prejudice to the generality of an employer's duty under the preceding subsection, the matters to which that duty extends include in particular….(e) the provision and maintenance of a working environment for his employees that is, so far as is reasonably practicable, safe, without risks to health, and adequate as regards facilities and arrangements for their welfare at work.

Managing the weather conditions is one of the major problems during diving operations, and the diving supervisors and superintendent need to organise all the necessary precautions to monitor closely the weather and recover the divers safely any time.

It must be remembered that IMCA 14 says point 3.5 that the supervisor is the only person who can launch a dive. IMCA 14 indicates also point 3.5 that the supervisor has authority to give orders in relation to Health and Safety to any person taking part or who has any influence over the diving operation…

To launch a bell diving operation, depending on the surface support and its positioning, the following guidelines should be kept in mind:

- Diving operations from an unstable surface support are hazardous and must not be launched.
- The sea condition a closed bell can be launched should be risk assessed, taking into consideration the stability of the surface support used, the exposition of the dive station to the weather, and the procedure selected for the rescue of the diving bell.

The dive can be launched only if the supervisor is 100% sure that the bell and the means of rescue selected (divers or ROV) can be launched, and recovered safely. The dive should be stopped if it appears that the means for the rescue of the bell cannot be launched safely.

For example:

- If the means of rescue planned is surface supplied divers using baskets, the maximum sea condition on the Beaufort scale should be those applicable for the launching of the surface supplied diving operation (between force 4 and 5 with a maximum of 1.5 m wave height under the diving station), despite the fact that a closed bell can be launched in the roughest conditions.
- If the vessel is a powerful dynamic positioning equipped with 2 heave compensated bells coming down from the middle of the ship, and with a dive station enclosed inside the vessel, the maximum sea condition can be according to what the ensemble vessel - bell can withstand.

- The underwater current speed must be as indicated in point 5.8, and the conditions should be suitable for the means of rescue selected.
- The divers must also be trained to work and orientate in reduced underwater visibility, or better in the complete darkness in case of water with high turbidity.

Other precautions:

Some accidents not linked to diving, but to vessels caught in storms despite weather forecast alerts, have happened. Some of these accidents were the result of decisions of the onboard teams to follow instructions coming from their company offices onshore. That is why the points indicated below must be remembered by the people on board the vessel:

- Despite the huge progress resulting from modern means of observation and analysis, the weather forecast remains only prediction, and the situation on the site could be different (worse). It is the duty of the people on board to observe the evolution of the weather and take appropriate action regarding the safety of the people and the materials they are in charge of.
- It is the duty of the diving supervisors and diving superintendents to warn the people in charge, of the dangers their vessel may face if they consider that the safety of the vessel and the onboard personnel may be jeopardized.
- It is the duty of the vessel master to ensure that all the precautions are in place to be able to withstand safely the planned weather conditions and to leave an area without damage if the weather conditions get worse than initially planned. These precautions include the capacity to recover the anchors of the vessel safely.

6 - Communications

The Diving Supervisor must have reliable communications with everyone involved in the operation and needs access to all of the communications of the vessel or installation. Communications include all available systems, word of mouth, documentation, radio, telephone, fax , E mail, etc…

Video is also a type of communication system, letting people see what is happening. It has also been used to transmit hand signals or written messages when audio communication has failed.

The Diving Supervisor is directly responsible for communications with the diver. He must have voice communication and be able to monitor the diver's breathing pattern at all times. He must not hand over communication to any other person except another properly appointed and qualified Diving Supervisor.

When an ROV is in use, the Diving Supervisor has overall responsibility for the safety of the whole operation. Close communication with the ROV supervisor is vital. There should be a dedicated communications link and a repeat video monitor showing the same picture seen by the ROV pilot.

6.1 - Verbal communications

6.1.1 - Language

Most teams working in the offshore industry are multinational diving teams where English is the language for communications. Still, it may happen that some divers do not speak fluent English and that the language they use is their national language. In this case:

- The language used must be common to all the members of the team.
- The supervisor and some members of the team must also speak fluent English to communicate to other teams.
- The communications between the supervisor and the divers must be direct communications. The use of translators create the risk of messages being misinterpreted and should be banished.

6.1.2 - Voice communication through radio and on deck

Voice communication is used to pass clear, complete and accurate information in plain language.
Since English is the internationally accepted language, voice procedure and phonetic codes are based in English to communicate with external teams and inside the team when English is the common language. The following words and phrases are used in radio voice communication:

Word	*Translation*
Acknowledge	*I understand your message.*
Affirmative	*Yes, or you are clear to proceed.*
All stop	*Stop the action and wait for further instructions.*
Come up or down	*Lift or lower, on a winch or crane.*
Correction	*An alteration to the previous message.*
Easy	*Lift or lower slowly on a winch or crane. "Slowly" is also used*
Go ahead	*Proceed with your message.*
How do you read?	*How are you receiving me?*
I say again	*Repetition of a message.*
Negative	*No, or you are not clear to proceed*
Over	*Message ended and waiting for a reply*
Out	*Message ended and no reply expected*
Read back	*Repeat the message as received*
Repeat	*Similar to "say again" but usually used to emphasise a word or phrase*
Roger	*I have received all of your last transmission.*
Say again	*Repeat your message*
Say again from..	*Repeat your message from..*
Slowly	*Lift or lower slowly on a winch or crane. "Easy" is also used*
Speak slower	*Self explanatory*
Standby	*Wait for another message*
That is correct	*Self explanatory*
Verify	*Confirm the accuracy of your last message*
Wilco	*I have understood your message and will carry out the instructions.*

As indicated before, the national language may be used inside some teams, and in this case, the procedures used in English must be adapted.

- Written aide-memoire must be used.
- Voice communications have to be reduced to the minimum.
- Voice communication must be slow and clear.
- IMCA D 022 recommends not using ambiguous words like 'may', 'might', 'should', 'could' , or 'can', but use more directive words.
- Standard words and phrases to be used.
- The recipient of the messages must be able to repeat all instructions back.
- Let the other person know when you've finished speaking, usually by saying "over".
- There must be a procedure to deal with communications breakdown. Back up and alternative methods of communication must be in place before starting the job.

For spelling out words, it is preferable to use the phonetic alphabet. It is intended for unambiguous international use, as is the pronunciation of the numbers. If there is any difficulty in remembering the phonetic alphabet, other suitable words can be used.

Letter / number	Pronounce		Letter / number	Pronounce
A	Alpha		Q	Quebec
B	Bravo		R	Romeo
C	Charlie		S	Sierra
D	Delta		T	Tango
E	Echo		U	Uniform
F	Fox-trot		V	Victor
G	Gulf		W	Whisky
H	Hotel		X	X ray
I	India		Y	Yankee
J	Juliet		Z	Zulu
K	Kilo		0	Zero
L	Lima		1	Wun
M	Mike		2	Too
N	November		5	Fiver
O	Oscar		6	Sixter
P	Papa		7	Sev-en

6.1.3 - Voice Communication with the Diver

a) Communication during the working phases

- There must be two-way voice communication with the diver at all times. Voice communications are made more difficult by the noise of the diver's breathing and other noises such as water jetting, burning, hydraulic tools etc.
- Communications from the surface should, as far as possible, be fitted around these noises. It is time-wasting and tiring to try and talk over a loud noise.
- If there is an urgent need to talk to the diver, most underwater tools and equipment must be switched off at the surface to reduce noise, provided there is no hazard to the diver.
- Talking to the diver during lifts, lowers, or other operations where he may need to warn the surface urgently of any problems has to be avoided.
- The tasks must be planned so that they involve the minimum amount of voice communication.
- The names for the tools, equipment, locations, and procedures that will be involved must be agreed before starting the dive. Two or three syllable names are clearer than single syllable names.
- The messages must be short and simple. The diver may have to turn off his free flow or stop breathing to listen.
- The diver and supervisor must be aware of the time lag in the chain of communication. An instruction from the diver may take 30 seconds or more to reach the crane diver via the Diving Supervisor, and more time before the instruction is acted upon.
- All voice communications, starting with the pre-dive checks must be recorded. The recording must be kept until it is clear that there have been no problems during or following the dive. It is recommended that recordings are kept for at least 24 hours. If an incident or accident occurs, the tape must be kept in a safe place for the investigation.

- Rope and hand signals may be used routinely for tender to diver and diver to diver. Different signals may be used by divers trained in different countries so on a multinational crew signals must be standardised.

b) Communications when using heliox

Note that such communications are also described in the document "Description of a saturation system"

When breathing Heliox mixes, divers' speech are very high-pitched and hard to understand to people not used to it. The distortion is a result of two changes in environment:

1) The speed of sound, and thus the resonance frequencies change with the gas mixture. For example, at depths of 300 meters or more, the heliox mixture contains so much helium that the speed of sound in the mixture is about the same as the speed in pure helium, which is 2.9 times the speed in air.
2) The change of pressure adds a stiffness to the throat and mouth and gives the first resonance an additional upward shift. Notice that at high frequencies the pressure has no noticeable influence.

The total effect from these two changes in the environment is a strong non-linear compression of the resonance. The pitch (the fundamental frequency generated by the vocal cords), however, is kept almost constant.

To solve the problems of distortion due to the use of helium, means for processing of speech (unscrambling) should be available. These requirements should apply to verbal communication from diver's helmets, bells, chambers.

The models can be divided into two groups, depending on their processing algorithm:

- Time domain
- Frequency domain

During the 80's and 90's, most of the commercial unscramblers were based on "time domain", and some materials from this period are still in use. Materials only based on time domain algorithm are much dependent on speech quality: Helmet free flow noise, poor quality microphones and badly distorted voices (due to oral/nasal-mask shunting) are some of the problems that impair the function (the pitch detection) and speech restoration in this type of unscramble.

New models which are based on the association of the 2 principles, or only on full frequency domain solutions are now available on the market and have greatly improved communications.

The communication system for divers in both water and hyperbaric chambers should be tested for intelligibility under as realistic operational conditions as possible.

NORSOK standard U-100 edition 4 recommends a 'modified rhyme test' (MRT) to be used to verify that the operational communications systems are in accordance with the requirements for speech intelligibility in the table below:

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

c) Loss of communication

- In case of loss of voice communication, the surface should:
  - Contact the diver using line signals, or by flashing the diver's light, or if using a tool linked to surface, stopping the tool, or if it is on site, use the ROV lights.
  - The diver can reply by line signals or by hand signals to a video camera. He should return to the bell.
  - If contact cannot be established, or there is any doubt about the diver's condition, the standby diver should be sent in immediately.
- If the diver receives no answer to his/her voice message:

Signal	Tender to diver	Diver to tender
Succession of pulls	Stand-by diver on his way	Emergency! I need assistance
4 pulls	Go back to the bell	I am going back to the bell. Or: Pull me up
3 pulls	Go down	I am going down. Or: Give me some slack
2 pulls	Come up	Come up on my umbilical
1 pull	Stop	Stop

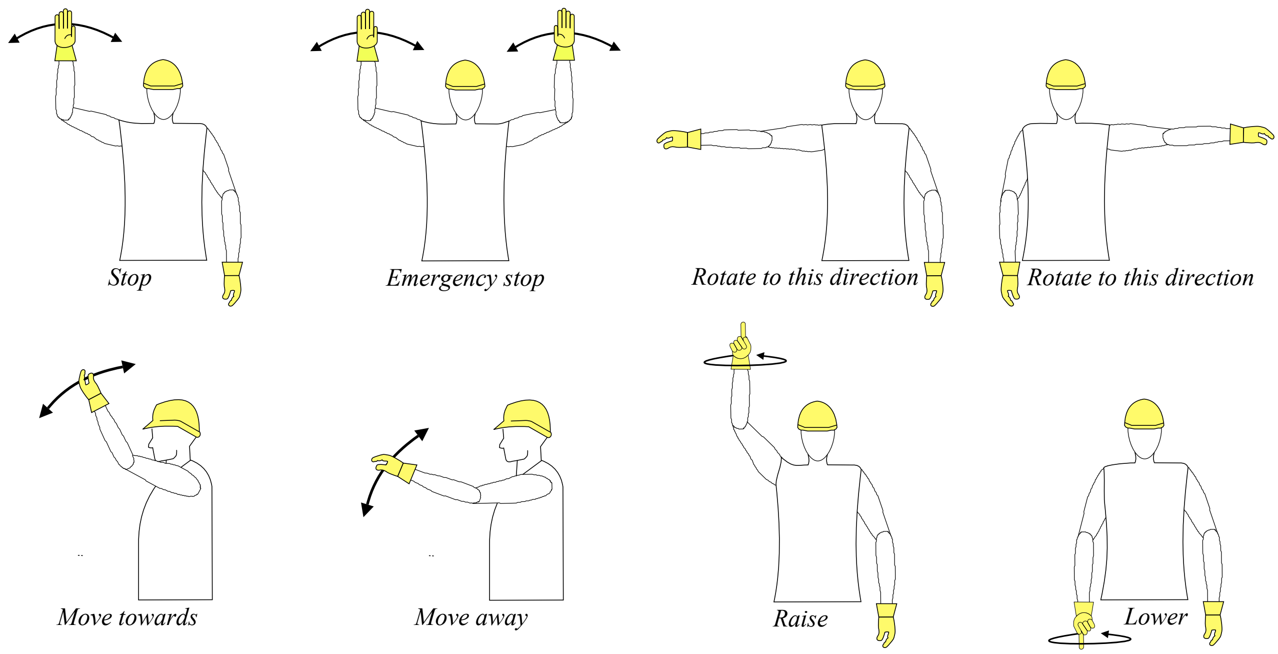
d) Loss of communication of the bell(tapping code):

In case of a lost bell, and the communications through the umbilical are impossible, through water communications should be deployed to restore the contact with the divers in the bell. If the though water communications are not working, the Tapping code IMO/IMCA/OGP should be used:

Tapping code	Situation
3.3	Communication opening procedure (inside and outside)
1	Yes or affirmative or agreed
3	No or negative or disagreed
2.2	Repeat please
2	Stop
5	Have you got a seal?
6	Stand by to be pulled up
1.2.1.2	Get ready for through water transfer (open your hatch)
2.3.2.3	You will NOT release your ballasts
4.4	Do release your ballast in 30 minutes from now
1.2.3	Do increase your pressure
3.3	Communication closing procedure (inside and outside)

6.2 - Hand signal communications

Hand signals are frequently used to control lifting operations using winches and cranes.
Under normal circumstances, the direction of the crane on deck is the responsibility of the banks-man/slinger, but on small units, it may be done by experienced divers.
The signals given below are those generally employed everywhere. Nevertheless, many other codes may be used by organizations that should be confirmed by the team involved before starting the operation. Also, note that since there are portable radios that can be integrated into the helmet of the banks-man, the crane operator must be directed using such devices. Thus, hand signal communications should be used only to confirm what is said by radio.



Regarding the responsibilities, IMCA SEL 019/ M 187 says the following:

- *The lift supervisor, who should be nominated by the competent person, is defined as the person who is charged with actively supervising the lifting operation on site. This could be a deck officer, diving superintendent, competent person, deck foreman, banksman/slinger, shift supervisor or similar.*
- *Supervision should be proportionate to the exposure to risk created by the lifting operation and the experience and capabilities of the personnel involved in individual lifting operations.*

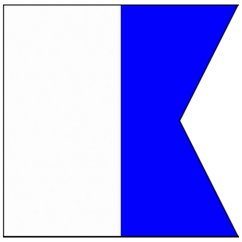
6.3 - Flag and lights communications

Flags are used in maritime communication to indicate a status, a need or an intention of action. These flags correspond to the letter of alphabet. Each flag has a meaning and can be used also in combination to compose a message.

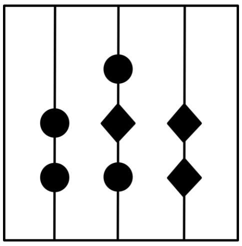
Meanings of flags used individually		
Alpha: *Diver in the water*	Juliet (1): *Fire on board*	Quebec: *My vessel is healthy and I request to enter in port.*
Bravo: *I have a dangerous cargo*	Juliet (2): *Leaking dangerous cargo*	Romeo: —
Charlie: *affirmative*	Kilo: *I wish to communicate*	Sierra: *I am operating astern propulsion*
Delta: *Keep clear of me*	Lima (at sea): *Stop your vessel (order)*	Tango: *Keep clear of me*
Echo: I alter my course to Starboard	Lima (in harbor): *Ship quarantined*	Uniform: *You are running into danger*
Foxtrot: *I am disabled - contact me*	Mike: *I am stopped*	Victor: *I require assistance*
Golf: *Pilot asked*	November: *Negative*	X-ray: *Stop you intention*
Hotel*: Pilot on board*	Oscar: *Man overboard*	Yankee: *I am dragging anchor*
India*: I alter my course to port*	Papa: *Vessel ready to sail*	Zulu: *I require a tug*

Flags and lights used during diving operations:

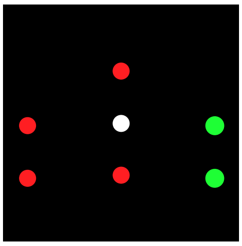
The flag that must be on the mast of the boat to indicate diving operation is the alpha flag. Before starting the diving activities, the team must ensure that the Alpha flag is installed and visible from any direction. This flag will have to be removed after the diving operations.



In addition to the Alpha flag the working signals for a vessel undertaking underwater operations during daylight, which is Ball - Diamond - Ball, must be displayed . The 2 balls indicate the obstructed side, diamonds indicate clear side.



During the night the vessel must indicate the diving operations using light signals. The main signal is Red - White - Red . The red lights indicate the obstructed side, green lights indicate clear side.



6.4 - Audible alarms

Particular elements such as Dynamic Positioning system light status are fitted with audible alarms associated to a light colour (yellow or red). The bridge also uses audible alarms to inform the teams of onboard emergencies, and these codes must be remembered by the divers (particularly the young divers) during the tool box talks:

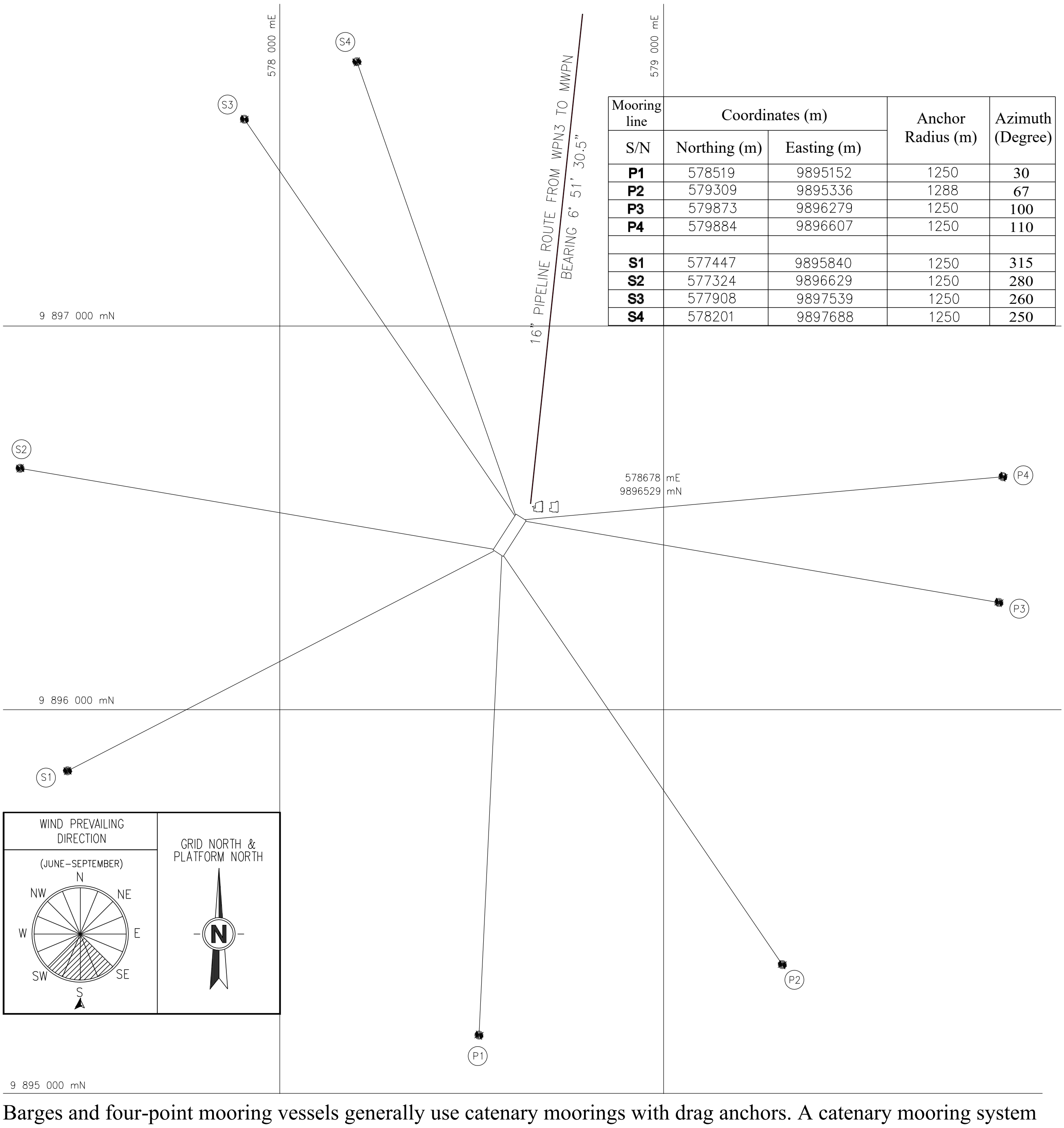
- General Alarm
  The general alarm on the ship is recognised by 7 short rings of the bell followed by a long ring or 7 short blasts on the ship's horn followed by one long blast. The general alarm is sounded to make the crew on board aware that an emergency has occurred.
- Fire Alarm
  A fire alarm is sounded as continuous ringing of the ship's electrical bell or continuous sounding of the ship's horn.
- Man Overboard Alarm
  When a man falls overboard, the ship internal alarm bell sounds 3 long rings and ship whistle will blow 3 long blasts to notify the crew onboard, and the other ships in the vicinity.
- Abandon Ship Alarm
  When the emergency situation onboard ship gets out of hand and the ship is no longer safe for crew on board the ship, the master of the ship can give a verbal Abandon ship order, but this alarm is never given in ship's bell or whistle. The general alarm is sounded and every body comes to the emergency muster station where the master or his substitute (chief Officer) gives a verbal order to abandon ship.

7 - Working from barges or moored vessels

A lot of diving projects are organized from barges and four-point mooring vessels. Barges are often used for installation projects necessitating powerful cranes and 4 points mooring vessels are commonly used for small projects. Nevertheless, the procedures for diving from these surface supports are similar.

7.1 - Mooring plan

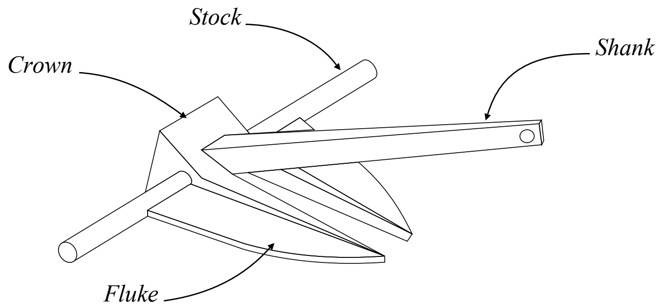
Mooring is not permitted in an oilfield without a mooring plan accepted by the client.
This plan indicates the pre-established position of the anchors, the mooring lines, the dangerous areas, and obstructions. An analysis of this mooring plan should be performed by specialists to predict the tension of the lines and the force applied to the anchors resulting from the environmental conditions on-site and other actions. It should indicate the maximum conditions the mooring can withstand considering the type of anchor used, the soil conditions, and the winches pull limits. This analysis should also take into account that manual adjustments of the lines are often performed for operational reasons or foreseeable environmental events. The method planned for dropping and retrieving the anchors should also be taken into consideration.



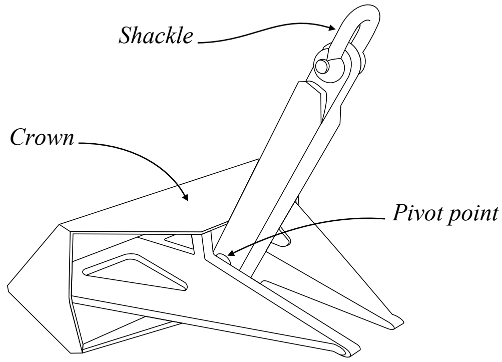
Mooring line	Coordinates (m)		Anchor Radius (m)	Azimuth (Degree)
S/N	Northing (m)	Easting (m)		
P1	578519	9895152	1250	30
P2	579309	9895336	1288	67
P3	579873	9896279	1250	100
P4	579884	9896607	1250	110
S1	577447	9895840	1250	315
S2	577324	9896629	1250	280
S3	577908	9897539	1250	260
S4	578201	9897688	1250	250

Barges and four-point mooring vessels generally use catenary moorings with drag anchors. A catenary mooring system consists of a line merely deployed from the ship to the bottom of the sea. The name "catenary" comes from the curve of the chain or cable due to its weight when supported between two points (for example, electrical lines between 2 posts). It is the most common mooring system in shallow waters.

Drag anchor holding capacity is calculated in the function of several factors, such as the anchor type and its behavior during deployment. Regarding this point, a lot of factors are considered, such as the opening of the flukes and their penetration in the seabed, the planned depth of burial of the anchor and its expected stability during dragging, the anticipated soil behavior over the anchor shape, and others. There are a lot of models of anchors that can be selected. Among the proposed solution, two models, the "Danforth* LWT" ("lightweight") and the "flipper delta", that are designed with the head pivoting at the extremity of the shank, are commonly employed on four-point mooring ships and barges *(* Danforth is a brand)*.

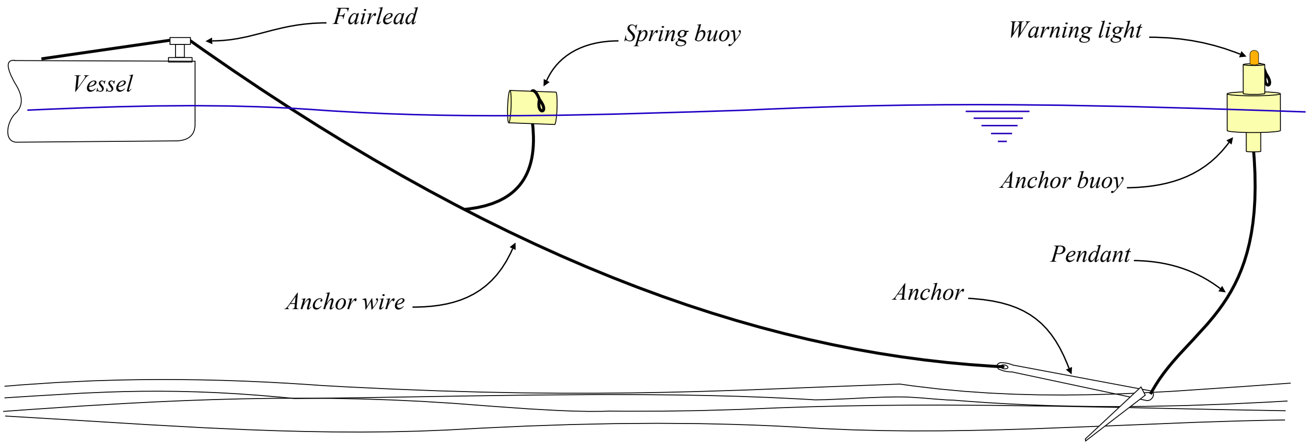


Danforth anchor



Flipper delta anchor

Anchor are connected through wire ropes (anchor wires) which are adjusted by the anchor winches of the barge or the support vessel. A line is attached to the crown (bottom end) of each anchor and connected to buoys to facilitate the recovery of the anchors. Some intermediate buoys (spring buoys) can be fitted on the line. The combination of one anchor, the attaching anchor wires, a crown line and an anchor buoy represents one “anchor leg”.



Regarding the elements listed above, note the following points:

- The mooring wire ropes should be certified by a recognized competent body, and be terminated by a resin or zinc-poured socket at the end of each rope section. Note that these cables do not have a fibre core.
- Spring buoys are usually designed to remain at the surface. They should have a maximum of 67 % of submergence and be compartmented to minimize the risk of sinking in the event of damage. In case that units are planned to be used under the surface of the water, they should be designed in accordance with a recognized standard for use at the maximum operational depth identified by the mooring analysis.
- The minimum clearances between the vessel or its mooring components and the oilfield installations may change from one client to another one. However, they must be in accordance with national regulations.
- Linked to above, a long drag distance may be required for an anchor to reach full penetration and develop the ultimate holding capacity. EN ISO 19901-7 says that if the drag path of an anchor to a floating structure is expected to bring it within close proximity to another installation, the final anchor position should be such as to allow a margin of at least 300 m of drag before contact can occur with the installation. Otherwise, the final anchor position should be at least 100 m from the installation.
- EN ISO 19901-7 also says that when a mooring line within the elevated part of its catenary crosses a pipeline on the seafloor, a minimum vertical clearance of 10 m under the intact condition should be maintained. A mooring line may pass over and be in contact with a protected pipeline provided this contact is not interrupted throughout the full range of predicted intact line tensions, in other words, the contact does not occur in the thrash zone. Note that when pipelines and other service lines such as power cables are planned to be in contact with mooring lines, they are usually protected using a mattress or protection frames commonly called “sleepers”.
- The ship crew must be able to know the tension in the lines and the lengths paid out. For this reason, the vessel should be equipped with a calibrated system for measuring the tension and the length of cable paid out of each mooring line. That should be displayed at least on or near each winch. Note that these displays are generally provided on the bridge. Also, a heading device (gyrocompass) is mandatory.
- The anchors are deployed and recovered by one or several Anchor Handling Tug Supply Vessels (AHTS).

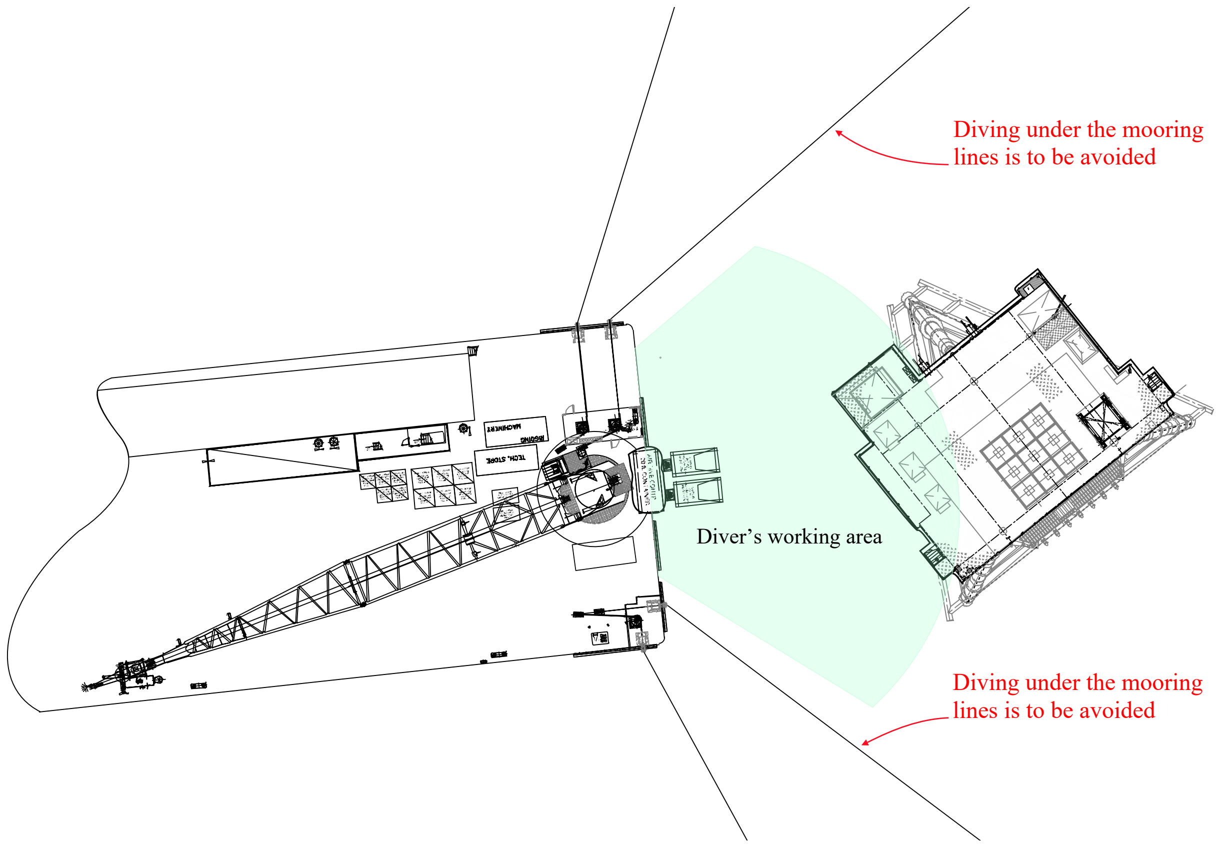
Diving projects generally consist of installation or repair jobs that do not require to change too much the position of the surface support. For this reason, one or two mooring plans are usually sufficient to perform the project. However, barges carrying out pipeline or cable laying use their anchor winches to move forward, which obliges to continuously reposition the anchors according to the progression of the barge. In this case, mooring plans for each phase of the project have to be provided.
The anchoring of a moored vessel is the responsibility of the vessel master, the surveyors, and the Offshore Construction Manager. This phase is normally closely monitored by the client.

7.2 - Diving from a four-point mooring vessel or a barge in a static position

7.2.1 - Preparation

Diving from a barge or a four-point mooring is usually not as complicated as from dynamic positioning vessels, because they are stable surface supports that are static. However, some safety rules have to be implemented:

- There must be a main and back up means of communications between the dive control, the bridge, and the other parts of the vessel.
- The mooring must be completed before starting the dives, and the mooring lines must have been inspected, particularly in areas where wear is likely, such as the fairleads.
- The mooring lines must be secured, and their tension must conform to what is planned in the mooring plan.
- The position of the anchors and the anchor lines must be displayed in the dive control.
- To minimise the transfers underwater, the vessel must be as close as reasonably practicable to the work site. IMCA D 022, section 10.3 indicates that the following factors should be considered:
    - The distance of the job from the proposed bell/basket location.
    - The maximum duration of the divers' bailout systems at the planned depth: In case of loss of gas supply, the diver in trouble must be able to return to the bell/basket using his bailout system, which dictates the maximum distance he can be from the bell/basket.
    - The characteristics of the umbilical: An extended length of negatively buoyant umbilical tends to drag a diver down, while a bulky umbilical may pull him in the current
    - The condition of the worksite, including debris, rocks, or other obstructions which could impede the diver's return to the bell/basket in an emergency.
    - The unforeseen safety factors needed for particular situations such as loss of diver heating or trapped umbilicals.
- The mooring lines must not be above the job site to avoid injuries to the diver or trap him in case of a rupture.
- The water intakes near the dive station must be stopped or reduced (this must be included in the risk assessment)
- The position of the dive station must be assessed.



7.2.2 - Specific procedures to be in place during the dives

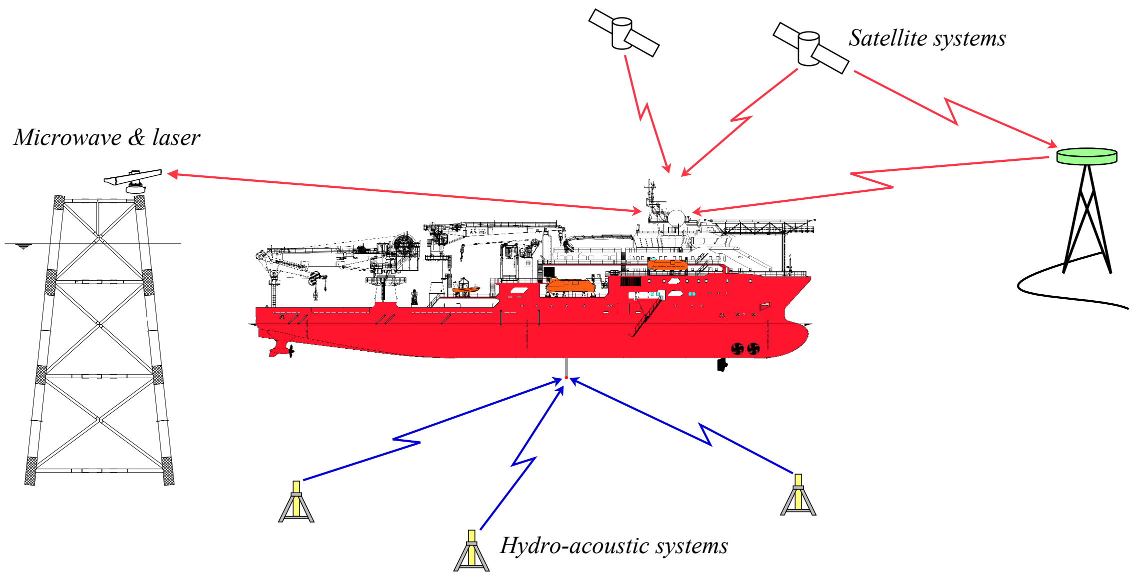
Diving from a barge often implies that simultaneous operations of teams preparing other phases of the project are ongoing. For this reason, the transfer of the diving team to and from the dive station must be secured as well as the dive station itself. Also, it often happens that barge crews are not familiar with diving projects.
For these reasons, it is crucial to ensure that the standard diving rules, indicated in this handbook, are understood by the barge crew and that relevant precautions are in place.
Also, specific procedures linked to the management of the mooring, and the fact that the surface support is static and cannot be quickly moved must be in place:

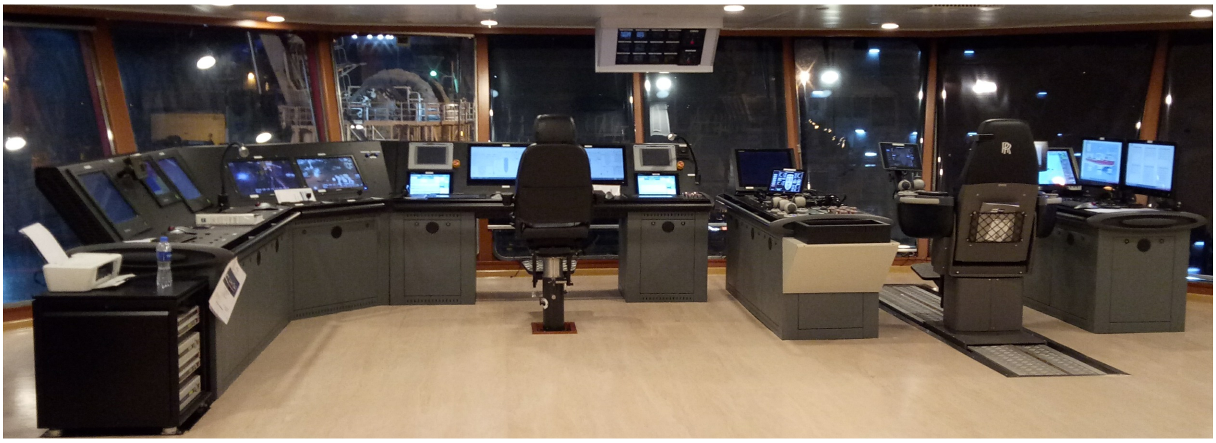
- The tension and wear of the mooring lines must be monitored at regular intervals, and any change regarding the status of the anchor legs must be indicated to the diving supervisor.
- As with every diving vessel, the weather conditions, and boats cruising at the proximity of the ship or the mooring lines must be indicated to the diving supervisor. Note that the diving supervisor has the authority to accept or reject vessels approaching the diving support vessel.
- If the vessel needs to be adjusted, the diving supervisor (and the divers) must be informed. Also, the movement must be safely executed:
    - The move is done slowly and step by step.
    - The divers' umbilicals are clear from any debris and obstruction.
    - The divers understand the move, and they are in a safe location that is not to be under a line.
    - The divers can easily return to the bell/basket.
    - The move can be stopped at any time.

8 - Diving from Dynamic Positioning (DP) vessels

8.1 - Purpose

Dynamic Positioning vessels are ships that automatically maintain their position and heading by using their propellers and thrusters through a computer-controlled machinery and position reference systems that are combined with environmental sensors and controlled from a specific station installed in the bridge of the vessel. Thus, these vessels do not require the usage of anchors to maintain their position and are ideal for various offshore operations, particularly those where dropping anchors would be complicated or impossible. Also, these ships provide excellent maneuverability compared with anchored ones and can quickly jump from one operation on a job site to another one in another place.
Dynamic Positioning systems are today used for all types of offshore activities. Except for very small passenger boats used for the transfer of personnel, we can say that ships operating offshore are equipped with this technology.
Note that the positioning reference used can be based on technologies using satellites, microwaves (radar), laser, and hydro-acoustic, that are described in the next point





Dynamic positioning control station UDS Picasso

8.2 - Basic design of a DP vessel

8.2.1 - Technical references

Dynamic positioning and propulsion systems are interdependent and are closely linked to the progress of the computing and electronic industries. So, they are among the elements of the ship that evolve the most quickly, and it is not rare that these systems are upgraded to new standards several times during the life of the vessel.
Four organizations, that are described in point 1.2 of this book, are known for providing guidelines and rules regarding the design and the use of dynamic positioning vessels:

- The International Maritime Organization (IMO);
- the International Marine Contractor Association (IMCA);
- the Diving Positioning Committee (DP Committee).
- The Association of Diving Contractors International (ADCI)

In addition to these organizations, manufacturers of propulsion and dynamic positioning systems publish guidelines to explain how their products should be ideally exploited. Also, the International Organization for Standardization (ISO) has published the document ISO 19901-7 *"Specific requirements for offshore structures - Part 7: Station keeping systems for floating offshore structures and mobile offshore units"*. However, this document does not speak of diving.

8.2.1.1 - IMO - Maritime Safety Committee circular 1580

The circular 1580 has been approved in June 2017 by the Maritime Safety Committee of the International Maritime Organization. This circular applies to all vessels built after the 9th of June 2017. It replaces the guidelines of the circular 645 published in 1994, that remains in force for ships constructed before the 9th of June 2017, except that the guidelines of section 4 "Operational requirements" of Circular 1580 apply to all vessels.
The purpose of these guidelines is to recommend the design criteria, equipment, operating provisions and testing as well as a documentation regime for dynamic positioning systems in order to reduce the risk to the personnel, the vessel, other vessels or structures, sub-sea installations and the environment, while performing operations under dynamic positioning Control. Note that it is the responsibility of the states where the boats are flagged to ensure that these guidelines are implemented.

8.2.1.2 - IMCA guidelines and incident reports

The procedures from this organization are based on those emitted by IMO to which complementary safety procedures and guidelines are added. The following documents exist that may be completed by new publications.

DP incident reports are indicated in the "Station keeping incidents" that are published every year.

8.2.1.3 - Dynamic positioning committee guidelines

The guidelines from this organization are also based on those emitted by IMO to which high level safety and technical procedures and studies are added. The organization also promotes some IMCA guidelines.

8.2.1.4 - ADCI guidelines

The Association of Diving Contractors International (ADCI) also provides some guidelines regarding diving from Dynamically Positioned vessels in point 8.3 of the publication "International consensus standards for commercial diving and underwater operations".

8.2.2 - Class of vessel

There are 3 classes indicating the capability of a vessel to maintain a position in the event of the failure of a component or an undesirable event such as a fire, a flooded compartment, and others:

- Class 1: Loss of position may occur in the event of a single fault.
- Class 2: Loss of position and heading should not occur from a single fault of an active component such as a generator or thrusters. It may occur after failure of a static component such as a cable, a pipe or manual valve.
- Class 3: Loss of position and heading should not occur for any single failure, including a complete burnt fire subdivision or flooded watertight compartment.

Regarding the selection of class for operations, the Dynamic Positioning Committee (DP Committee) lists the following minimum requirements. Note that requirements from some clients have been added in the remarks.

Operations	*Minimum class*	*Remarks*
Diving	2	Some clients may require class 3 for some operations
ROV in open water	1	Some clients may require class 2 for some operations
ROV at the proximity of an installation	2	Usually required inside the 500m limit
Drilling	2	
Pipe laying	2	
Lifting	2	Some clients may require class 3 for some operations
Floating production	2	
Accommodation	2	
Seismic and survey outside the 500 m zone	–	Class to be in accordance with the contractual requirements
Well stimulation	2	Vessels of lesser Class may be used with the appropriate structured risk identification and mitigation measures in place.
Logistics	2	

Comments regarding the selection of class for diving operations:

- The class does not refer to the power of the vessel. This point must be taken into account when selecting the surface support: Events have been reported where ships have lost their position during diving operations due to lack of power, particularly when the current was pushing them sideward.
- Vessels class 1 must not be used for diving operations.
- DP diving support vessels must be at least class 2.
- The class of vessel required must be decided during the preparation of the project, and must be risk assessed. Some clients may request a DP 3 vessel for the following operations:
    - Diving in an enclosed space such as inside a jacket, a Pipe Line End Manifold (PLEM), or any structure where there is a risk of having the diver endangered in case of a loss of position.
    - Diving in an Anchor pattern

8.2.3 - Power systems

IMO says that "power system" means all components and systems necessary to energise the DP system. This system includes but is not limited to: Prime movers with necessary auxiliary systems (including piping, fuel, cooling, pre-lubrication and lubrication, hydraulic, pre-heating, and pneumatic systems); Generators; Switchboards; Distribution systems (cabling and cable routing); Power supplies, including uninterruptible power supplies (UPS); and Power management system(s) (as appropriate).

8.2.3.1 - Propulsion and power supply systems commonly used

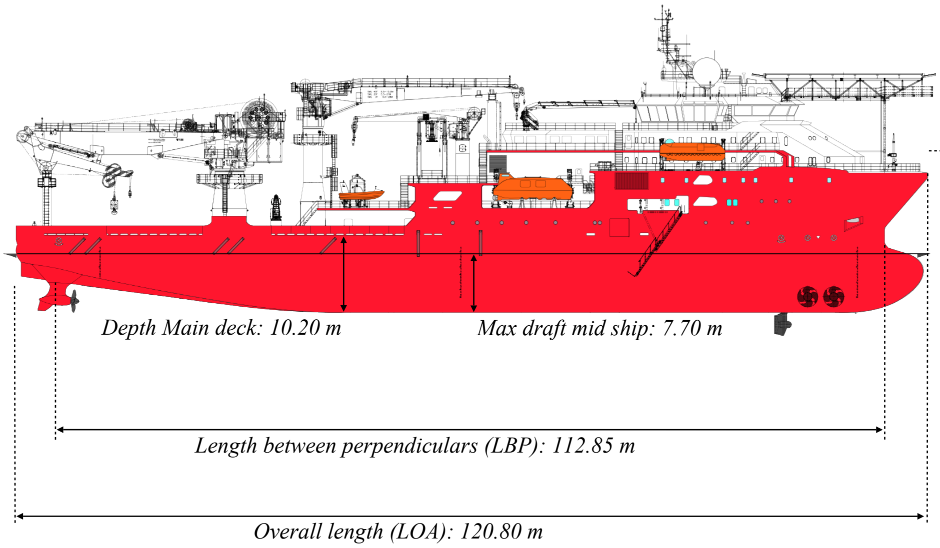
Recent dynamic positioning vessels use a diesel-electric propulsion, which means that they are powered by generators that energize the electric motors of the thrusters used for sailing, maneuvering, and keep the vessel in position when it is under dynamic positioning mode. These generators are also used to provide sufficient main and backup electrical supplies to the diving and ROV systems and to the other systems of the vessel.

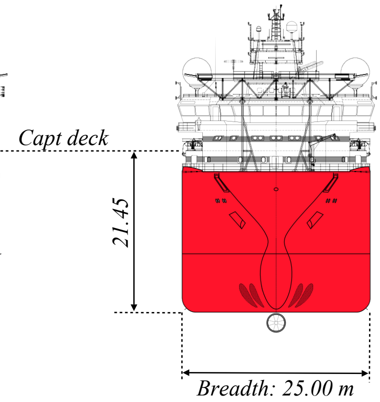
Diesel-electric propulsion is not a new concept. As an example, "Emile Allard", a signalization buoys installer vessel built in Le Havre (France) in 1933 by Augustin Normand shipyard and sunk near Brest by the RAF the 14th of April 1943, was already propelled by two electric motors 447 kW powered by two diesel generators. The reason for this conception was that electrical motors were found more responsive and soft than thermal engines for the operations the boat was planned for. Also, diesel-electric propulsion has been used by German type XXI U-Boats that were built at the end of the second war and was the most modern submarines built during this period. Some of the advantages of this concept can be summarized as follows:

- A better control of fuel consumption and emissions due to the possibility to optimise the power delivered by the diesel engines according to the needs.
- As the vessel is powered by several powerful diesel generators, there is sufficient power delivered to continue to operate the vessel safely in the case of the failure of one of them.
- Improved manoeuvrability and station-keeping ability due to the increased availability and flexibility of the electrical motors. Note that an electric motor can provide its maximum torque at low speed while a thermal engine needs to rotate within a range below which the torque delivered is insufficient.
- The generators do not need to be adjacent and aligned with the shaft transmitting their motion to the propeller as the energy is transmitted to the electric motors of the thrusters by electrical cables. Also, electric motors take less space than thermal engines and they can be mounted in any position
- As there are less mechanical parts in movement, diesel-electric propulsion emits fewer vibrations and is more silent.

As an example of a recent unit using this system, Ultra Deep Solutions "Lichtenstein" is a DP 2 Diving Support Vessel (DSV) that has been designed by Marin Teknikk in Norway and built by China Merchant Industry Holdings Ltd.

This vessel that has a deadweight of 7000 tonnes and a gross tonnage of 11115 tonnes for an overall length of 120.8 m is equipped with a twin bell saturation system designed for 18 divers *(NOTE: For the understanding of this diving system, refer to the document "Description of a saturation system")* and is designed for various tasks even those that require particular equipment such electrical cable installation, J-lay pipeline installation, or others.
For this reason, she is also equipped with an Active Heave Compensation (AHC) offshore crane that is designed to lift 140 ton at 12 m, a second subsea crane which can lift 40 ton at 35 m, and a third subsea crane 10 ton at 12.5 m that is installed on the mezzanine/ROV deck. Active and passive ship stabilization systems are provided.
These pieces of equipment and the propulsion systems of this ship are all energized by electricity.

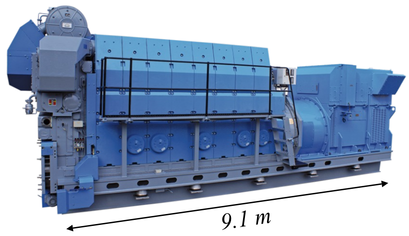


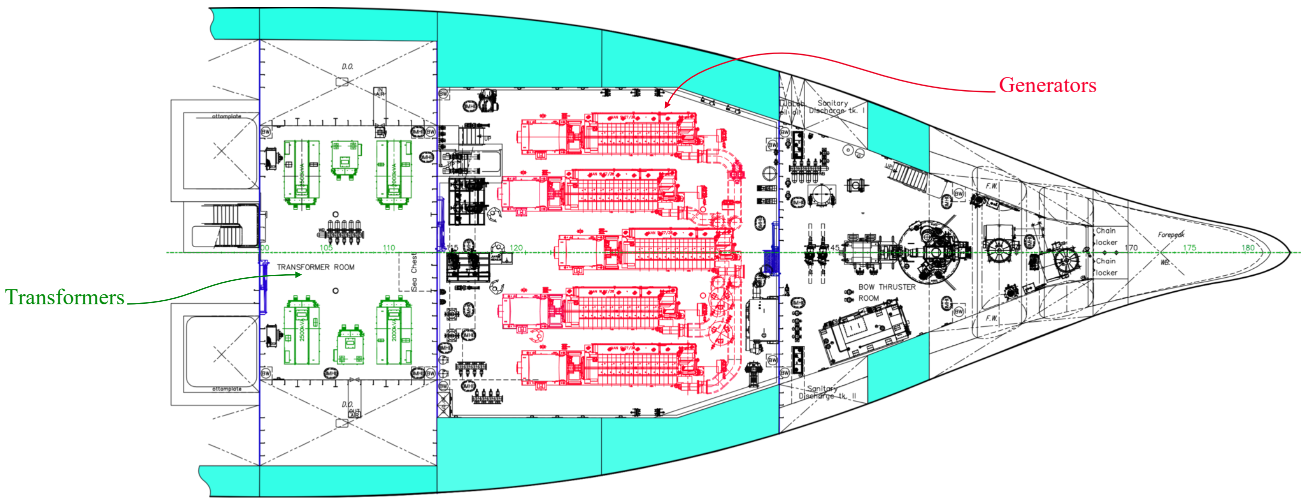


Dead-weight: 7000 tonnes
Gross Tonnage (GT): 11115 tonnes
Net Tonnage (NT): 3335 tonnes

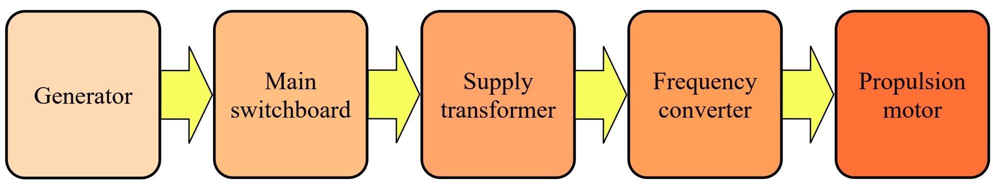
This electricity is produced by five diesel powered generators that are manufactured by Weichai Heavy Machinery co. Ltd. They are installed in a room situated in the lower parts and near the bow of the vessel.

- Each unit delivers 3168 KVA (2534.4 kw) at 720 r/min.
- The current delivered is 690 volts/60 hz. The electrical part (dynamo) model 1DB1036-8AY05-Z is designed by Siemens and assembled in China.
- The diesel engine is a Weichai-Man type 9L9738 that delivers 2970 kw (3983 hp) at 720 r/min. This engine is an in line four stoke 9 cylinders 21.8 litres/each.





The classical scheme of a diesel-electric propulsion is as follows:



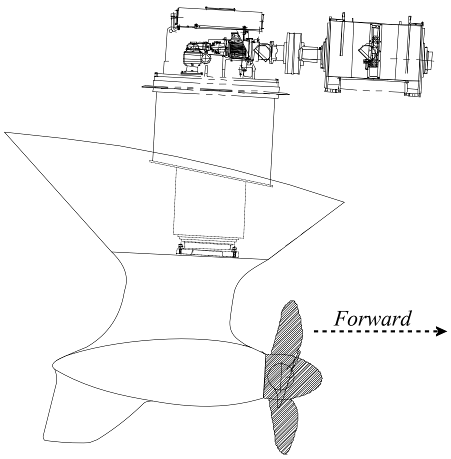
Definitions:

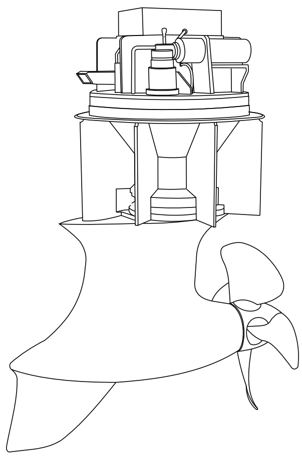
- *An electric switchboard is a device that directs electricity from one or more sources of supply to several smaller regions of usage. It is an assembly of one or more panels, each of which contains switches that allow electricity to be redirected.*

- *A transformer is a device used to change the voltage of an alternating current in one circuit to a different voltage in a second circuit. Transformers consist of a frame-like iron core that has a wire wound around each end. As a current enters the transformer through one of the coils, the magnetic field it produces causes the other coil to pick up the current. If there are more turns on the second coil than on the first coil, the outgoing current will have a higher voltage than the incoming current. This is called a step-up transformer. If there are fewer turns on the second coil than on the first, the outgoing current will have a lower voltage. This is called a step-down transformer. On Lichtenstein, some of the transformers are situated in the adjacent room and some others next to the thrusters.*
- *A frequency converter is a device that converts alternating current (AC) of one frequency to alternating currents of other frequencies. As the speed of an AC motor is dependent on the frequency of the AC power supply changing this frequency allows changing the motor speed. As a result, the rotational speed of the propeller can be adjusted using this means instead of using a gearbox, which allows saving energy.*

Lichtenstein is propelled, manoeuvred, and maintained into position by azimuth and tunnel thrusters. Azimuth thrusters tend to replace the classical fixed propellers driven by shafts to which diesel engines or electric motors are connected through specific gearboxes.

- Two stern azimuth thrusters Royce Rolls Azipul types developing 3500 kW *(4694 hp)* with a torque of *278*54 Nm each are used to propel the vessel and maintain it in position while in dynamic positioning mode. The electric motor is energised by a current of 675 volts / 60.4 Hz.
  Opposite with classical azimuth thrusters, the propeller of the Azipull thruster is pulling instead of pushing, so the propeller works in the front of the mechanism as with most airplanes using propellers.
  The advantage of this system is that it combines the benefits of traditional propellers and classical azimuth thrusters. Thus, it offers a high manoeuvrability with the possibility to rotate 360º that is combined with low drag. Also, the pitch of the blades can be controlled, which gives the possibility to oriented them to move ahead or astern without changing the orientation of the thruster.
  this system avoids the installation of tunnel thrusters at the stern of the vessel as it is the case with classical propellers. Note that the four blades propeller is motioned by a mechanical drive system using bevel gears at the top and bottom of the leg. Power is fed to the unit through a horizontal input shaft within the hull, and the unit incorporates its steering motors for azimuthing. As every thruster used with the dynamic positioning system, each thruster is electronically controlled.

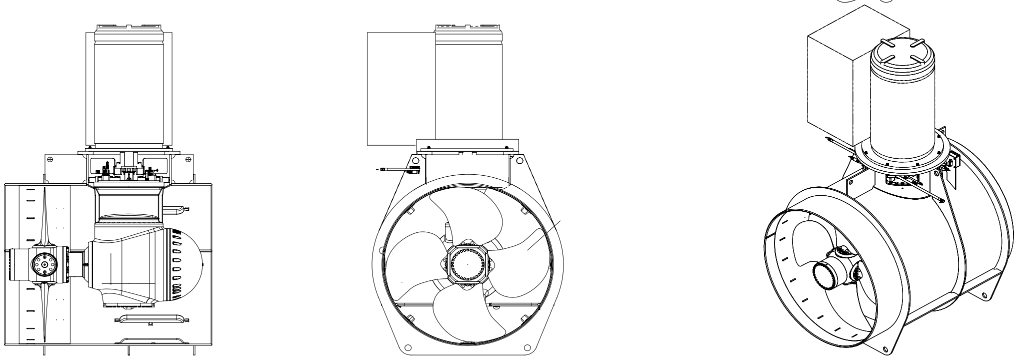




Topside parts of Azipull: Starboard side.

Topside parts of Azipull: portside.

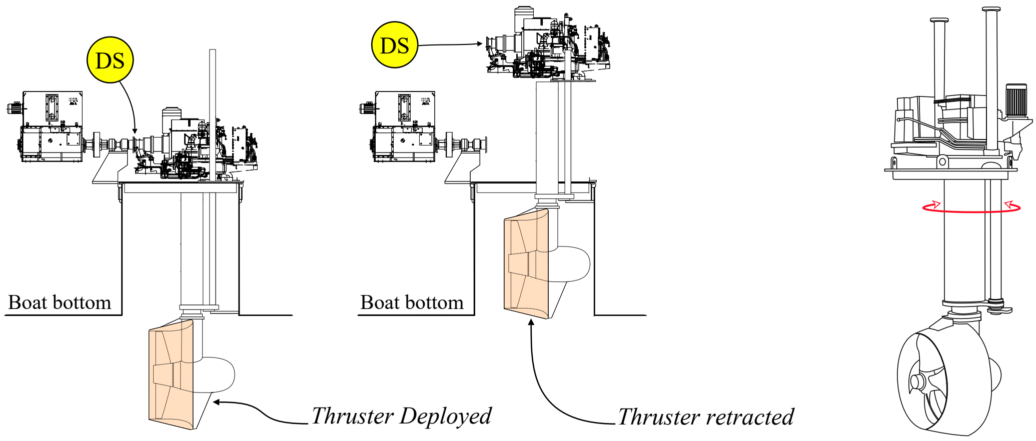
- Two bow tunnel thrusters Rolls-Royce TT2650 DPN CP, delivering 1910 kW (2588 hp) with a torque of 20479 Nm each, are installed to give a side force when maneuvering the ship or maintaining it in position while under dynamic positioning control. Their four blade propellers of 2.65 m diameter are equipped with a controllable pitch which allows to fully orientate them to push the vessel from one side to the other without changing the direction of the rotation of the motor. As with the thrusters at the stern, the motion is transmitted to the propeller by the means of gears.



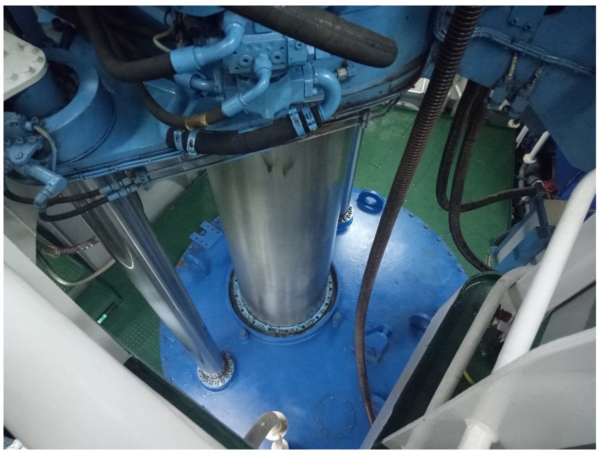

Upper parts of the tunnel thrusters of UDS Lichtenstein


Tunnel thrusters of UDS Van Gogh

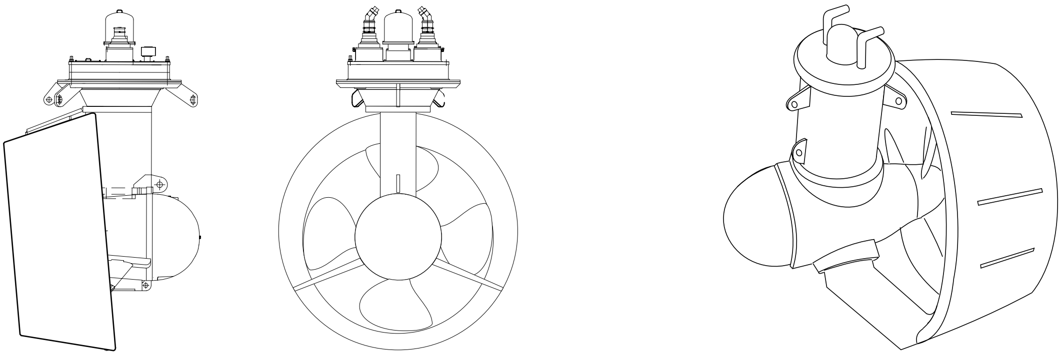
- To complete the force of the two tunnel thrusters, one azimuth retractable thruster 1500 kW *(2011 hp)* is installed at the bow. This azimuth thruster, which is manufactured by Rolls-Royce, can rotate 360º and gives more control and flexibility to manoeuvre the vessel and maintain it in position when operating in dynamic positioning mode. Note that this thruster is equipped with a four blades fixed pitch propeller of 2.3 m diameter. The advantage of a retractable thruster is that it improves the hydrodynamics of the ship during the transits and also protects the thruster that is lifted in its casing when it is not in use. The thruster is deployed using hydraulic jacks. The internal mechanism is similar to the models described above. However, to protect the mechanism and avoid uncontrolled manoeuvres, the drive shaft (DS) is automatically disconnected when the thruster is lifted up.



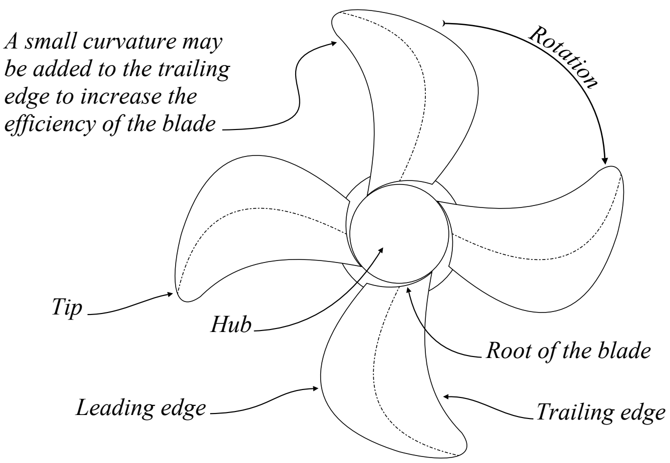
Thruster retracted: Upper parts

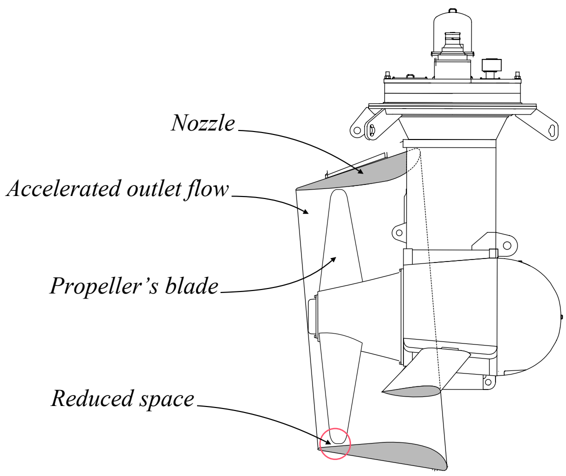

Thruster retracted: downward view from the upper parts

- Note that propulsion thrusters with nozzle are commonly installed in place of Azipull on a lot of ships. It is the case of UDS "Van Gogh" in the photo below. With this system, the propeller is surrounded by a nozzle that canalises the water flow to and from the propeller.

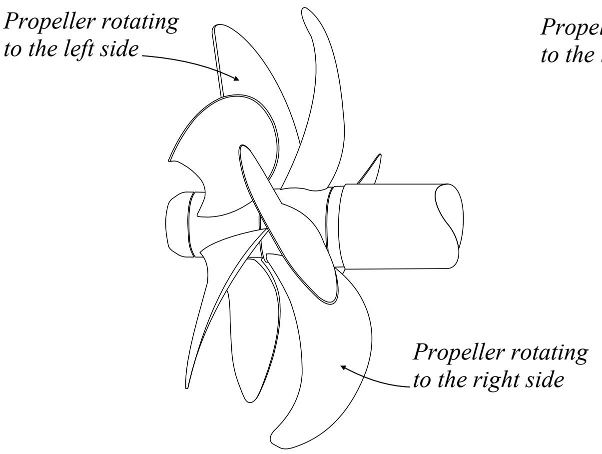


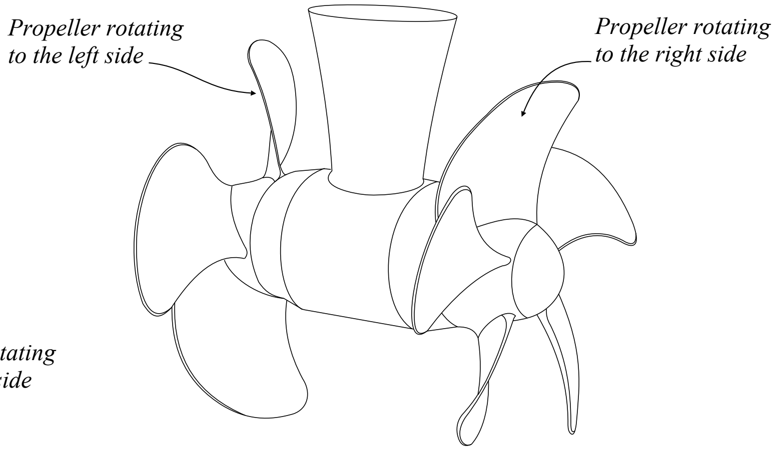
Several types of propellers can be used:
The propeller acts in the water similarly as a screw in a solid material, so it transforms the rotational movement of the engine or the electric motor into rectilinear motion.
The propellers have evolved since the first models, and the manufacturers continue to enhance their efficiency. One of the problems to solve is the loss of energy at the tips of the blades, which can be corrected by elaborate shapes. Another system to fix this problem is the installation of a nozzle around the propeller with a limited gap with the extremities of the blades to reduce the vortices and the effects of cavitation at their tips. Another advantage of the nozzle is that it increases the velocity of the water flow, and so allows for a more efficient thrust than a standard propeller. However, the nozzle creates additional friction to the water, which increases with speed. For this reason, specialists say that propellers fitted with a nozzle are ideal for providing high pulling power, but are not suited for high-speed ships.



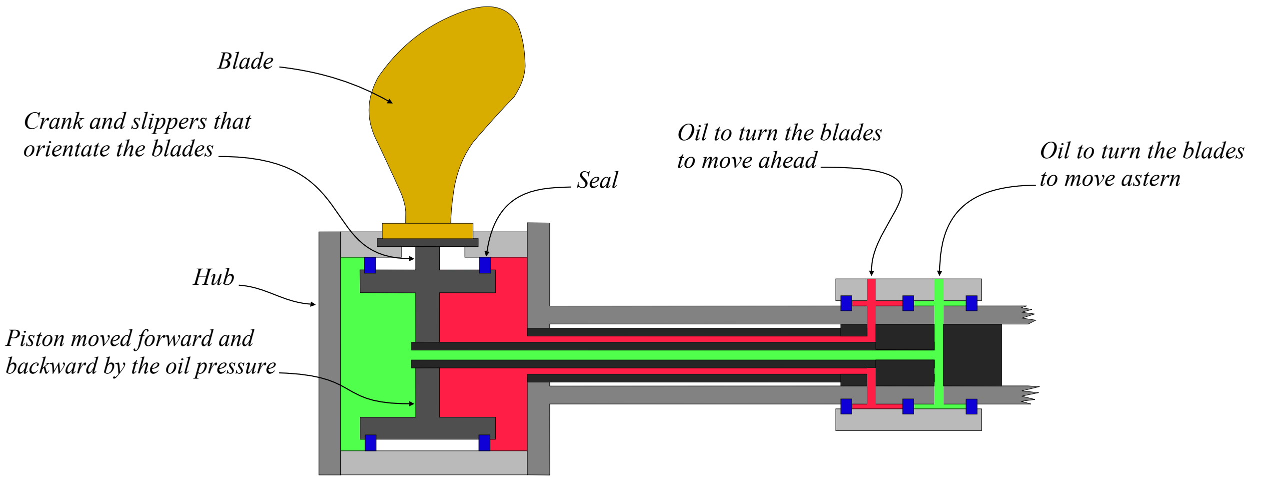


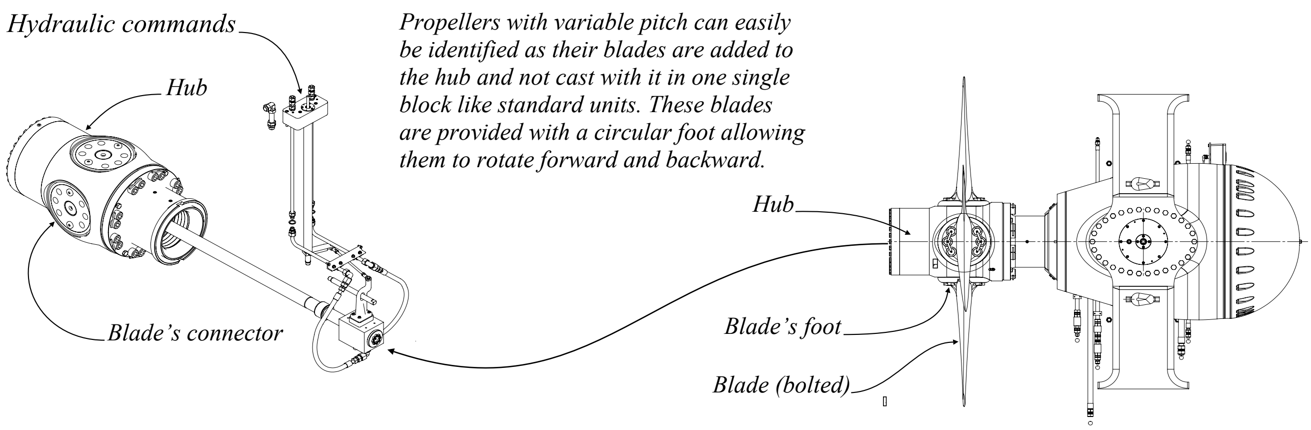
Note that it is said that the propulsive efficiency can also be increased by installing propellers with large diameters. However, the size of the propeller is limited by the draught of the vessel, and propellers of large diameters generate more constraints. For this reason, an alternative design that can be used is to increase the number of blades of the propeller.
Contra-rotating propellers is another solution proposed by the manufacturers for increasing the efficiency of the propulsion. This system consists of two propellers situated one behind the other and rotating in opposite directions. It provides the advantage of recovering a part of the slipstream energy of the 1st propeller, which would otherwise be lost with a conventional single-screw system. Furthermore, because of the two propeller configuration, contra-rotating propellers possess a capability for balancing the torque reaction from the propulsion. Militaries have used this system for a very long time for this reason and because it allows for high speeds.





In complement of the designs indicated above, propellers can be equipped with a variable pitch controlling system. It is the case of the thrusters of UDS Lichtenstein that are described in the previous page.
With classical fixed pitch propellers, the blades cannot be orientated, and its propulsive forces are limited to only one ideal configuration, which leads to power wastage and increased stresses when the propeller is used outside the limits of this configuration. These stresses and loss of power can be prevented by changing the pitch of the propeller, so the propeller can be adapted to sail at an elevated speed, perform works that require high thrust, or be oriented to move backward without changing the direction of rotation of the propeller. Thus, this system avoids constraints on the gears and the electric motor or the diesel engine. Another advantage of this system is that because the propeller can be optimised for the working conditions, vibrations and noise are minimized.
The blades are usually oriented hydraulically by a piston that moves forward and backward. Also, an electronic system allows controlling the mechanism that can be operated from the engine room and the bridge. Note that in case the control system fails, the blades can be locked in the ahead position with the help of a locking device.





Acoustic reference systems are used for positioning control systems on the majority of DP vessels. For this reason, the Dynamic Positioning Committee says that the prevention of any acoustic interference between the reference systems and the noises generated by the propulsion devices is mandatory. Three different sources of noises are reported:

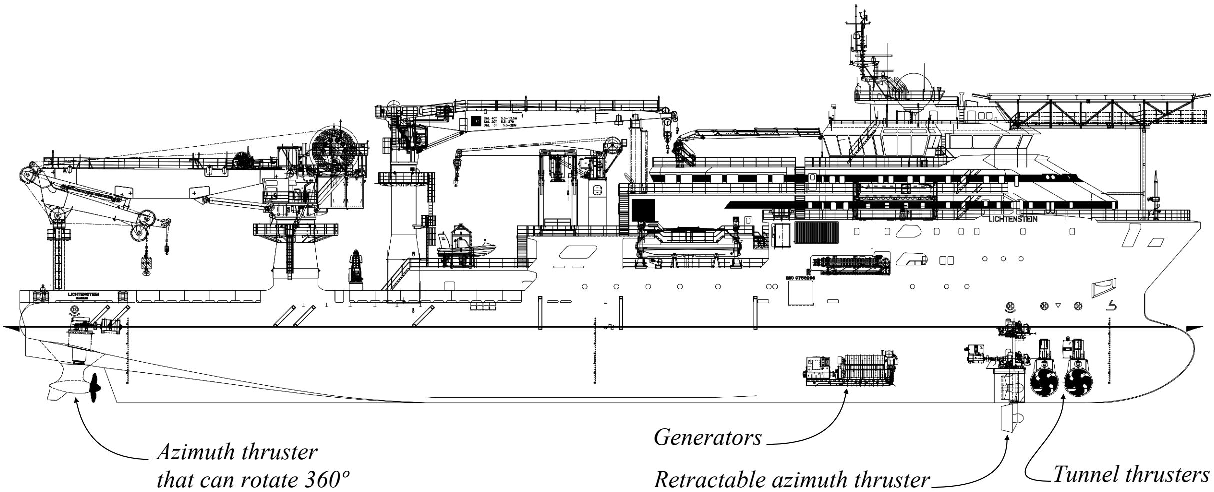
1. Cavitation results from the modification of the flow along with the propeller blades. It occurs when the pressure in certain places in the flow field decreases below the vapour pressure of the fluid. That leads to a reduction of the efficiency of the propeller, triggers the formation of tiny bubbles that implode and can damage the propeller's blades, and the emission of noises. These problems can be minimized by:
    - Installing the propeller as deeply as possible to increase the static pressure acting upon the propeller;
    - providing hydrodynamic shapes to the hull and elements situated inflow to the propeller;
    - avoid install propellers with oblique inflow angles;
    - Optimising the profile of the blades, and/or install a nozzle around the propeller (indicated before);
    - Cleaning and polishing the surfaces of the propeller and the elements situated at its inflow.
2. The singing of the propeller is a critical vibration phenomenon of the blades, which results in a high-pitched noise similar to the one made by a crystal glass. These harmonics are the result of many factors, such as the diameter, the thickness, and the profiles of the edges of the propeller's blades. This problem is usually solved by an anti-singing edge, which is a chamfer that is made on the suction side of the propeller, near the trailing edge of the blades, that cleanly separates the flow running off and so avoid the creation of the curving flow eddies at the origin of such parasite vibrations.
3. Noise created by the propeller jet: The Dynamic Positioning Committee says that thruster propellers installed under the bottom of the hull are commonly associated with this problem that is the result of accelerated water masses leaving the propeller/nozzle with a high velocity shed along the bottom of the hull. These noises may interfere with the acoustic positioning system, and can be magnified if the hydrophones are located in or near the passage of the jet. The interference may be reduced by the strategic placement of the hydrophones outside of the jet path or a deflection of the jet at a downward angle away from the hull. Installing guide vanes in the nozzle exit or tilting the propeller axis to a certain extent can deflect the jet.

The presentation of the propulsion systems of existing vessels in the previous pages shows that a lot of solutions exist that can be used for ships but that their selection to obtain an ideal dynamic positioning diving support vessel is not easy and usually result in a compromise. Regarding this point, the Dynamic Positioning Committee says the following in the document “Principle aspects of Thruster selection”:

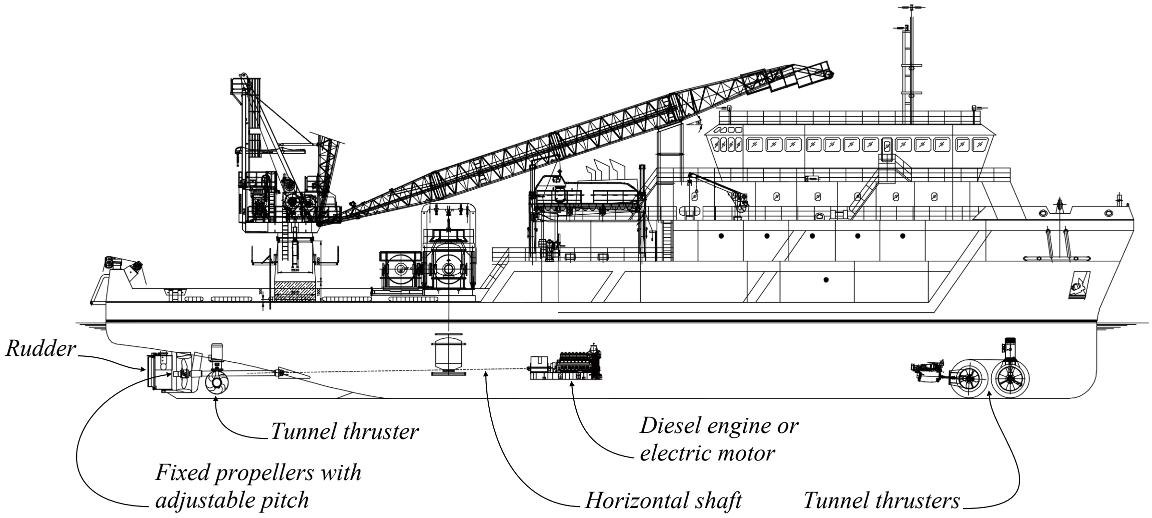
- A propulsion system applied for dynamic positioning of vessels must be able to generate counter forces against environmental forces such as wind, current, and waves, as well as forces resulting from the drag of a deployed array, pipes, risers, etc. during station-keeping operations. Environmental forces are omni-directional; therefore, propulsion systems or devices must have the ability to generate thrust in the full 360 degrees. In order to move the vessel from location to location, the propulsion system installed on DP vessels needs to generate the conventional propulsion forces in the longitudinal direction of the vessel.
- A DP vessel, is designed to operate in and survive extreme environmental conditions, although statistically these conditions occur very rarely.
- During station-keeping at very low inflow velocities, the propellers’ torque characteristic is very different from the characteristic at transit speed. It is very difficult for many propeller/drive machinery combinations to match their characteristics for these two modes.
- The thrust generated by the propulsion devices must be continuous and controllable in step-less increments over the entire operating range, from zero to maximum power in both directions of operation.

To summarize what is developed previously, two main types of configuration can be found with Diving Support Vessels:

- Vessels with azimuth thrusters for the main propulsion, and tunnel thrusters for the lateral propulsion of the bow, plus a retractable azimuth thruster installed near the bow to increase the manoeuvrability of the ship. The propulsive trusters can rotate 360º, and can be of Azipul type, or equipped with a nozzle, or provided with contra-rotating propellers. Such configurations are the most efficient, and those that are commonly found with last generation Diving Support Vessels (DSV) and many kinds of modern ships, including large boats.



- Vessels propelled by two fixed propellers with adjustable pitch, connected to electric motors or diesel engines by classical horizontal shafts, and equipped with tunnel thrusters at the bow and the stern of the boat for the lateral propulsion. A retractable thruster can also be provided as an option. The main propellers can be equipped with nozzles, or be of contra-rotating types. Such configuration is encountered with some Diving Support Vessels (DSV) of the previous generation, and a lot of multipurpose ships that can be used as temporary surface supports for portable diving systems.
  Regarding the motorization, the Dynamic Positioning Committee says that although typical diesel-driven propulsion arrangement is employed with the majority of commercial vessels, it is the less desirable for dynamic positioning applications for the following reasons:
  - The Rotations Per Minute (RPM) of the engine cannot be controlled below a certain minimum (the engine idling RPM is approximately 40% to 50% of rated RPM).
  - Increased engine maintenance problems occur when operating a Diesel engine continuously at lower power levels (lower than 50% to 60% of rated power for many engines).
  - The Diesel engine is able to match the torque characteristic of the propeller only at the design point, so, at full rated power.



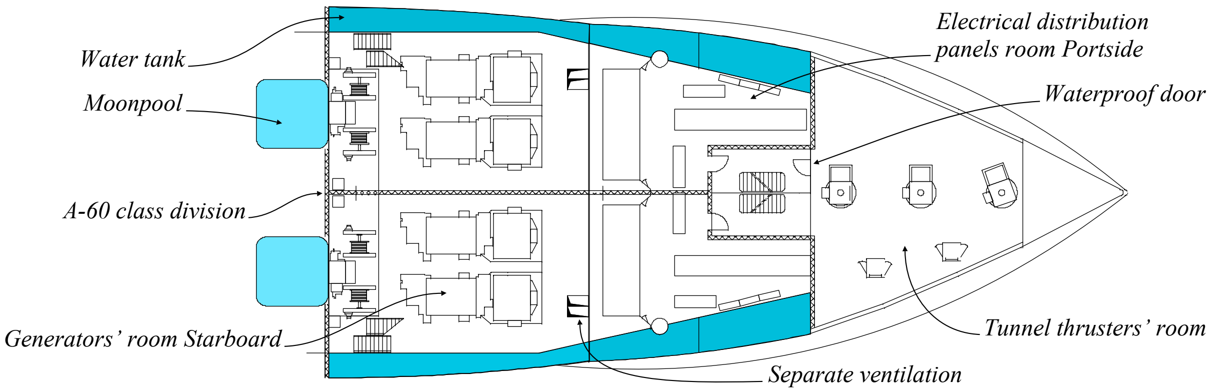
8.2.3.2 - Requirements from the International Maritime Organization (IMO) regarding power and thruster systems

The requirements from IMO Maritime Safety Committee Circular 1580 are international standards that are valid everywhere in the world and on which the standards of other organizations are built.

Regarding the power systems of vessels that can be used for diving, so class 2 and 3, it is said the following:

- For equipment class 2, the power system should be divisible into two or more systems so that, in the event of failure of one sub-system, at least one other system will remain in operation and provide sufficient power for station keeping.
  The power system(s) may be run as one system during operation, but should be arranged by bus-tie breaker(s) to separate the systems automatically upon failures which could be transferred from one system to another, including, but not limited to, overloading and short circuits.
- For equipment class 3, the power system should be divisible into two or more systems so that, in the event of failure of one system, at least one other system will remain in operation and provide sufficient power for station keeping. The divided power system should be located in different spaces separated by "A-60 class divisions".
  An "A-60 Class Division" means a bulkhead or part of a deck which is:
  - Constructed of steel or other equivalent material and suitably stiffened;
  - constructed as to be capable of preventing the passage of smoke and flame for 60 minutes, and insulated with suitable non-combustible materials, so that the average temperature on the unexposed side of the division does not increase more than 139°C above the initial temperature within 60 minutes.

  If the power systems are located below the operational waterline, the separation should also be watertight.



- The power available for position keeping should be sufficient to maintain the vessel in position after worst-case failure. Also, at least one automatic power management system (PMS) should be provided and should have redundancy according to the equipment class and a blackout prevention function.
  Alternative energy storage (batteries and fly-wheels) may be used as sources of power to thrusters as long as all relevant redundancy, independency and separation requirements for the relevant notation are complied with.
- Sudden load changes resulting from single faults or equipment failures should not create a blackout.

Regarding the thruster systems of vessels class 2 and 3, it is said the following:

- Each thruster on a DP system should be capable of being remote-controlled individually, independently of the DP control system.
- The thruster system should provide adequate thrust in longitudinal and lateral directions, and provide yawing moment for heading control. The thruster system should be connected to the power system in such a way that it is operational even after failure of one of the constituent power systems and the thrusters connected to that system.
- The values of thruster force should be corrected for interference between thrusters and other effects which would reduce the effective force.
- Failure of a thruster system including pitch, azimuth, and/or speed control, should not cause an increase in thrust magnitude or change in the thrust direction.
- Individual thruster emergency stop systems should be arranged in the DP control station and should have loop monitoring. For equipment class 3, the effects of fire and flooding should be considered.
  Note: *A loop monitoring system operates hardware components and software control functions to monitor and regulate the devices, instrumentation, and machines in use in the vessel.*

8.2.4 - Position reference systems and sensors

8.2.4.1 - International Maritime Organization rules regarding the selection of reference systems and sensors

IMO Safety Committee Circular 1580 says that Position reference systems should be selected with due consideration to operational requirements, both with regard to restrictions caused by the manner of deployment and expected performance in working situations.

- The following requirements are mandatory regarding the position reference systems of diving support vessels:

- At least three independent references should be installed and simultaneously available. Also, they should not all be of the same type, but based on different principles and suitable for the operating conditions.
- The position reference systems should produce data with adequate accuracy and repeatability for the intended DP operation. They should be monitored, and warnings should be provided when the signals from the position reference systems are either incorrect or substantially degraded.
- For equipment class 3, at least one of the position reference systems should be connected directly to a backup control system and separated by an A-60 class division from the other position reference systems. Note that this backup control system is described in the next point.

- The following requirements are mandatory regarding the sensors of diving support vessels:

- Vessel sensors should at least measure vessel heading, vessel motions and wind speed and direction.
- When an equipment control system is fully dependent on correct signals from vessel sensors, these signals should be based on three systems serving the same purpose. So, 3 wind sensors, 3 heading reference sensors, and 3 motion reference sensors.
- Sensors for the same purpose which are connected to redundant systems should be arranged independently so that failure of one will not affect the others.
- For equipment class 3, one of each type of sensor should be connected directly to the backup DP control system, and should be separated by an A-60 class division from the other sensors. If the data from these sensors is passed to the main DP control system for their use, this system should be arranged so that a failure in the main DP control system cannot affect the integrity of the signals to the backup DP control system.

8.2.4.2 - Reference systems

8.2.4.2.1 - <u>*Global Navigation Satellite System (GNSS):*</u>

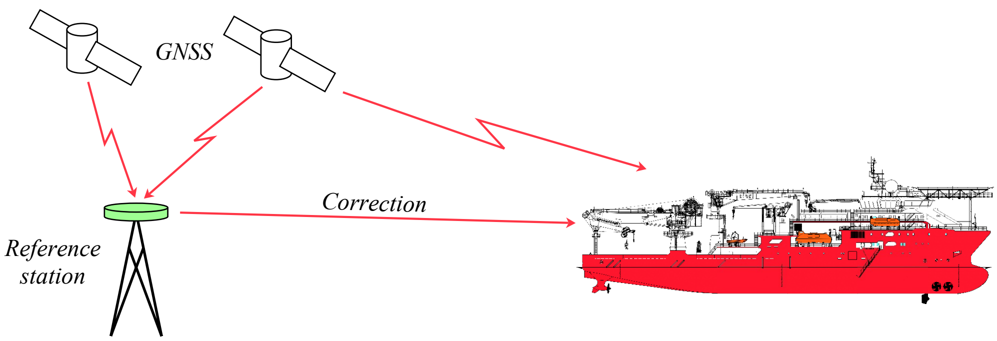
Global Navigation Satellite Systems have existed for many years and use cross-references from satellites to position vessels. The 1st system in use was the United States of America "Global Positioning System" (GPS), which is today based on 24 satellites, that can be complemented by onshore station references and is called Differential Global Positioning System (DGPS) in this case. Note that the primary usage of this system was for military purposes.
For several years other countries have developed alternative systems that are now available and can be used by these types of reference systems in replacements or the complement of the American GPS:

- GLONASS (Globalnaya Navigationnaya Sputnikovaya Sistema) is a Russian system that is an inheritance from the military system developed by the Soviet Union and uses 24 satellites.
- GALILEO system is developed by the European Space Agency for the European Union and associated states. The system that is not fully deployed will consist of 30 satellites, and is planned to be among the most accurate systems. Also, it can combine the data from its satellites with those of other networks.

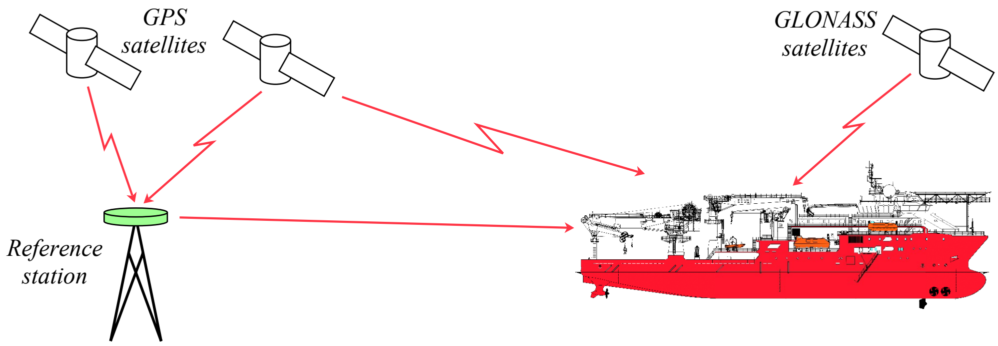
- BEIDOU (Běidǒu Wèixīng Dǎoháng Xìtǒng) is a Chinese satellite navigation system already active in Asia-Pacific that is planned to provide a global coverage by the end of 2020 and to be fully deployed end 2035 (5 geostationary, 27 in medium Earth orbit and 3 in Inclined Geosynchronous Orbit).
- QUASI-ZENITH SATELLITE SYSTEM is a four-satellite regional time transfer system and a satellite-based augmentation system development by the Japanese government to enhance the United States-operated Global Positioning System (GPS) in the Asia-Oceania regions, with a focus on Japan.
- IRNSS (Indian Regional Navigation Satellite System) is an independent regional navigation satellite system being developed by India. It is designed to provide accurate position information service to users in India as well as the region extending up to 1500 km from its boundary, which is its primary service area. An Extended Service Area lies between primary service area and area enclosed by the rectangle from Latitude 30 deg South to 50 deg North, Longitude 30 deg East to 130 deg East. IRNSS will provide two types of services, namely, Standard Positioning Service (SPS) which is provided to all the users and Restricted Service (RS), which is an encrypted service provided only to authorised users. The IRNSS System is expected to provide a position accuracy of better than 20 m in the primary service area.

Several modes of operations are applicable with Global Navigation Satellite Systems:

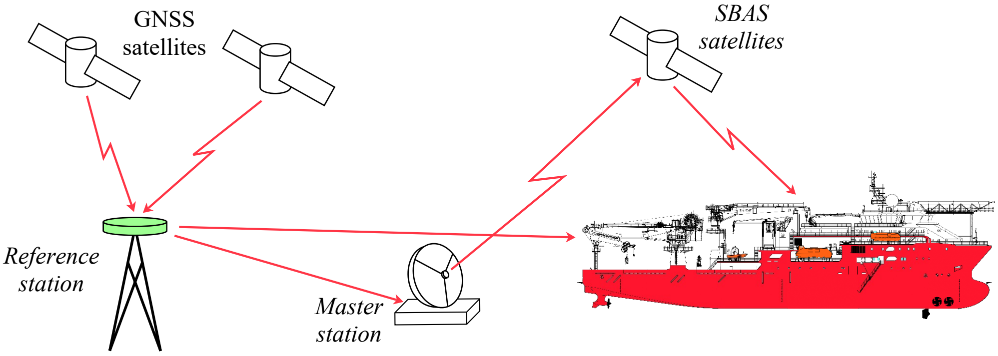
- “Differential GNSS”:
  Such devices are based on the system already developed for American DGPS, that uses a network of fixed shore based reference stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions. Using this system the improvement of the accuracy is from 15 -10 metres nominal GNSS accuracy to about 50 cm. This system is one of the most used, However some problems of accuracy can be encountered due to the following reasons:
  - GNSS and Differential signal interference due to satellite communications, and localized radio transmissions from civilian or military sources.
  - Physical obstructions blocking GNSS and differential signals, an example would be a DP vessel working alongside a platform that relocates to another face of the platform, and in the process loses all signals due to the platform obstructing the signals.



- Global Navigation Satellite System (GNSS) combined with Inertial navigation system (INS):
  Global Navigation Satellite System (GNSS) provides an acceptable accuracy when at least four satellites are connected to it. When the connection to one or several satellites is blocked by obstructions such as a platform or a floating facility, the positioning of the vessel is not sufficiently accurate to be used safely. A solution to avoid the problem is to combine the data from the Global Navigation Satellite System with those from an inertial navigation system.
  An “Inertial Navigation System” consists of accelerometers and gyros, that compose the “Inertial Measurement Unit” (IMU), which provides acceleration and angular velocity measurements that are used by a computer to calculate the position of the vessel according to a known starting point. Note that the Inertial Measurement Unit (IMU) is sometimes called the Inertial Reference Unit (IRU). When it is associated with it, the Global Navigation Satellite System is used to reset the starting point of the IMU periodically.
- Differential Global Navigation Satellite System (DGNSS) using the data of two different satellite networks:
  As an example, the Kongsberg DPS 232 is a Global Navigation Satellite System (GNSS) based position reference system using the American GPS with the Russian GLONASS to have more satellites available to fix positions more quickly and accurately, especially in areas where the view to some satellites is obscured by facilities. Note that GLONASS is also more suitable for use in high latitudes (especially North).

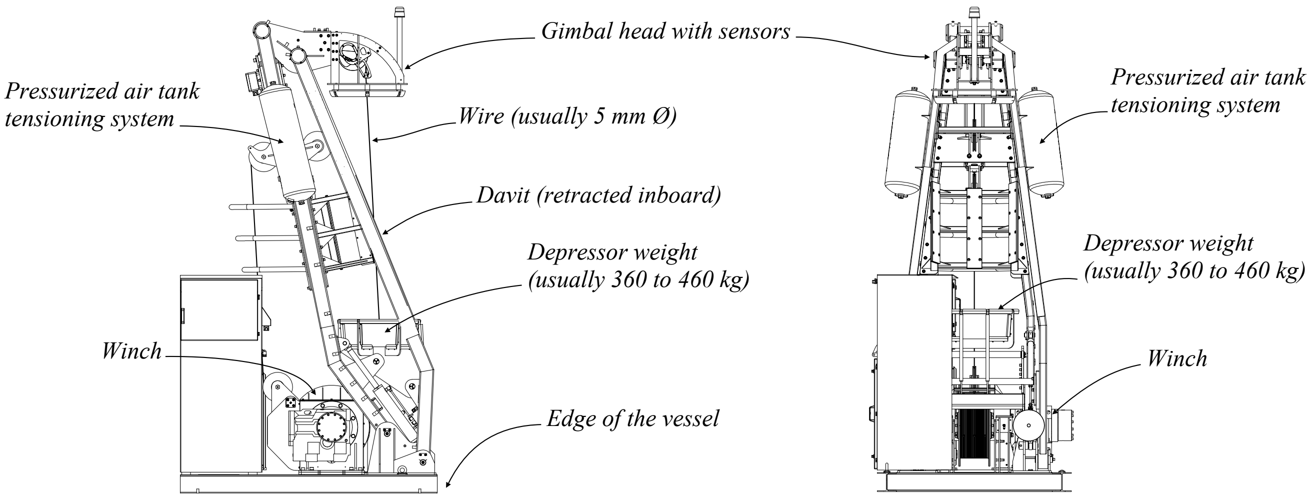


- SBAS (Satellite-Based Augmentation Service) system with a dual channel IALA (International Association of Lighthouse Authorities) beacon receiver:
  As an example of such a system, the Kongsberg DPS 132 uses GPS (Global Positioning System) with SBAS and IALA systems.
    - The "International Association of Lighthouse Authorities" (IALA) is an intergovernmental organization that collects and provides nautical expertise and recommendations that are used to install on-shore reference stations that are used to provide adequate correction to the variations in positions given by basic Global Navigation Satellite System (GNSS) signals.
    - Satellite Based Augmentation Systems (SBAS) are Geosynchronous satellite systems that provide services for improving the accuracy, integrity and availability of basic Global Navigation Satellite System (GNSS) signals.

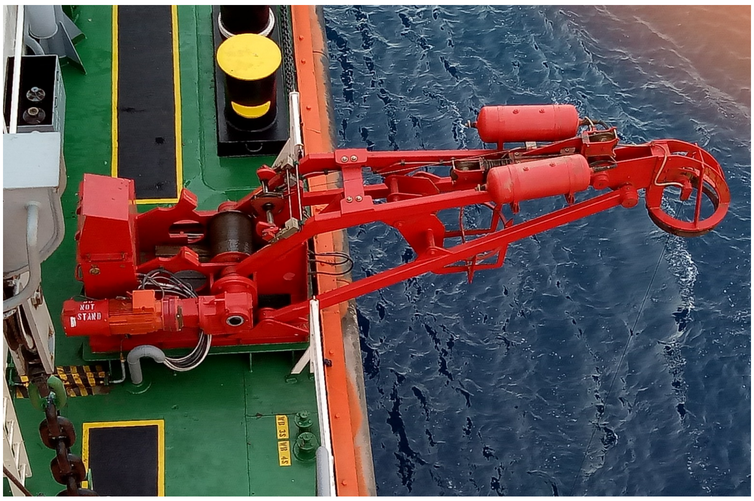


8.2.4.2.2 - *Taut wire:*

A taut wire is a vertical system consisting of a cable attached to a load deployed to the bottom using a davit or an A-frame. The wire is held in constant tension to remove vessel motion from the system through a powered winch. This winch may be pneumatically, hydraulically, or electrically actuated.
The angle of the cable is analyzed by sensors such as inclinometers, with calculation reference is the vertical, or by a potentiometer which calculation is made with respect to the davit. The position of the weight is calculated using these angles and the length of cable deployed (horizontal distance = distance of the sensors from the bottom of the sea multiplied by the tangent of the angle). When the angle of the cable is outside the set limits, an appropriate response is implemented to return it to its initial value.



Taut wire retracted (not working)



Taut wire deployed (at work)

The Diving positioning committee says that when the angles are calculated with respect to the davit, then they need to be compensated for roll and pitch so that on some vessels, all the position reference systems can be reliant on the measurements of the vertical reference units.

Taut wire systems are often used with diving support systems for the following reasons:

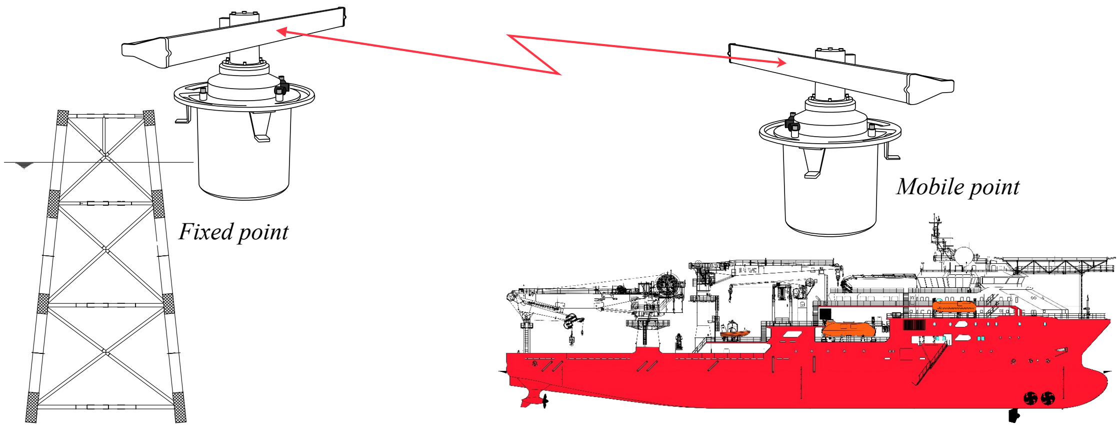
- The system is reliable and in use in the industry for decades.
- They are reputed robust and easy to maintain.
- They are easily deployed and recovered, and do not need any outside assistance.
- When correctly used, their accuracy is reputed to be very good.
- They are not affected by underwater noises such as those described in point 8.2.3.1.

Taut wires also have some inconveniences:

- Strong currents can create a catenary that may affect the accuracy of the system: A catenary is a curve made by cables held in two points that results from their weight (such as the curve of telegraphic cables between posts). Strong currents can create or increase such effect on the taut wire. The extend of catenary depends on the depth and the diameter of the cable (The deeper is the bottom, and the thicker is the cable, the bigger the catenary is). Manufacturers provide correction tables to control this problem.
- Snagging of the taut wire may happen during diving and ROV operations, and may result in problems such as a loss of position. For this reason, divers and ROV must be at a reasonable distance from the taut wire not to be snagged in it. Also, the taut wire should be clearly marked to distinguish it from the other cables, and its position must be indicated in the procedures and that navigation screens of the diving supervisor and ROV pilot.
- The weight can be trapped in debris laid on the bottom and be unable to be recovered. Also, it can be lowered on a sub-sea equipment and damage it. For these reasons, its deployment should be performed only in clean areas.
- The taut wire winch may be unable to follow the vessel movement in heavy seas.
- Taut wires are limited in-depth and are usually not designed to be used with bottoms exceeding 450 m. The Diving Positioning Committee says that some tests have been done at 800 and 1000 m, but these systems are not currently proposed.
- The vessel's movement is restricted to the range of angle measurement, often 30 degrees, or when the wire touches the vessel's side. In case the vessel is to be moved and/or the taut wire angle arrives at its limit, the weight must be relocated. However, IMCA says that re-plumbing a taut wire, when it is one of the three position references, does not constitute a violation of the requirements, if such action is completed as quickly as is safe and practicable, and the station keeping was stable when the taut wire was deselected prior to re-plumbing. Note that for any action on the taut wire, the diving supervisor is to be informed.

8.2.4.2.3 - Artemis Surface Reference System (Microwave link):

This system is classified among the microwave radar systems. It operates with very low power microwave transmissions (9.2 - 9.3 Ghz) using an antenna installed on a fixed point and a mobile antenna on the vessel. These antennae are similar to those of radars and can rotate to search for their counter stations. The position is determined by measuring the absolute distance and the relative angle between the two stations, so this system accurately measures the range and bearing of the vessel relative to the fixed position.



This system provides the following advantages

- Artemis is safe for use in zone 1. However, it should be switched off during radio silence or explosive work.
- The system usually has a range of 600 m, and its accuracy is up to 0.25 m and 0.2 degrees or better. It can be used during unfavourable sea conditions.
- New models are designed with automatic beacon and sensor acquisition.
- The system has tracking and data logging capability.

This system has the following inconveniences

- The old versions of the system accept the only signal of the DP vessel on which they are used.
- The system can have interference with other DP signals and radar. It can also have interference with objects like scaffoldings, pipes, containers.

An Artemis sensor can be checked without the need for a second unit using a specific tool called "validator".

8.2.4.2.4 - Fanbeam laser:

This system uses the principle of laser range finding by measuring the time taken for a pulse of laser light from the laser source to the target and back again, and hence deduces the distance of the target.

The system utilizes non-powered static targets that are intrinsically safe and can be easily mounted in almost all areas of an offshore platform or drilling rig. These targets are reflecting tubes or prismatic reflectors. The maximum operational range is about 2000 m for an accuracy of 20 cm. However, IMCA M 170 says that the combined repeatable bearing accuracy will limit the range at which stable position inputs can be obtained, suitable for automatic dynamic positioning. The maximum range for use with DP is therefore likely to be < 150 metres using reflective targets and < 500 metres using retro prisms.

This system is considered as a relatively cheap and transportable positioning reference for use in conjunction with other positioning reference systems for the dynamic positioning of marine vessels.

The size of the emitter/receptor is 260 X 300 X 297 mm, which allows for easy installation and transfer.

Despite its advantages note that the following inconveniences may be encountered:

- The system does not operate with sun shining into the lenses, or its performances are highly degraded in such conditions;
- The lenses can be affected by condensation, rain and salt spray;
- The operating range of the system is reduced in fog, snow or heavy rain;
- The system may become confused at night if there are bright lights close to the target. Or, it maybe interfered with by reflective items on the vessel or the platform; such as safety notices, reflective jackets, etc. However the manufacturer says that this problem has been corrected with the last models.
- Reflectors have to be installed on the facility, which may oblige to transfer personnel for this operation.

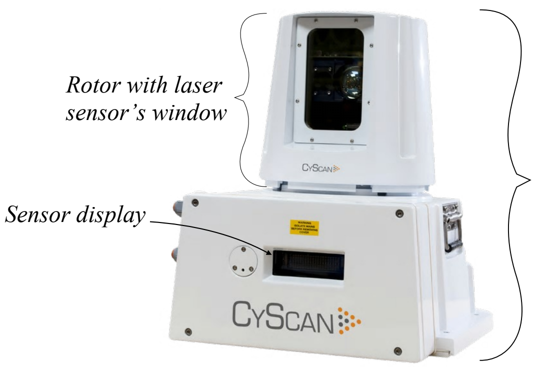
Reflecting tubes & prismatic reflectors

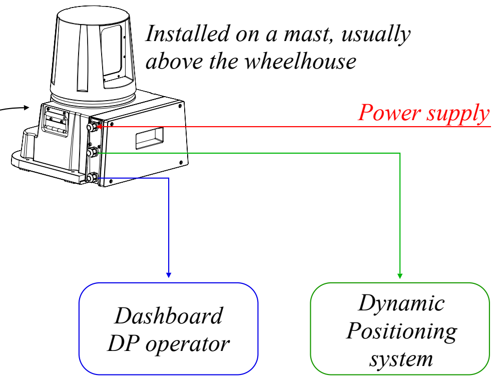
Laser emitter & receptor

8.2.4.2.5 - CyScan:

Similarly to Fanbeam laser, CyScan system operates on the principle of infra-red laser to pre-positioned reflector panels or prisms that can be installed on a structure or another vessel. This system is composed of:

- A sensor, which incorporates the rotating scanner head with laser optics, stabilization hardware and electronics for control, signal processing, and communications. It measures the range and bearing of the targets on 360.
- The "dashboard" that provides the DP operator with status information and control of the system and the data that are automatically transmitted to the vessel's DP system.
- The retro-reflectors consisting of reflective tape mounted on a flat or cylindrical support, or prismatic reflectors, that are similar to those used with the Fanbeam system.





The manufacturer indicates an operational range up to 3250 m with an accuracy of 20 cm. However these performances are dependent on target size and atmospheric conditions, and IMCA M 170 says that the range is limited to 400 metres in the majority of operating environments.

The system can operate in single target and multi-targets modes. It does not rely on gyro compass input.

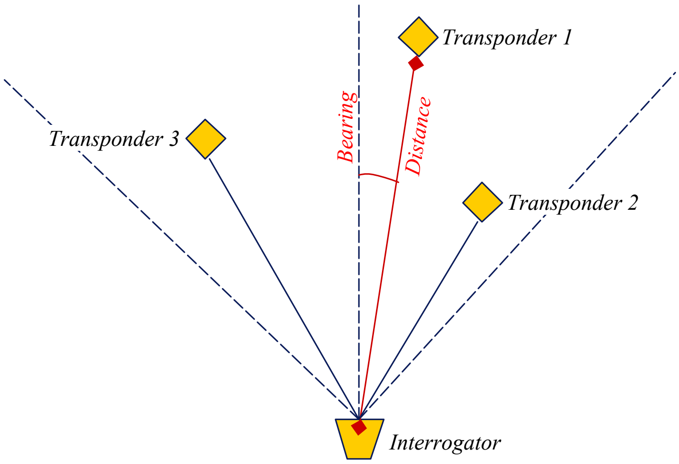
Like Fanbeam, it is considered as a relatively cheap and transportable positioning reference, for use in conjunction with other positioning reference systems for the dynamic positioning of marine vessels.

The inconveniences that have been reported with this system are similar to those of the Fanbeam system.

Note that regarding the installation of the reflectors, the manufacturer says that the targets should be placed in positions where the sensor can see them while the vessel is within the expected working area. Flat reflectors should not be too far along the structure from the expected working area as that can reduce the viewing angle for close operations that should not be above 45º. Also, the targets should be positioned with unequal spacing between them, and not closer than 5 m. Also, a permanent location of targets is recommended throughout the operations.

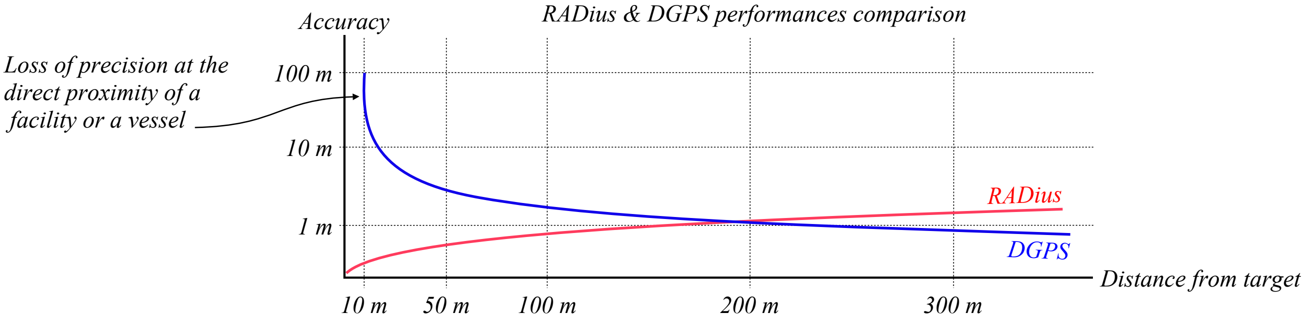
8.2.4.2.6 - RADius:

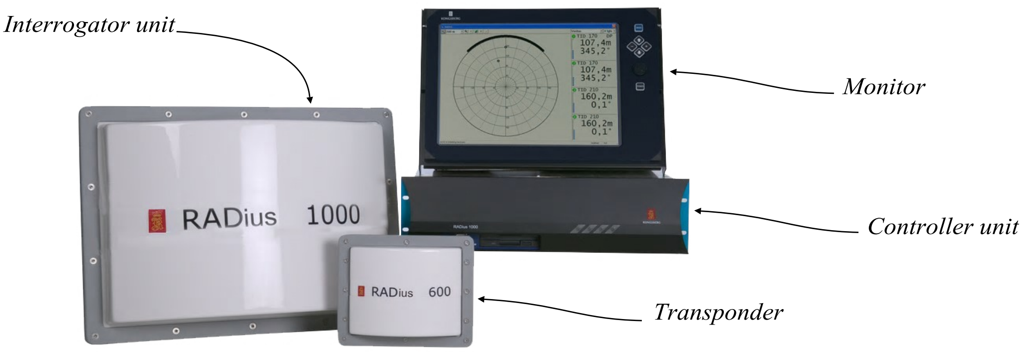
RADius is a relative position reference system developed by Kongsberg that utilises radar principles in short range and direction monitoring and is designed to operate in close proximity to structures and other vessels.
This system consists of an interrogator located on the DP vessel and one or several transponders with unique identity deployed on the target (vessel or installation). The RADius system measures distance and bearing from the interrogator to the transponders.



Differential Global Navigation Satellite Systems (DGNSS) suffer from a limited view of the sky when moving close to the structure. This can be crucial when the dynamic GNSS constellation is at its minimum and the most important satellite disappears behind the structure. Opposite of DGNSS, the RADius system increases its performance as the vessel moves closer to the transponders located on the structure. As a result, the RADius system can be used as a complement to the DGNSS system. It is composed of the following elements:

- The RADius interrogator unit is mounted outside on the vessel with free view to the horizon. It contains antenna elements, a receiver, a transmitter and a signal processing front end.
- The RADius controller unit is a 48 cm rack which contains the RADius processing unit that runs the final signal processing software, a graphical user interface and it provides serial interface lines to the DP and other possible users. The controller unit also contains keyboard and video display unit together with a power/connection module that provides network communication and power to the interrogator.



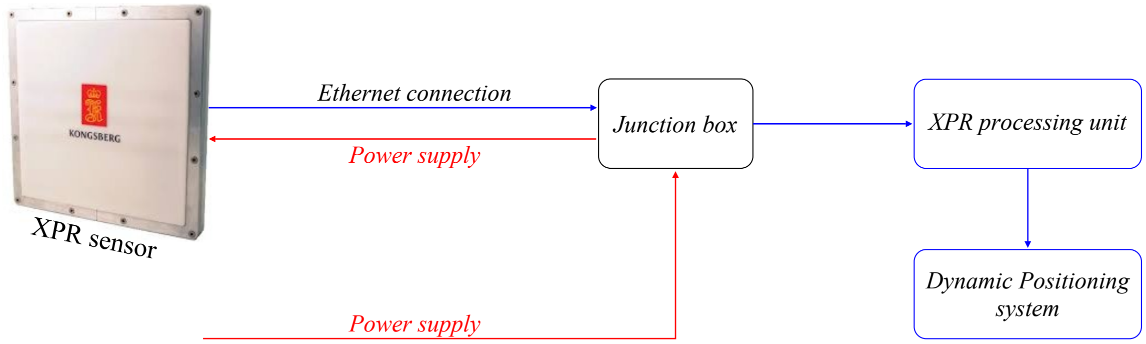


Operational advantages of the system:

- There are no motors, stabilized platforms or other moving parts within the system.
- It operates in all weather conditions and has wide opening angles both horizontally and vertically and will therefore be unaffected by high sea states.
- The system allows for multi user operability, which means that several vessels can utilize the same transponders simultaneously.
- It operates in a radio band that is allocated to marine radio navigation and is license free.
- The system efficiently mitigates radio interference. This is due to the wide frequency range over which the transmitter is sweeping.

8.2.4.2.6 - XPR long range relative positioning system:

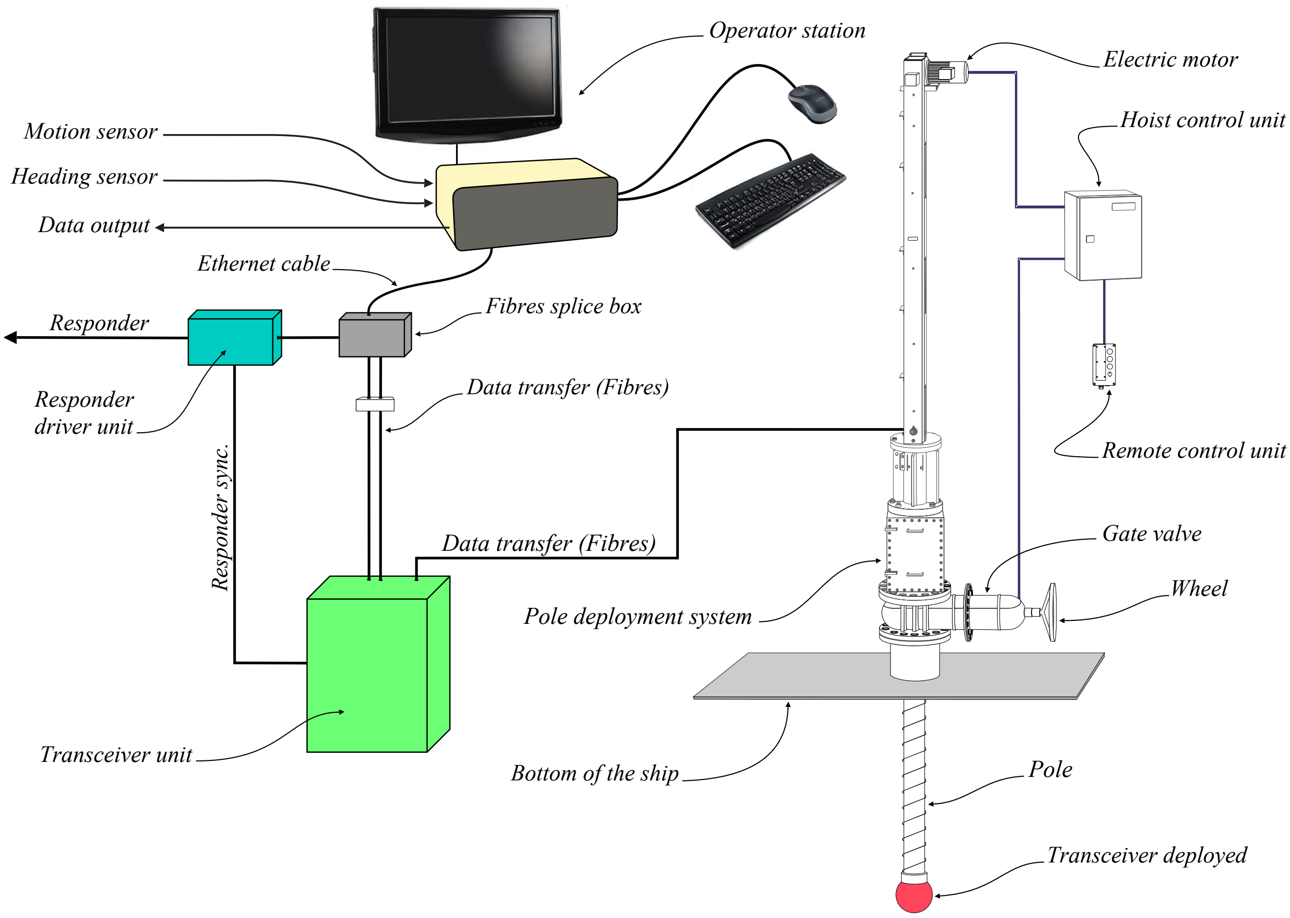
The XPR is a microwave-based solution for long-range relative positioning, that is also developed by Kongsberg. This system that operates in the 9.2-9.3 GHz band can be used with all weather conditions.
The system does not use moving parts, and each sensor unit has an opening angle of 100°. Also, sensor units can be combined to create an operational area of up to 280°.
The system automatically performs a function check prior to operation. Also, the target selection is automatic, and the devices stores them and continuously monitors in all directions to mitigates false targets lock and provide a high-speed acquisition. Its operational range indicated is from 10 m to 5 km with an accuracy of 1 m.
This system is complementary to other Dynamic Positioning solutions, and is compatible with the Artemis Mk4, Mk 5, and Mk 6.



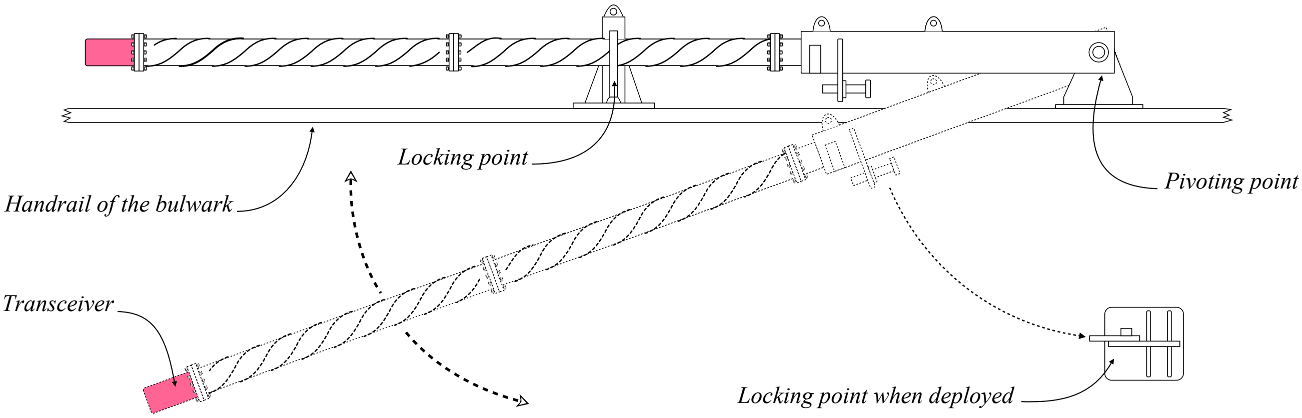
8.2.4.2.7 - Hydro acoustic systems:

A hydro-acoustic positioning system consists of both a transmitter (transducer) and a receiver (transponder). A signal (pulse) is sent from the transducer, and is aimed towards the seabed transponder. This pulse activates the transponder, which responds immediately to the vessel transducer. The transducer, with corresponding electronics, calculates an accurate position of the transponder relative to the vessel.

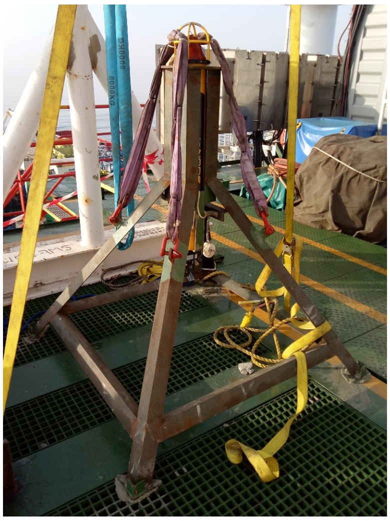
- SSBL (Super Short Base Line) & USBL (Ultra Short Base Line):
  They are hydroacoustic systems able to operate in shallow and deep waters to maximum ranges of 4000 metres to 10000 metres, depending on the performances of the equipment used.
  The calculation of positioning is based on the distance and vertical and horizontal angle measurements from a single multi-element transducer referenced to the system's heading unit, which is usually the gyrocompass.
  The transceiver of the boat is often deployed through the hull. As an example, the HIPAP system is an integrated solution designed by Kongsberg where this sensor is lowered several meters below the vessel hull through a gate valve until it is below the critical surface water layers as well as the noises generated by the propulsion devices of the vessel *(see the drawing below)*. Note that other manufacturers provide similar systems.



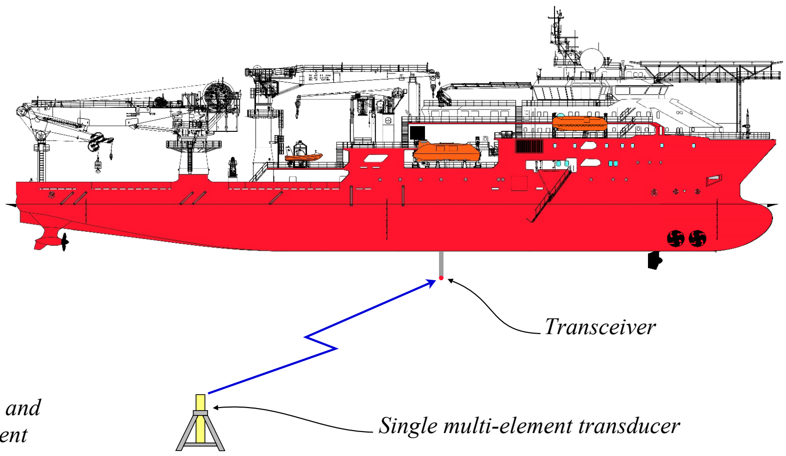
Deployment poles over the side may also be used. These systems are found with ships where through-hull deployment options are not available or practical. It is often the case when a diving operation is to be organized from a vessel of opportunity. With such systems, the metal pole is maintained along the side of the ship by a pivoting attach and two locking points; one when the mast is deployed in the water; and the other when it is secured along the bulwark. The deployment and recovery of the transceiver are usually made using a cable and a small winch.



Note that strong currents can damage deployment poles, and for this reason, manufacturers give some maximum limits for their deployment. As an example, Sonardyne indicates 7 to 10 knots operational limit and 15 knots survival for transceivers deployed through the hull and 5 knots operational limits and 10 knots short term survival speed for devices deployed over the side.
The transceiver contains digital transmitters, pre-amplifiers and beam-forming electronics. It communicates with the Acoustic Positioning Operating System (APOS) via fibres optic cables.
The transponder is deployed on the seabed using a crane or a davit, and/or an underwater vehicle.



Transducer and its deployment rigging



In the dynamic positioning committee conference by Keith Vickery (Sonardyne) regarding acoustic positioning systems, it is said that the advantages of Ultra Short Baseline (USBL) positioning systems are the following:

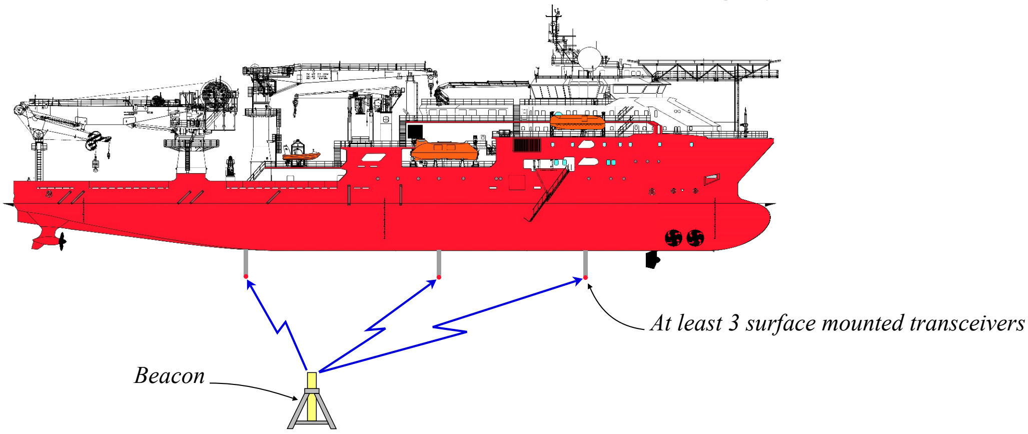
- Low system complexity makes USBL an easy tool to use.
- Ship based system – no need to deploy a transponder array on the seafloor.
- Only a single transceiver at the surface – one pole/deployment machine.
- Good range accuracy with time of flight systems.

The same author list the following disadvantages of Ultra Short Baseline (USBL) positioning systems:

- Detailed calibration of system required - usually not rigorously completed.
- Absolute position accuracy depends on additional sensors - ship's gyro and vertical reference unit.
- Minimal redundancy – only a few commercial systems offer an over-determined solution.
- Large transceiver/transducer gate valve or pole required with a high degree of repeatability of alignment.

- SBL (Short Base Line):

The Dynamic Positioning Committee says that “short baseline” systems derive a bearing to a beacon from multiple (at least 3 units) surface mounted transceivers. This bearing is derived from the detection of the relative “time of arrival” as a ping passes each of the transceivers. If a time of flight interrogation technique is used (Transponder or Responder) a range to that beacon will also be available from the SBL system.
A SBL system can work in pinger, responder or transponder mode. Any range and bearing (position) derived from a SBL system is with respect to the transceivers mounted on the vessel and as such a SBL system needs a Vertical Reference Unit (VRU), a Gyro, and possibly a surface navigation system to provide a position that is seafloor (earth) referenced.



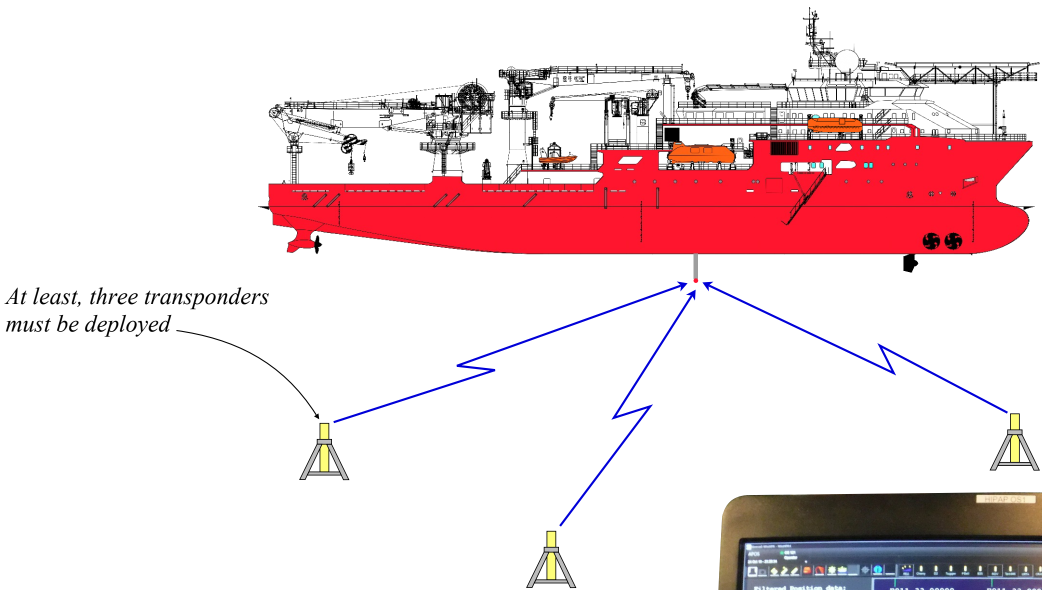
The deployment and recovery of the transceivers and beacons are similar to the SSBL and USBL.
In the Dynamic Positioning Committee conference regarding acoustic positioning systems indicated previously, the advantages of Short Base Line (SBL) positioning systems are listed as follows:

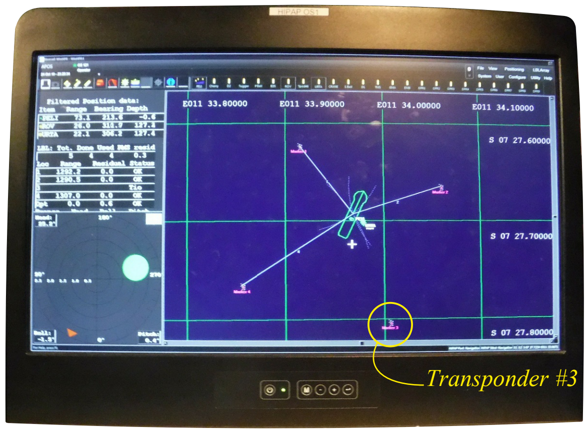
- Low system complexity makes SBL an easy tool to use.
- Good update rate when used with a pinger
- Good range accuracy with time of flight system.
- Spatial redundancy built in.
- Ship based system – no need to deploy transponders on the seafloor.
- Small transducers/gate values.

The disadvantages of Short Baseline (SBL) positioning systems are listed as follows by the same author:

- System needs large baselines for accuracy in deep water (>30m).
- Very good dry dock/structure calibration required.
- Detailed offshore calibration of system required - usually not rigorously completed.
- Absolute position accuracy depends on additional sensors - ship's gyro and vertical reference unit.
- At least three transceiver deployment poles/machines needed.

- LBL (Long Base Line):
A Long Base Line system provides a position with respect to an area where three or more transponders that are located at known positions on the seabed are interrogated simultaneously by a transducer fitted to the Diving Support Vessel, so the position provided is with respect to seafloor coordinates. The distance between these transponders can be of several kilometers. The deployment of these devices is also similar to SSBL and USBL.





Note that it is usual to deploy more transponders than the minimum. That provides some redundancy in case of a failure that allows not to stop the operations.
It is the case in this photo, where the transponder #3 has ceased emitting. However, #1, #2, and #4 are still active, and the operations can be continued.

Using the same source as for the Ultra Short Base Line USBL and the Short Base Line (SBL), the advantages of Long Base Line positioning systems are listed as follows:

- Very good position accuracy independent of water depth.
- Observation redundancy.
- Can provide high relative accuracy positioning over large areas.
- Small transducer – only one deployment machine/pole.

According to the source above, the disadvantages of Long Baseline (LBL) positioning systems can be listed as follows:

- Complex system requiring expert operators.
- Large arrays of expensive equipment.
- Operational time consumed for deployment/recovery.
- Conventional systems require comprehensive calibration at each deployment.

- Combined systems:
DP specialists say that it is possible to combine the above systems to provide very reliable and redundant positions systems. Among the numerous possibilities, note the following combinations:

- Long + Ultra Short Base Line;
- Long + Short Base Line;
- Short + Ultra Short Baseline;
- Long + Short + Ultra Short Baseline.

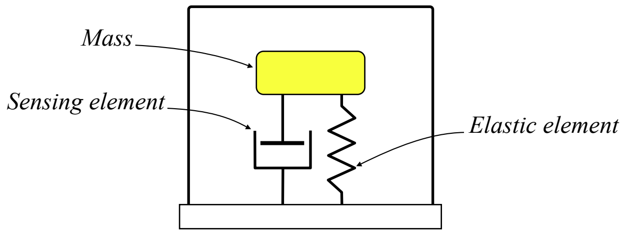
Also, multi-user systems are required where more than a single vessel is working within close proximity. The reason is that the acoustic positioning systems cannot provide sufficient channels within the standard bandwidth available to allow all vessels to position without interference between systems.

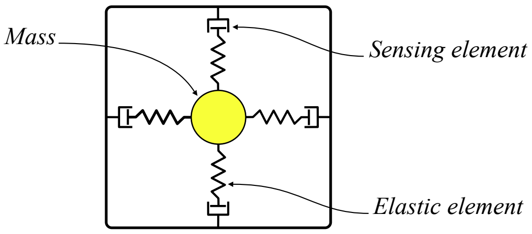
8.2.4.3 - Navigation systems and sensors

8.2.4.3.1 - Inertial navigation system (INS):

As already indicated in point 8.2.4.2.1, an "Inertial Navigation System" consists of accelerometers and gyroscopes, that compose the "Inertial Measurement Unit" (IMU), which provides acceleration and angular velocity measurements that are used by a computer to calculate the position of the vessel according to a known starting point. Note that the Inertial Measurement Unit (IMU) is sometimes called the Inertial Reference Unit (IRU).
This system that is usually designed to work with Global Navigation Satellite System (GNSS), combines three accelerometers and three gyroscopes

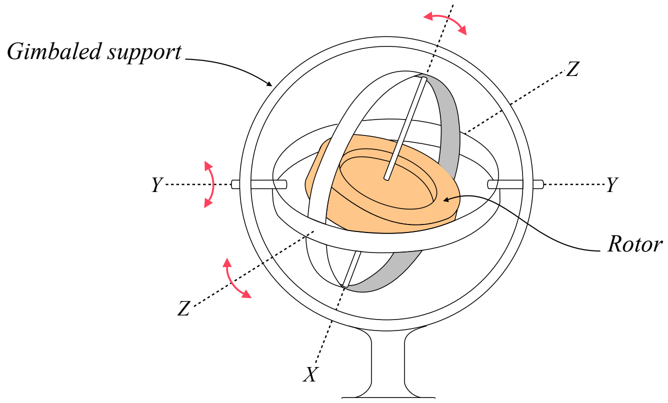
- Accelerometers are devices that measure acceleration, which is the rate of change of the velocity of an object. They provide their measures in metres per second squared (m/s^2), which is the official unit in the International System of Units (SI), or gravitational force equivalent, commonly called G-forces (g). A G-force is equivalent to 9.8 m/s^2. To provide a measure, the accelerometer converts the acceleration into a proportional electrical signal, usually voltage output. It is generally done using a small mass connected to elastic and sensing elements that measure the change of velocity in a given direction.





Accelerometers can measure acceleration on one, two, or three axes. Three-axis units are those used with boats. These devices can be analog or digital.

- A Gyroscope detects and measures the angular motion of an object relative to an inertial reference and has the orientation of its axis unaffected by tilting or rotation. So, it measures the absolute motion of an object without any external infrastructure or reference signal. These devices that were initially mechanical systems mounted on gimbaled supports *(see below)* are today replaced by electronic sensors.



8.2.4.3.2 - Heading Reference Sensors:
The heading is the direction to which a vessel is pointing. It is expressed as the angular distance relative to the north, which is usually expressed in degrees. The mechanical models of heading reference sensors are navigation gyrocompasses that looks like mechanical gyroscopes. A gyrocompass is a non-magnetic compass that is based on a fast-spinning disc and the rotation of the Earth to find geographical direction. Such devices have two significant advantages over magnetic compasses:

- They indicate the true north, which is not the case of magnetic compasses that are attracted by the magnetic north.
- They are unaffected by ferromagnetic materials, so they can be used in ships made of steel, which is the case of almost all working vessels.

However, these devices are gradually replaced by electronic systems using fibre optics and that do not use moving parts. IMCA M 252 says that these new models are considered more reliable, more accurate, and require less maintenance than the mechanical ones.

8.2.4.3.3 - Motion Reference Unit (MRU):
As already discussed with active heave compensation (AHC) systems, the Motion Reference Unit (MRU) is an inertial measurement unit with multi-axis motion sensors that actively measures all the movements of the vessel, and calculates the necessary counter-motion and controls of the system in real time. Note that the sensors of these devices are to be calibrated regularly for maintaining accurate operation.

7.2.4.3.4 - Anemometers
An anemometer is an instrument that measures wind speed, pressure, and direction. A lot of models exist that can be used for various applications. Among these systems, three types are commonly encountered on ships:

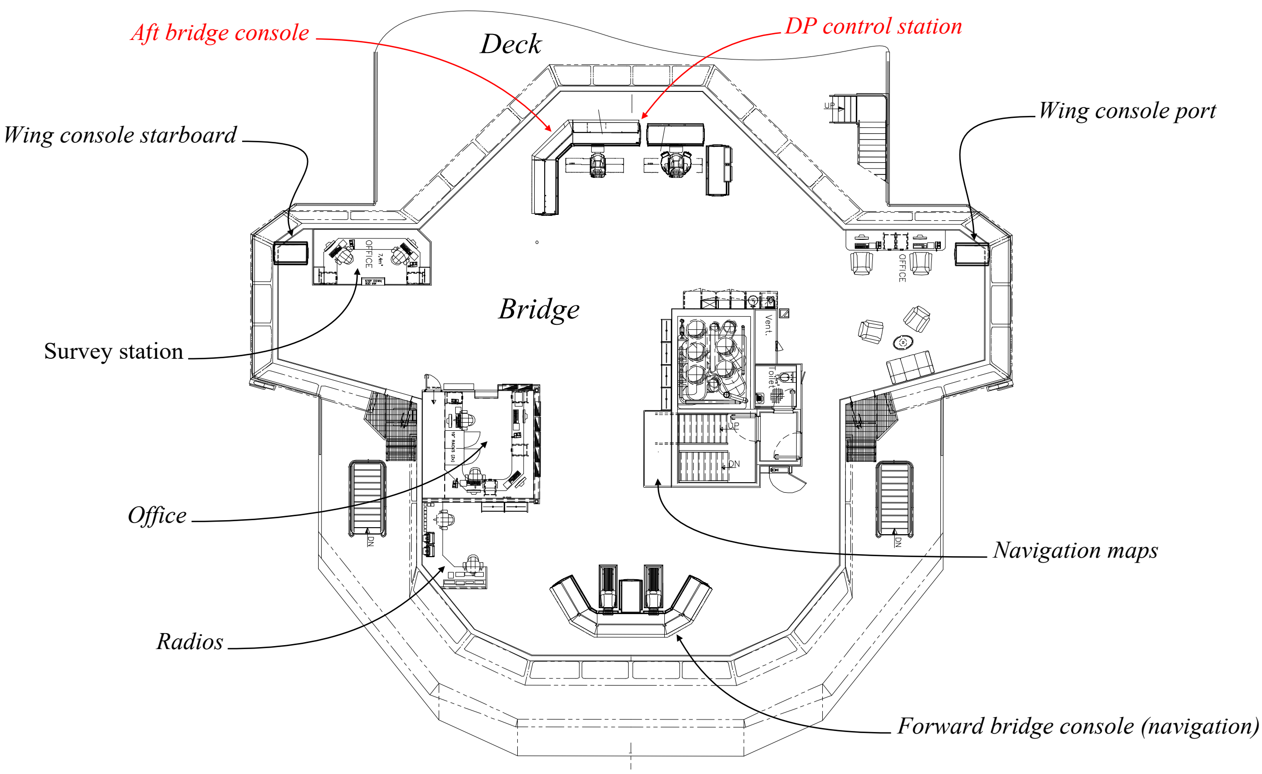
- Cup anemometers, that are four hemispherical cups mounted on horizontal arms, which are installed on a mast.
- Vane anemometers, that are propellers also installed on a mast.
- Ultrasonic anemometers use a transducer that emits ultrasounds that are speeded up by the wind and are then collected by a 2nd transducer. A computer measures the time between the two sensors to analyze the velocity at which the sound travels and calculate the wind speed. Also, because the speed of sound varies with temperature, such devices can be used as thermometers. The advantage of these systems is that they do not use mobile parts.

8.2.4.3.5 - Combined navigation and reference sensors:
As a result of the progress of electronics, manufacturers propose devices that combine several functions such as an example, Motion Reference Unit (MRU), plus heading and Global Navigation Satellite System (GNSS).

8.2.5 - Control systems

8.2.5.1 - General design of the Dynamic Positioning station

The Dynamic Positioning control system should be arranged in a control station where the operator has a good view of the vessel's exterior limits and the surrounding area. Usually the DP station is installed at the aft of the bridge, so the operator can see the deck and the main parts of the vessel. It is the case in the drawing below from UDS Lichtenstein.



The forward console is to be used when the vessel is in transit, and the aft navigation console is designed to manoeuvre the vessel and control her while she is in DP mode. Note that it is usually possible to start transiting from the aft console and then switch to the forward console.
Last generation DP vessels are provided with "wing consoles" on the port and starboard of the bridge that can be used for maneuvering the vessel in joystick mode for operations such as mooring alongside a vessel or a jetty.

On the vessel taken as example for this description, which is the Ultra Deep Solution Lichtenstein, the "forward console" is divided in six sections as follows:

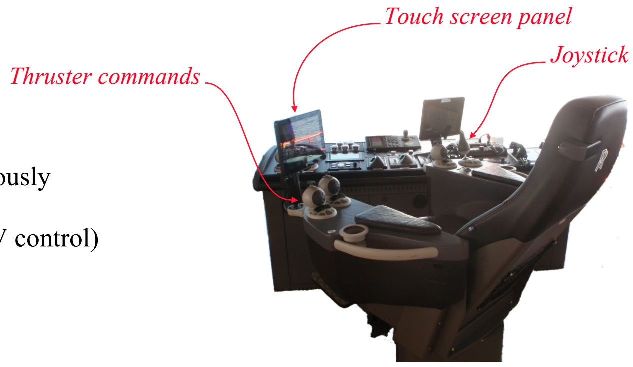
- Port section contains the following:
  - Water mist alarm panel & Emergency stop system.
  - Voyage Data Recorder (VDR) panel.
  - Bridge ventilation control panel.
  - Signal light control panel, searchlight control panel & ship telephone.
- The port corner section house the Electronic Chart Display Information System (ECDIS).
- Center section and center mid section contain the elements the most used during the navigation:
  - Gyro display (ECDIS) and rate of turn indicator.
  - Sound powered telephone and public address call station.
    whistle controller, Global Maritime Distress and Safety System (GMDSS) control panel with UHF (ultra high frequency and VHF (very high Frequency) transceivers.
  - Bridge watch call panel.
  - Manual thrusters levers and autopilot controllers and thruster emergency stop panel.
  - Automatic Identification System (AIS) transponder display (used to track the position of the vessel).
  - Speed log panel, magnetic compass display, X and S band radar displays.
- Starboard corner section houses the Close Circuit Television (CCTV) monitor.
- Starboard section contains:
  - Watertight door control panel.
  - Windless control panel.
  - Window wiper control panel.
  - UHF & VHF radios.
  - Call control units and survey monitors.

The aft console is organised in six sections as follows:

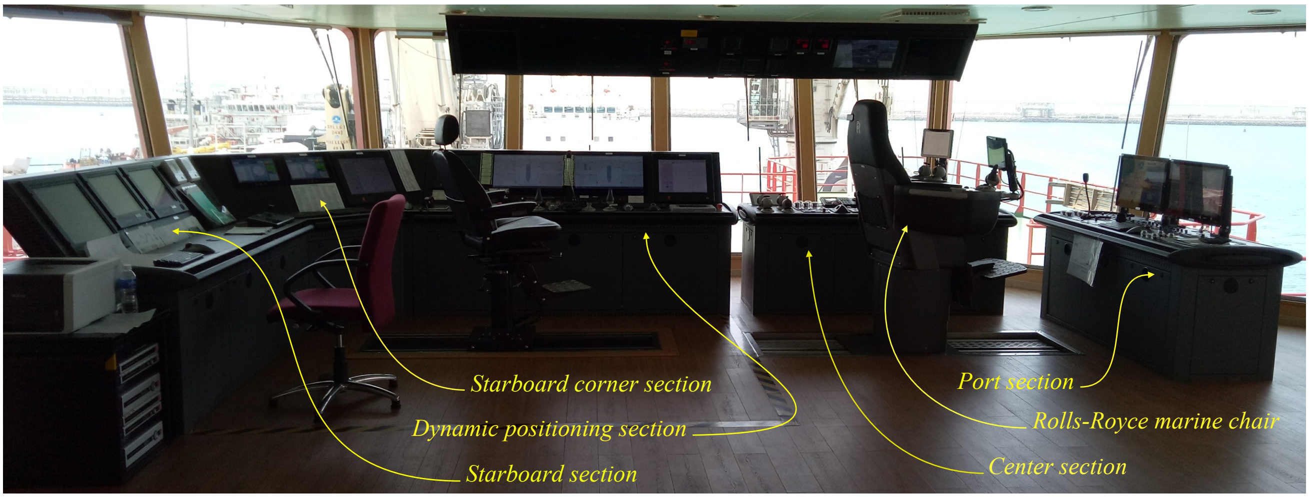
- Port section contains:
  - Public address system panel
  - General alarm, emergency stop panel, sprinkler control panel
  - Window wiper control
  - Joystick docking
  - DP chair manoeuvre mode selection panel.
- Center section includes:
  - Radar display selector switch
  - Telephone and sound powered telephone
  - Searchlight
  - Global Maritime Distress and Safety System (GMDSS) control panel with UHF (ultra high frequency and VHF (very high Frequency) transceivers
  - X and S band slave radar control.
  - Close Circuit Television (CCTV) monitor
  - DP system manoeuvre mode selection panel
  - Air whistle button

Hyperlink Tables of contents

- Rolls-Royce marine chair:
    - Thruster commands
    - PC touch screen panel
    - Joystick operation lever
- Dynamic positioning section contains:
    - The two DP operator stations described previously
    - Thruster emergency stop panel
    - Communication panel (to dive control & ROV control)
    - Port hydro-acoustics positioning control
    - CyScan laser control
    - UHF & VHF transceivers
- Starboard corner section
    - Starboard hydro-acoustics positioning control
    - DGPS 3 & 4 operating panel
- Starboard section contains:
    - CCTV monitor panel
    - Port & starboard bells phone station
    - Diver audio speaker
    - DGPS 1 & 2 display monitors
    - Computer loading station
- Wing consoles are installed port side and starboard side of the bridge they house:
    - A joystick docking point
    - A search light control panel
    - Manoeuvre mode selection panel
    - Bridge watch call reset button



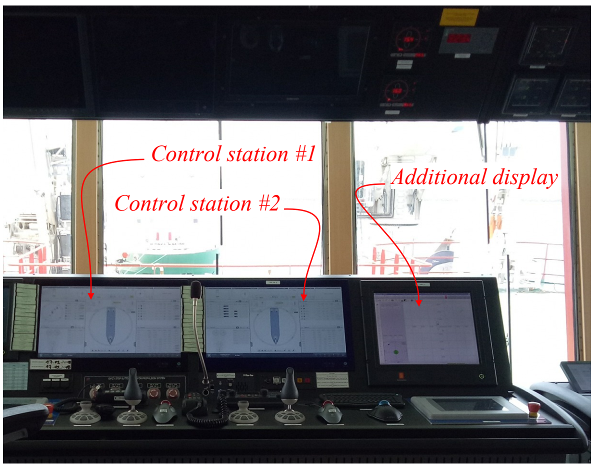
Rolls-Royce marine chair



The Circular 1580 from the IMO Marine Safety Committee (MSC.1-Circ.1580) says the following regarding ergonomics and safety devices that must be in place in the Dynamic Positioning station of diving support vessels:

- The DP control station should display information from the power system, thruster system, and DP control system to ensure that these systems are functioning correctly. Information necessary to safely operate the DP system should be visible at all times. Other information should be available upon the operator's request.
  Note that regarding this requirement, such information is usually displayed on the screens and the consoles in front of the operator as with the two examples below.

DP consoles Seven Pelican

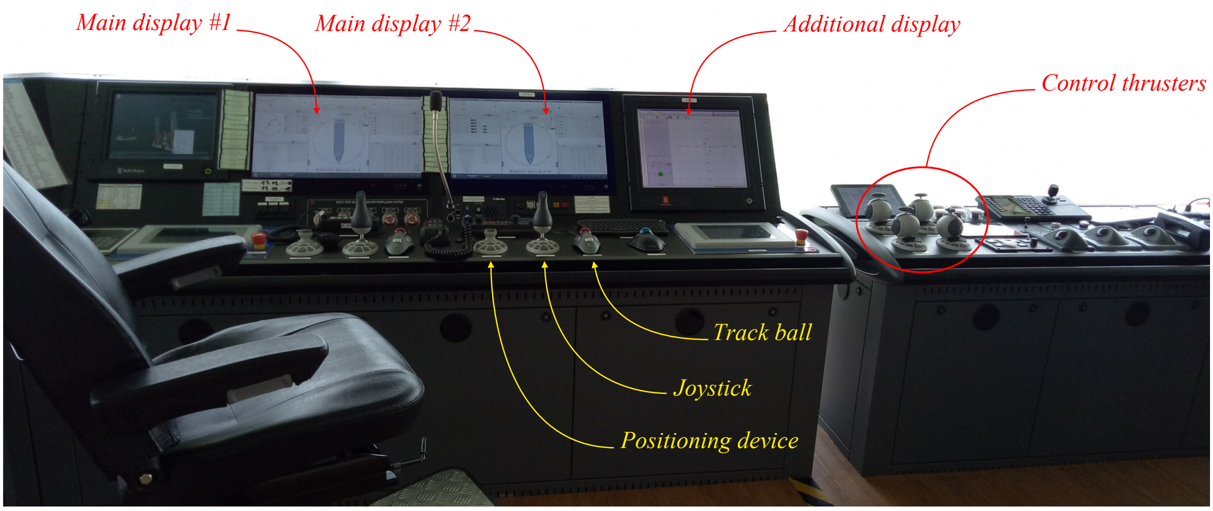


DP consoles UDS Lichtenstein

- Display systems and the DP control station, in particular, should be based on sound ergonomic principles that promote proper operation of the system.
The DP control system should provide for easy accessibility of the control mode, i.e. manual joystick, or automatic DP control of thrusters, propellers, and rudders if part of the thruster system. The active control mode should be clearly displayed. Operator controls should be designed so that no single inadvertent act on the operator's panel can lead to a loss of position and/or heading.
Note that it is the case of the two consoles displayed as an example on the previous page. Also, the control station must be appropriately illuminated to allow the operator to identify each control and command during the operations by night when the bridge cannot be lightened as the people on duty need to have a visual of the boat and her distance from a facility *(see the photo below)*.

- Alarms and warnings for failures in all systems interfaced to and/or controlled by the DP control system should be audible and visual. A record of their occurrence and of status changes should be provided together with any necessary explanations.
- The DP control system should prevent failures being transferred from one system to another. The redundant components should be so arranged that any failed component or components may be easily isolated so that the other component(s) can take over smoothly with no loss of position and/or heading.
- It should be possible to control the thrusters manually, by individual levers and by an independent joystick, in the event of failure of the DP control system. If an independent joystick is provided with sensor inputs, failure of the main DP control system should not affect the integrity of the inputs to the independent joystick.
Note that it is the case in the photo below where manual commands are organized to allow the operator to intervene immediately. Also, in the system taken as an example, and as a summary of the elements indicated above, each main operator station gives the user the possibility of fully controlling the system, and consists of:
    - A main touch screen display
    - Input device(s)
    - Graphical User Interface (GUI) computer
    - A shared printer that is used by the system to print alarm reports and graphs when the system is active.

The user interaction is done through a touch interface on the touch screen display 24” or 26” in combination with the input devices. An additional trackball is available as an option.
The communication between the operator station and the control system is done through a combination of Control Area Network (CAN) “bus” and a redundant Ethernet connection *(see the definitions on the next page)*.
The Main Display presents all necessary data for the user to operate the Dynamic Positioning (DP) system.
Note that the joystick input device and the positioning device can be used to perform the most common operations in addition to control manually the vessel in case of a problem with the DP system.
In addition, the operator can have manual control from the “Rolls Royce chair” (or similar) that is displayed on the previous page. However, note that this chair that allows controlling the vessel as an ROV is optional and not installed in most DP vessels.



Note the definitions below that are commonly used in computer architecture *(refer to the previous page)*:
- A "bus" is a communication system that transfers data between components inside a computer, or between computers.
- An "ethernet connection" is the most common way to set up a Local Area Network (LAN). Such a connection provides data transfer at acceptable rates over the network.

- Two Uninterruptible Power Supplies (UPS) should be provided for a class 2 equipment control system, and three for equipment class 3, to ensure that any power failure will not affect more than one computer system and its associated components. An Uninterruptible Power Supply (UPS) is an electrical apparatus that provides emergency power stored in batteries when the primary input power source fails, allowing sufficient time to switch-on the backup supply. Also, it acts as an electrical supply regulator, which avoids the computers and other sensitive equipment from being damaged by variations of voltage.
  The reference systems and sensors should be distributed on the UPSs in the same manner as the control systems they serve, so that any power failure will not cause loss of position keeping ability. An alarm should be initiated in case of loss of charge power. UPS battery capacity should provide a minimum of 30 minutes operation following a main supply failure.
  Note that the charge power for the UPSs supplying the main control system should originate from different power systems.

8.2.5.2 - Computer systems

Computers are the essential components of a Dynamic Positioning system, as they control the elements that allow analyzing a situation and provide an appropriate reaction to maintain the vessel in position.
Regarding the way such devices must be designed and organized for diving support vessels, IMO Maritime Safety Committee Circular 1580 (MSC.1/Circ.1580) says:

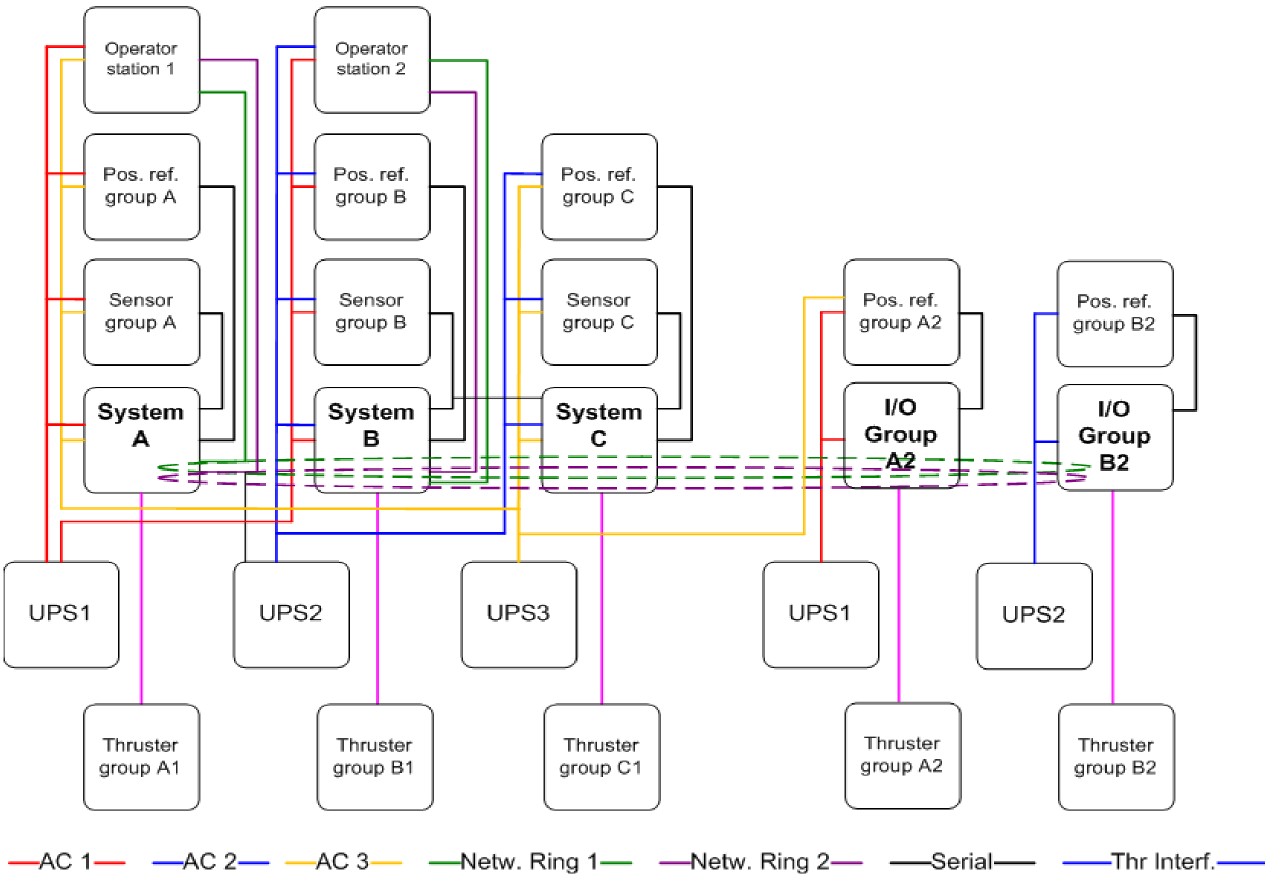
- For equipment class 2, the DP control system should consist of at least two computer systems so that, in case of any single failure, automatic position keeping ability will be maintained. Common facilities such as self-checking routines, alignment facilities, data transfer arrangements and plant interfaces should not be capable of causing failure of more than one computer system. An alarm should be initiated if any computer fails or is not ready to take control.
- The requirements for equipment class 3 are similar as above except that a separate backup DP control system should be arranged. This backup DP control system should be in a room separated by an A-60 class division (capable of resisting fire for 60 minutes) from the main DP control station.

- The DP control system should include a software function, normally known as "consequence analysis", which continuously verifies that the vessel will remain in position even if the worst-case failure occurs.
  This analysis should verify that the thrusters, propellers and rudders (if included under DP control) that remain in operation after the worst-case failure can generate the same resultant thruster force and moment as required before the failure. It should provide an alarm if the occurrence of a worst-case failure were to lead to a loss of position and/or heading due to insufficient thrust for the prevailing environmental conditions (e.g. wind, waves, current, etc.).
  For operations which will take a long time to safely terminate, the consequence analysis should include a function which simulates the remaining thrust and power after the worst-case failure, based on input of the environmental conditions.

- Redundant computer systems should be arranged with automatic transfer of control after a detected failure in one of the computer systems. The automatic transfer of control from one computer system to another should be smooth with no loss of position and/or heading.
  Also, during DP operation, the backup control system in the separate room should be continuously updated by input from at least one of the required sets of sensors, position reference system, thruster feedback, etc. and be ready to take over control.
  The switchover of control to the backup system should be manual, situated on the backup computer, and should not be affected by a failure of the main DP control system. Main and backup DP control systems should be so arranged that at least one system will be able to perform automatic position keeping after any single failure.
- Each DP computer system should be isolated from other on-board computer systems and communications systems to ensure the integrity of the DP system and command interfaces.
  This isolation may be effected via hardware and/or software systems and physical separation of cabling and communication lines.
  Robustness of the isolation should be verified by analysis and proven by testing. Specific safeguards should be implemented to ensure the integrity of the DP computer system and prevent the connection of unauthorized or unapproved devices or systems.

As an example of what is described above, the drawing below describes the communication between the different system parts of an existing DP2 vessel. Note that:

- The system is based on a triple controller system with a dual fibre-optic ring network.
- The interfaces to sensors and position reference systems, power system, and thruster system are split into groups.
- The interface to external systems (Input/Output) is separated from DP network to preserve the segregation between the systems.
- The DP cabinets, operator stations, sensors and position reference systems are powered through dedicated Uninterruptible Power Supply (UPS) systems.



8.2.6 - Safety rules for cabling and piping systems

Electrical and data cables, and also pipings are essential for the monitoring of the surrounding, and adequate response of the Dynamic Positioning System. For this reason, they should be designed with due regard to fire hazards and mechanical damages. Also, the following additional rules should be implemented for class 3 systems:

- Cables for redundant equipment or systems should not be routed together through the same compartments. Where this is unavoidable, such cables may run together in cable ducts of A-60 class, the termination of the ducts included, which are effectively protected from all fire hazards except that represented by the cables themselves. Cable connection boxes may not be provided within such ducts.
- Routing through separate compartments or in A-60 class ducts also applies to pipe systems.

8.2.7 - Voice communications and DP emergency alarm system

8.2.7.1 - Voice communications between the dive control and the DP station

Note that the way communications should be designed in the dive control is described in the document "Description of a saturation system".

IMCA says that voice communication by a priority system should be available between dive control and the DP control location. Open hands-free line with priority is a desirable facility. Such communications should be hard wired.
There should be a backup to this system which in most cases would be a common internal telephone network.
These communications should be checked during the initial DP stabilisation period. Also, marine radio communications can be used as a 2nd backup.

During the dive, the diving supervisor and the DP operator should inform each other about any change in operational circumstances, either existing or planned. The lists below gives an indication of the type of information which should be passed:

- Dive control to DP control:
  - Bell status, diver status, down-lines status.
  - Intention to use and use of water jetting equipment.
  - Possibility of divers, bell, or equipment blanking or moving acoustic reference signals.
  - Requests to move the vessel.
  - Intention to release high volume compressed air subsea.
  - Any situation which is unusual or may need a change to agreed procedures.
- DP control to dive control:
  - Intention to move vessel or change heading.
  - Changes in operational status affecting position control.
  - Any situation which is unusual or may need a change to agreed procedures.
  - Any forecast or actual significant changes in weather.
  - Vessel movements in the vicinity.
  - Intention to handle down-lines of any description, including repositioning taut wire weight.
  - Platform information relevant to operations.

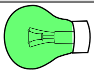
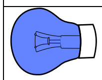
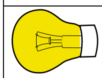
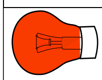
8.2.7.2 - Diving Dynamic Positioning emergency alarm system

A system of lights and audible alarms, manually activated from, and repeated in the DP control room, should be provided in dive and ROV controls and working areas.

Also, the distinctive alarm for emergency alert should sound in the cabins of the master, the Offshore Construction Manager, the senior diving supervisor, and the client representative, in conjunction with a flashing red light.

A means of acknowledging and silencing these alarms should be available to allow for clear communications between the people involved in emergency actions.

The Dynamic positioning alarms of Diving Support Vessels can be classified as follows:

Colour	Status	Response to alert
 ***Green***	Normal operational status (green light). • Vessel under DP control and DP system operating normally with appropriate backup systems available. • Thruster power and total power consumption are optimal. • Vessel's indicated position and heading are within predetermined limits. • Negligible risk of collision exists from other vessels.	- Full DP diving operations can be undertaken.
 ***Blue***	Advisory status (blue light) *Note that this status is optional, and not available on a lot of vessels* • Approaching performance limits or reportable alarm status. • Operations may continue whilst risks are being assessed. • A failure has occurred that does not affect DP redundancy	- A risk assessment must be conducted to determine whether to continue, change position, or cease operations. - The diving supervisor should inform the divers and the team to prepare for a possible degraded status.
 ***Yellow*** (flashing + buzzing)	Degraded status (yellow alert). • A failure in a sub-system has occurred leaving the DP system in an operational state such that an additional fault would cause a loss of position. • Vessel's position keeping performance is deteriorating and/or unstable or deviates beyond limits determined by risk analysis or HAZOP. • Risk of collision exists from another vessel. • Weather conditions are judged to be becoming unsuitable for DP diving. • Any other condition or circumstance which could reduce the status from normal.	- The diving supervisor should instruct the divers to suspend operations and move to a safe location. - The DPO, after consultation with the diving supervisor, should decide if any further action is necessary. - If the diving supervisor is unable to get clear advice from the DPO he will instruct divers to return to the bell.
 ***Red*** (flashing + buzzing)	Emergency status (red alert). • System failure results in an inability to maintain position or heading control; • Any external condition exists, including imminent collision, preventing the vessel from maintaining position. • Onboard, this alert is often referred to as 'abandon ship'.	- The diving supervisor instructs the divers to return immediately to the basket and be recovered as soon as possible after due consideration of hazards involved in the recovery. - Key DP personnel should use all reasonable means available to limit the loss of position while the divers are being recovered.

These alarms must be tested before starting the diving operations. Note that sometimes the yellow emergency status light is amber or orange colour.

When supporting divers on DP, a clear procedure indicating the recommended responses to yellow and red alerts is required. The events that should trigger these alerts should be based upon the operating status levels reflecting the capability of the DP system to maintain the vessel on station within safe working limits.

Priorities should be clearly established for dealing with a DP emergency:
The authority of the master and diving superintendent are of fundamental importance at such times. They must cooperate closely on these priorities so that there is no room for doubt or dissension and so that the senior Dynamic Positioning Operator and diving supervisor on duty at the time of an emergency act with the same priorities without undue hesitation. For this reason, the following priorities should be considered:

- The safety of life is the first priority.
- The master has ultimate authority to assess and decide on courses of action in this respect. The advice of the diving superintendent should be taken into account.
- The safety of property is of lower priority. No effort should be made to safeguard property at the expense of safety to life, but the potential danger to life associated with certain threats to property should not be overlooked.
- The advice of the client's representative and offshore installation manager should be considered, where possible, with respect to the safety of offshore platforms and equipment.

8.3 - Dynamic positioning vessel documentation

The Dynamic Positioning Committee (DPC) says that, in addition to the IMO documentation requested to every ship, it is recommended that DP vessel owners and operators should maintain the documentation regarding the DP systems of their boats for the purposes listed below:

- Ensuring the safe and effective management of the vessel in DP.
- Ensuring the technical suitability of the vessel for each DP activity it is required to carry out.
- Determining the configuration for the critical activity mode of operation and the task appropriate mode.
- Understanding the vessel’s station keeping capabilities following the worst case failure.
- Ensuring compliance with appropriate standards and guidelines.
- Providing training and familiarization material to vessel crews.

These documents are used by the National authorities maintaining registers of certificates and endorsements during the survey testing for the delivery of the Dynamic Positioning Acceptance Document (DPVAD). They should be kept on board and at the company office, and be updated. They may be in electronic or, hard copy format or, both.

8.3.1 - List of documents to be kept

No	*Document*	*Guidance from the Dynamic Positioning Committee*	*Additional explanations and guidelines*
1	DP system FMEA or FMECA	To be kept up to date, incorporating all modifications and additions since original study, if not in the document itself, then by other traceable means. All records to be on board.	Modifications and additions should be covered by a Management of change process that triggers updating the FMEA.
2	DP FMEA Proving Trials	To be conducted to prove initial DP FMEA and at other times to prove modifications and additions to the DP system. These trials should be repeated every five years. Findings and recommendations to be addressed in accordance with their criticality. All records to be on board.	Modifications and additions that should be proven by testing include all those that have direct effect or, potential to affect the performance or redundancy of the DP system. This will include protective, detection and monitoring functions
3	Annual DP Trials	To be conducted annually. Findings and recommendations to be addressed in accordance with their criticality. Previous trials reports and associated close out documentation to be on board.	The tests in the Annual DP Trials should be designed to prove system redundancy, as defined in the DP FMEA, system and equipment performance and functionality, to validate repairs and preventive maintenance, to protection and detection devices and their response so as to demonstrate that the vessel’s DP system remains fit for purpose.
4	DP Capability Plots	Hard copy DP Capability Plots relevant to the vessel’s areas of operations to be readily accessible to DPOs at the DP control location.	DP Capability Plots define by theoretical calculation the vessel’s capability to maintain position in various environmental conditions. *More explanations are provided in the next point.*
5	DP Footprint Plots	Hard copy DP Footprint Plots to be taken by DP operators and kept on board. See Note 1 at end of table.	The plots are of the vessel’s DP station keeping performance and limitations in various environmental conditions. *More explanations are provided in the next point.*
6	Service reports of the DP System	Complete history of service reports to be on board	There should be a process where the open items are highlighted, tracked and closed out.
7	Details of all DP related modifications and additions	Records of all DP related modifications and additions to be kept on board complete with interface and testing information.	Owners/ operators should keep adequate records and documentation relating to modifications and additions that could have an effect on the DP system, especially interfaces between equipment from different vendors. All modifications and additions should be subjected to FMEA type analysis and undergo Proving Trials type testing. New and modified software should be subjected to a thorough validation process, especially to avoid the acceptance of erroneous values.

No	Document	Guidance from the Dynamic Positioning Committee	Additional explanations and guidelines
8	Vessel audit reports and DP audits and inspection reports.	Complete history of all audit reports, DP audits and inspection reports, inc., findings and close outs to be on board.	There should be a process where the open items are highlighted, tracked and closed out.
9	DP Operations Manual	Vessel Specific DP Operations Manual , to be readily accessible at the DP control location and used by the DPOs as a reference for conducting DP operations.	It is recommended that owners/ operators develop a standardised table of contents for vessel specific DP Operations Manuals in their fleet. Modifications and amendments to the DP Operations Manual should be subject to Management of change processes, including changes to vessel specific checklists.
10	DP Incident Reports	Records of all DP station keeping and other DP related incidents to be kept on board, inc., investigation records and close outs.	All DP incidents should be investigated to an extent that reflects the potential consequences of the incident.
11	DP Mobilization/ DP Field Arrival/ Trials Procedures (Bridge and Engine Room)	Records of DP Mobilization Trials and DP Field Arrival Checklists to be kept on board for the period set by the owner/ operator and, where relating to a DP incident permanently stored in retrievable archives.	DP Trials and Checklists should be vessel specific and be developed from detailed information contained in the DP FMEA. They should confirm vessel performance, particularly following worst case failure, and that the vessel's DP system is set up properly and provides the required level of redundancy.
12	DP Location and Watchkeeping checklists (Bridge and Engine Room)	Records of all DP Location and Watchkeeping checklists to be kept on board for the period set by the owner/ operator and, where relating to a DP incident, permanently stored in retrievable archives	As above
13	DP related drills and emergency response drills	Records of DP related drills and emergency response drills to be kept on board in retrievable archives.	DP drills can be developed from fault and single point failure scenarios addressed in the vessel's DP FMEA. The drills should also cover extreme events that are outside the scope of the DP FMEA. The outcomes from these drills should be used in the development of DP emergency response procedures and used as training material for DP personnel. These records may be used in a cycle of continuous improvement.
14	DP fault log	Records of all faults related to the DP system to be kept on board permanently in retrievable archives.	DP faults should be recorded as soon as possible after they are discovered and action/ investigation taken appropriate to the potential consequences of the fault on the vessel's station keeping ability.
15	DP data logging	Where the vessel has DP data logging facilities electronic records should be kept on board for the period set by the owner/ operator and, where relating to a DP incident, permanently stored in retrievable archives.	DP data loggers perform an important function in helping to determine root causes of faults or failures. It is recommended that a DP data logging function is included as part of the DP system design specifications. DP data loggers should be commissioned and operational before DP system Customer Acceptance Trials (CAT) are carried out. The DP data logger should be incorporated in the Critical Activity Mode of Operation/ Task Appropriate Mode (CAMO/TAM) and running at all times when in DP. If not, this should trigger an Advisory condition. There should be specific procedures for the operation and analysis of output from the DP data logger. This should include clear instructions on how and where the records are kept. Retention of logging data should not be limited by time.

No	Document	Guidance from the Dynamic Positioning Committee	Additional explanations and guidelines
16	DP alarm printer readouts	Hard copy records of the DP alarm printer readout to be kept on board for the period set by the owner/ operator and, where relating to a DP incident, permanently stored in retrievable Archives.	Owners/operators frequently require DP alarm printer readouts to be kept for the duration of each well and then destroyed, unless relating to a DP incident or contractual dispute.
17	DP familiarisation and competency records	All records relating to vessel specific DP familiarisation and competency for DPOs, engineers and electricians to be kept on board permanently in retrievable archives.	Owners/ operators should implement an in-house DP competency assurance process for key DP personnel which is structured, systematic and progressive. It should be noted that Dynamic Positioning Officer (DPO) certification is only one element in the competency assurance process.
18	Résumés and vessel specific work records of all key DP personnel	Resumes of all key DP personnel, copies of certification and qualifications, records of DP watchkeeping hours to be maintained on board. Original DPO certificates and DP Log Books to be held by the DPOs onboard the vessel.	

8.3.2 - Definitions

8.3.2.1 - Dynamic Positioning FMEA

Failure Mode Effect Analysis (FMEA) is a document that provides a systematic analysis of systems and sub-systems to a level of detail that identifies all potential failure modes down to the appropriate sub-system level and their consequences. The difference between FMEA and FMECA (Failure Mode Effect Critically Analysis) is in the method of analysis used: FMEA is based on the evaluation of a Risk Priority Number based on severity, likelihood, and detection, where FMECA calculates the criticality of each potential failure *(more explanations regarding this point are given in point 4.3 in this book)*.

The Dynamic Positioning Committee says that the DP FMEA is the most important technical document in the list of required documents and is required by IMO Maritime Safety Committee circulars 645 (1994) and 1580 (2017).

In addition to complying with the IMO Guidelines and the relevant DP rules of the vessel's classification society the DP FMEA should achieve the standards of detail and analysis contained in the following industry guidance:

- IMCA M166 "Guidance on Failure Modes and Effects Analysis"
- IMCA M178 "FMEA Management Guide"
- MCA M04/04 2004 "Methods of Establishing the Safety and Reliability of DP Systems"

Note that FMEAs are a requirement to obtain DP Class 2 and 3 notation *(see in point 8.2.3)*.

Also, note the following definitions that are linked to FMEA:

- *FMEA proving trials* means the test program for verifying the FMEA
- *Hidden failure* means a failure that is not immediately evident to operations or maintenance personnel and has the potential for failure of equipment to perform an on-demand function, such as protective functions in power plants and switchboards, standby equipment, backup power supplies or lack of capacity or performance.
- *Worst Case Failure (WCF)* is the identified single failure mode in the DP system resulting in maximum effect on DP capability as determined through FMEA study.
- *Worst Case Failure Design Intent (WCFDI)* is the single failure with the maximum consequences that has been the basis of the design and operational conditions. This usually relates to a number of thrusters and generators that can simultaneously fail.
- *Redundancy Concept* is the means by which the Worst Case Failure Design Intent is assured.
- *Critical Activity Mode* is the configuration that the vessel's DP system should be set up and operated in so as to deliver the intent of the vessel's DP class notation. The objective is that no single failure should result in exceeding the worst case failure. Each DP vessel has only one critical activity mode which is unique to that vessel.
- *Thruster and generator operating strategy (TAGOS)* is a document that provides informed guidance, usually derived from a review of the FMEA and if necessary, validation from personnel knowledgeable about vessel specific information, on appropriate configurations of thrusters, generators and power distribution, and associated constraints, so as to enable correct choices to be made to provide optimum level of redundancy.

Key DP personnel, including the vessel Master, DPOs, Engineers and Electricians should have a detailed knowledge of the DP FMEA and should use the information provided to be fully informed about the capabilities and limitations of the vessel's DP system.

8.3.2.2 - Dynamic Positioning capability plots

The Dynamic Positioning Committee says that these theoretical plots are calculated from detailed information of the vessel's hull and superstructure form and available thruster power.
The calculations should use environmental data (sea state, wind and current) appropriate to the area in which the DP vessel is to operate. Also, they should show the limiting wind speed 360 degree envelopes for the scenarios below, where each point on the envelope represents the wind speed at which it is calculated that the vessel will be unable to maintain position in DP.

DP Capability Plots should include the following scenarios at current speeds of 0 kts, 1 kt and 2 kts, or at other current speeds that are representative of the location in which the DP vessel is to operate:

- Fully intact power generation and thrusters.
- Loss of most effective thruster(s).
- Following the worst case failure.

Note the following:

- The DP Capability Plots should be provided in a format that is intuitive to the user on board.
- The guidance IMCA M 140 "Specification for DP Capability Plots" is recommended for these calculations.

8.3.2.3 - Dynamic Positioning footprint plots

In addition to what is said above, the Dynamic Positioning Committee says that DP Footprint Plots should also be produced on board.
DP Footprint Plots are not theoretical. They are actual measurements of the vessel's DP station keeping performance in the actual environmental conditions and thruster configuration at the time the plot was taken. DP Footprint Plots should be taken whenever opportunities arise, such as during standby periods, weather downtime or on arrival at the field.
Plots should be taken for the thruster configurations used in the DP Capability Plots, i.e. fully intact, loss of most effective thruster(s) and after worst case failure.
Some DP systems have a software application that produces DP Footprint Plots electronically. DPOs can also produce DP Footprint Plots by manual methods using a plotting sheet.

The Dynamic Positioning Committee says that DP Footprint Plots serve two main purposes.

1. They provide a scatter plot of vessel positions at regular intervals around the required set position (this shows accuracy of station keeping)
2. They also provide comparison points on the limiting wind speed envelope given in the theoretical DP Capability Plots (this shows wind speeds at which it was seen that the vessel was unable to maintain position, thus validating or contradicting the theoretical DP Capability Plots for the various thruster configurations).

DP Foot print Plots can also be used for other purposes, including learning and familiarisation opportunities for DPOs and in providing snapshots of vessel station keeping behaviour for specific locations and activities.
In addition, theoretical DP capability plots and DP footprint plots combine together to enhance knowledge and understanding of the vessel's DP station keeping ability.

Note the following:

DP Footprint Plots originated in harsh weather regions, such as in the North Sea.
The plots are used to gain a better understanding of the vessel's actual station keeping performance and limitations in intact and, in various degraded thruster configurations, including worst case failure, whilst the vessel is being subjected to real environmental forces.

8.3.2.4 - Critical activity mode of operation

Critical Activity Mode of Operation (CAMO) is generally a tabulated presentation of how to configure the vessel's DP system, including power generation and distribution, propulsion and position reference systems, so that the DP system, as a whole, delivers the intent of the vessel's DP class notation. The CAMO table also sets out the operator actions should a required configuration not be met.

8.3.2.5 - Activity specific operating guidelines

Activity Specific Operating Guidelines (ASOG) are generally presented in tabulated format and set out the operational, environmental and equipment performance limits considered necessary for safe DP operations while carrying out a specific activity. The table also sets out various levels of operator action as these limits are approached or exceeded.
The ASOG will vary depending on the activity and are unique to that activity.

8.3.2.6 - Task appropriate mode

Task Appropriate Mode (TAM) is a risk based mode. Task Appropriate Mode is the configuration that the vessel's DP system may be set up and operated in, accepting that a single failure could result in exceeding the worst case failure and could result in blackout or loss of position.
This is a choice that is consciously made.
This mode may be appropriate in situations where it is determined that the risks associated with a loss of position are low and, where the time to terminate is low.

8.3.3 - Survey testing and dynamic positioning acceptance document (DPVAD) - (IMO-MSC.1/Circ.1580)

8.3.3.1 - Surveys and testing

IMO says that each DP vessel should be subject to the surveys and testing specified below:

- An initial survey which should include a complete survey of the DP system and FMEA proving trials for DP classes 2 and 3 to ensure full compliance with the applicable parts of the guidelines MSC.1/Circ.1580. Furthermore it should include a complete test of all systems and components and the ability to keep position after single failures associated with the assigned equipment class. The type of tests carried out and results should be recorded and kept on board.
- A periodical testing at intervals not exceeding five years to ensure full compliance with the applicable parts of the guidelines. The type of tests carried out and results should be recorded and kept on board.
- An annual survey should be carried out within three months before or after each anniversary date of the Dynamic Positioning Verification Acceptance Document 1 . The annual survey should ensure that the DP system has been maintained in accordance with applicable parts of the Guidelines and is in good working order. The annual test of all important systems and components should be carried out to document the ability of the DP vessel to keep position after single failures associated with the assigned equipment class and validate the FMEA and operations manual. The type of tests carried out and results should be recorded and kept on board.
- A survey, either general or partial according to circumstances, should be carried out every time a defect is discovered and corrected or an accident occurs which affects the safety of the DP vessel, or whenever any significant repairs or alterations are made. After such a survey, necessary tests should be carried out to demonstrate full compliance with the applicable provisions of the guidelines MSC.1/Circ.1580. The type of tests carried out and results should be recorded and kept on board.
- As indicated in the previous points an FMEA should be carried out for equipment classes 2 and 3.

These surveys and tests should be witnessed by officers of the Administration. The Administration may, however, entrust the surveys and testing either to surveyors nominated for the purpose or to organizations recognized by it.
In every case, the Administration concerned should guarantee the completeness and efficiency of the surveys and testing.
The Administration may entrust the company of the vessel to carry out annual and minor repair surveys according to a test programme accepted by the Administration.
After any survey and testing has been completed, no significant change should be made to the DP system without the sanction of the Administration, except the direct replacement of equipment and fittings for the purpose of repair or maintenance.
Note: Administration means the National authorities maintaining registers of certificates and endorsements.

8.3.3.2 - Dynamic Positioning Verification Acceptance Document (DPVAD)

The Dynamic Positioning Verification Acceptance Document (DPVAD) is issued by or on behalf of the administration. The document should be drawn up in the official language of the issuing country and in the form provided with the guidelines MSC.1/Circ.1580.
If the language used is neither English nor French, the text should include a translation into one of these languages. This document is valid for a period not exceeding five years, or for a period specified by the Administration.

The DPVAD should cease to be valid if significant alterations have been made in the DP system equipment, fittings, arrangements, etc. specified in the guidelines MSC.1/Circ.1580, without the sanction of the Administration, except the direct replacement of such equipment or fittings for the purpose of repair or maintenance.

It also should cease to be valid upon transfer of such a vessel to the flag of another country.

Also, the privileges of the DPVAD may not be claimed in favour of any DP vessel unless the DPVAD is valid.

The results of the DPVAD tests should be readily available on board for reference.

8.3.4 - Training and competencies of DP personnel

8.3.4.1 - IMO Maritime Safety Committee - Circulars 1580 and 738

IMO Maritime Safety Committee - Circular 1580 says:
Personnel engaged in operating a DP system should have received relevant training and practical experience in accordance with the provisions of the 1978 STCW Convention, as amended, the STCW Code, as amended, and the Guidelines for Dynamic Positioning System (DP) Operator Training (MSC/Circ.738, as amended).

IMO Maritime Safety Committee - Circular 738 says:
The Committee, at its ninety-seventh session (21 to 25 November 2016), noted information by IMCA that the Guidelines had been updated to ensure conformance with current best practice and reissued as IMCA M 117 Rev.2, which is annexed to document MSC 97/INF.9. The Committee also noted that there have been no changes to the core content of the Guidelines, and may be amended by IMCA from time to time in the future.
The Committee noted that the above-mentioned IMCA publication identifies training programs, levels of competency, and experience for the safe operation of DP vessels, the most recent one of which is available from the International Marine Contractors' Association (IMCA).

8.3.4.2 - Competencies of Key personnel

As indicated above, IMCA M 117 “The Training and Experience of Key DP Personnel” is recognized suitable for the training, competence, and experience required of all key DP personnel on dynamically positioned (DP) vessels by IMO. This guidance says the following regarding DP competencies of key personnel:

- *Master*:
  The master should understand the need for and implement good communications between the bridge and engine control room and have a comprehensive knowledge of the vessel's operations manuals including the FMEA and related FMEA trials as currently updated.
  Additionally, they should be competent to conduct annual trials, lead DP drills, direct the training of new and existing DP personnel.
  If it is a requirement for them to operate the DP control system, they should have greater or equivalent DP operational knowledge to the senior DPO.

- *Senior Dynamic Positioning Operator (SDPO)*:
  The person fulfilling the role of the Senior Dynamic Positioning Operator (SDPO) is the lead watch-keeper with responsibility for the navigational safety and control of the DP system necessary to achieve the effective and efficient progression of the industrial mission of the vessel whilst on watch.
  The SDPO should hold a formal qualification as a deck officer in accordance with current Standards of Training, Certification and Watchkeeping for Seafarers (STCW) Convention standard or flag state equivalent, and also hold a valid, industry recognised, DP operator certificate.
  The SDPO should satisfy vessel owner/operator requirements to undertake the role of lead Dynamic Positioning watch-keeper and should have been assessed by the master as having the experience, knowledge, and competence to take sole charge of a Dynamic Positioning watch.
  They should also be capable of providing supervision to other Dynamic Positioning Operators, for any DP operation that the particular vessel may be engaged in.

- *Dynamic Positioning Operator (DPO)*:
  The person fulfilling the role of Dynamic Positioning Operator is the second person on the watch and is therefore not in sole charge of the watch. Their required experience and knowledge depends on the type of DP vessel and the complexity of the current industrial mission of the vessel.

  Vessel owners/operators should consider the critical nature of the industrial mission, the Activity Specific Operating Guidelines (ASOG) or its equivalent and take a risk based approach to determine the level of experience, knowledge and competence required by the DPO. The person fulfilling the role of SDPO should be in the same work space and maintain continuous oversight of the activities of the DPO.
  Vessel owners/operators should take every opportunity to train DPOs to be capable of taking charge of the DP watch during DP operations.
  Two recognised categories of DPO can fulfil the role of the second person on the DP watch.
  - Certificated DPO, who is a DP operator who has successfully completed an industry recognised DPO training scheme and is in possession of a valid DP operator certificate. Although competent to be part of a DP watch a DPO acting in this role might not yet be expected to take sole charge of the DP watch.
  - A junior DPO who is a person participating in an industry recognised DPO training scheme managed and/or certified by a recognised industry body and not in possession of a valid DP operator certificate. The junior DPO is to be suitably supervised while on watch by a certificated DPO.

- *Chief engineer*:
  The chief engineer is responsible for ensuring the mechanical and electrical systems of the vessel are operated and maintained in a safe and efficient manner.
  The chief engineer should hold a professional qualification as chief engineer to current Standards of Training, Certification and Watchkeeping (STCW) convention standard or flag state equivalent, and have completed the manufacturer/supplier approved operator training course on the integrated DP/power management control system.
  In addition, if the vessel has a high voltage system, they should hold a certificate for operating an electrical high voltage system and have had instruction on the high voltage system installed.
  The chief engineer should have appropriate experience, knowledge and competence to take charge of an engine room watch during DP operations. He should understand the need for and implement good communications between the bridge and engine control room and have a comprehensive knowledge of the vessels operations manuals including the FMEA and related FMEA trials as currently updated.

- *Senior Engine Room Watch-keeper:*
  This person responsible for the safe and efficient running of mechanical and electrical systems whilst on watch.
  The senior engine room watch-keeper holds a formal, appropriate and current qualification to an approved Standards of Training, Certification and Watchkeeping (STCW) Convention standard or flag state equivalent, and have completed the manufacturer/supplier approved training course on any integrated DP/power management control system.
  In addition, if the vessel has a high voltage system, they should hold a certificate for operating an electrical high voltage system and have had instruction on the high voltage system installed.
  The Senior engine room watch-keeper should have sufficient knowledge, experience and competence to take charge of a watch in the engine control room (ECR) or equivalent during DP operations, and understand the operational requirements of the vessel and the consequences of various failures in equipment of importance to DP operations

8.4 - Prepare for diving operations from Dynamic Positioning vessels

8.4.1 - Prepare the umbilicals

8.4.1.1 - Hazard linked to active propellers and sea-chests

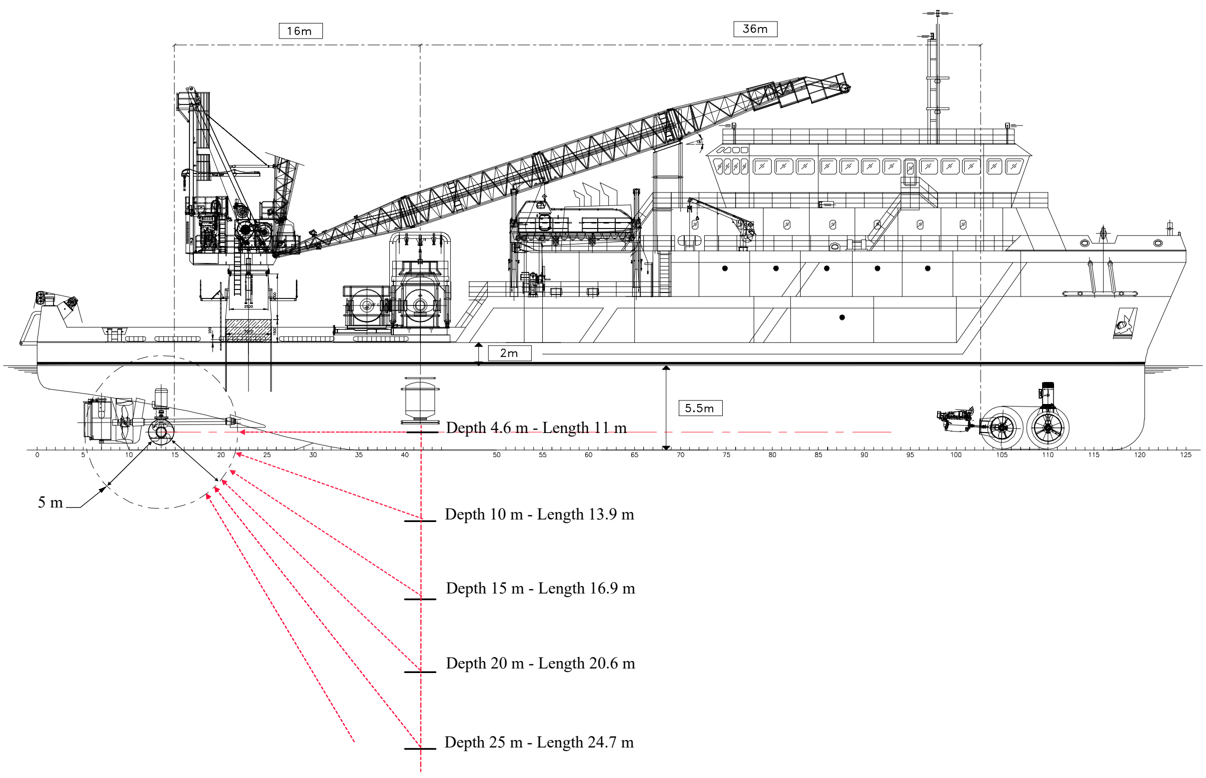
The thrusters and propellers used by Diving Support Vessels and described in point 8.2.3.1 can have propellers up to 5 metres diameter. As they are always active, these propellers are deadly traps for the divers. Also, even though it is common to protect the propellers of tunnel thrusters by grids mounted at the entrance of the tunnel to prevent damage to such equipment by large items or debris. It must be noted that specialists say that these guards are not to be considered capable of protecting divers.
Note that surface-orientated divers working close to the surface are vulnerable to such hazards as the divers can be at the direct proximity of such thrusters. It is less the case with surface-supplied and saturation dives sufficiently deep to be away from these dangers. Note that in the case of shallow dives on the bottom of the sea, the proximity of the propellers with the bottom may impact the divers' visibility.

Inlet sea-chests are usually protected by grids. However some of them have sufficiently strong suction to catch a diver moving at their direct proximity. Such hazards do not usually affect saturation divers as they do not intervene on the hull, and are deployed only when the bell has arrived at the working depth. However, they may affect a surface orientated diver working near the surface or sent to assist the recovery of the saturation diving bell during an emergency.

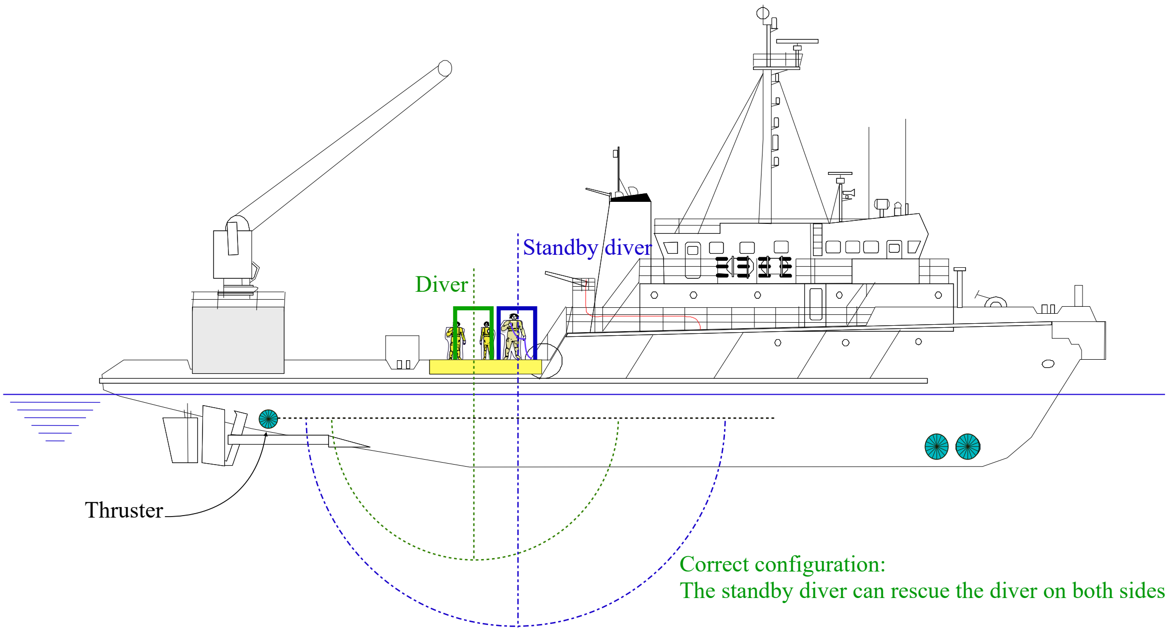
8.4.1.2 - Methods used to protect the divers from active propellers and sea-chests

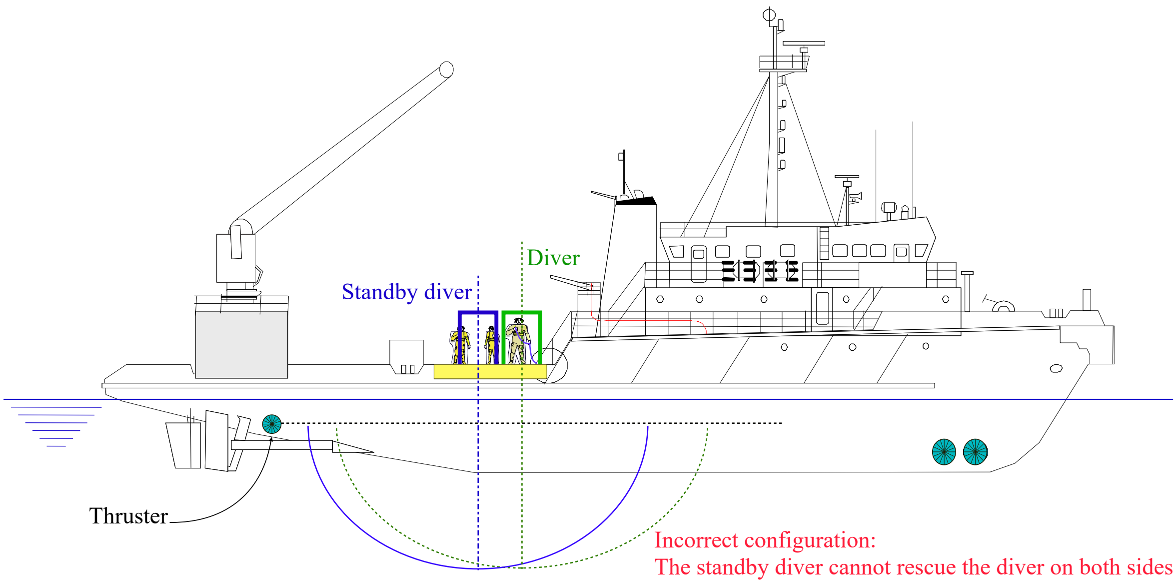
The method to apply consists of organizing the umbilicals and the launching station in such a way that the divers are not in the direct vicinity or contact with the hazards that have been identified:

- The 1st step consists of establishing a precise drawing of the boat where the propellers, thrusters, and sea-chests are identified and precisely located. Such drawings that are based on those used for the construction of the vessel are usually available in any ship. However, they are generally under DWG format or similar, and it may be necessary to clear them from unnecessary details.
- The second step consists in establishing the restrictions:
  - The deployed umbilicals should be restricted and secured, so the divers and bellman are physically prevented from coming into contact with the hazards that have been identified.
  - IMCA D 010 says that a thruster configuration diagram showing the deployment device at various depths, at 10 metre increments, and distance to the nearest thruster should be established. The distance will need to be measured from the centre line of the deployment device to the outer moving part of the thruster "envelope". IMCA also says that when producing the diagram, due consideration should be given to how and where the bellman's umbilical is deployed from and to where it is secured.
  - Most organizations say that the safe umbilical lengths for the working divers are the measurement procedure recommended above, minus 5 metres. Note that for the rescue diver, the safe umbilical distance is calculated using the procedure above, minus 3 m instead of 5 metres. So the rescue diver is 2 m closer to the danger than the diver. *The methods for calculating these distances are explained in the next point.*



- When the deployment of the standby diver and the working diver are from different locations, the proximity of hazards to these locations must be taken into account when calculating the umbilical lengths. It must be noted that such considerations may result in additional restrictions on the length of the working diver's umbilical.
- The standby diver basket must be selected to allow for a safe intervention of the standby diver in any situation. A wrong selection of this basket could make this intervention impossible or oblige to additional restrictions of the working diver's umbilical. Before starting the dives, drawings and calculations must be done to select the proper basket. See the example below with the diver's umbilical range in green and the standby diver in blue.



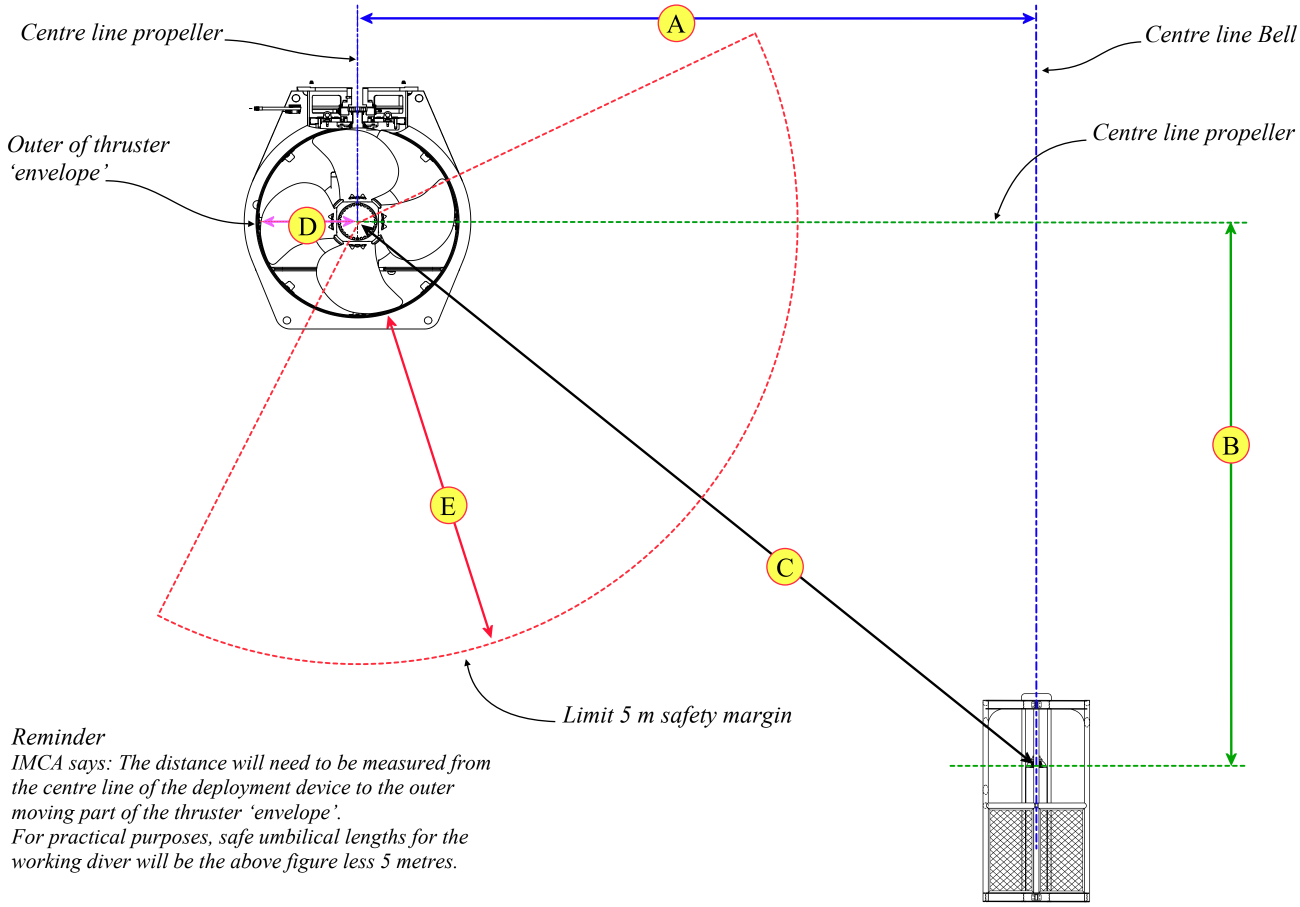


- Rules should be established for the management of the umbilicals:

- The working divers' umbilicals must be marked every 5 m. They must be tended and adjusted at all times during the operations. Also, they must be secured such that the maximum deployment range identified in the risk assessment cannot be exceeded. The devices that ensure the umbilicals must be designed such that they do not slide on the hoses, and do not damage them. Also, it must be possible to remove and reinstall them when required quickly.
- IMCA says that the length of umbilical deployed should be kept to a minimum to prevent it from becoming snagged and to permit easier recovery of a diver in an emergency, particularly when currents are present. At the same time, allowance should be made for vessel movement within the DP footprint. Also, the bellman should monitor the marking and relative position of the umbilical, and immediately inform the supervisor of any concern regarding its safety.
- Also, using negatively buoyant umbilicals may be a safer solution when diving close to propellers.
- All organizations say that the tending point is defined as the in-water point from which the diver's excursion umbilical can be securely tended. Tending can be achieved safely by employing:
  - The tender/bellman located in the deployment device from which the working diver is deployed
  - A additional in-water tender located in an additional device deployed from the DSV, such as a stage or gondola.
  - An unmanned in-water tending point, also deployed from the DSV.

8.4.1.3 - Calculate the divers' umbilicals lengths

The Pythagorean theorem is normally used to calculate the distance of the umbilical according to the recommendations indicated in point 8.4.1.2.
This theorem, which is also called the "Pythagorean equation", says that the square of the hypotenuse is equal to the addition of the squares of the two other sides. So, to obtain the hypotenuse "C" of the lengths "A" & "B" in the drawing below, we can use the formula "$A^2 + B^2 = C^2$ ", and then extract the square root of "C^2" to obtain the real value of "C".



The calculation of the umbilical length of the working diver consists of finding the hypotenuse *(Distance C)* of the distances A & B, from which the radius of the thruster *(Distance D)* and the safety margin (5 m) from the "outer moving part of the thruster envelope" *(Distance E)* are removed:

- The distance "A" is the distance from the center of the thruster to the center of the deployment device
- The distance "B" is the center of the thruster to the point of deployment of the umbilical
- The distance between the centre of the thruster and the waterline (surface of the sea along the hull) must be measured. Note that for a precise calculation of the hypotenuse, the computation must be performed using the vertical distance from the centre of the thruster to the point of deployment at depth (distance B). However, the gap between the centre of the thruster and the waterline must be taken into account to obtain rounded depths starting from the waterline because the recommended reference to adjust the bell is its depth from the surface of the sea. For example, if the centre of the propeller is at 4.5 m below the waterline, the 10 m depth from the waterline is 5,5 m below the centre of the thruster, and the 20 m depth is at 15.5 m from the centre of the propeller, etc. Besides, the distance of the reference point on deck, which is the point from which the length of umbilical deployed is measured, should also be evaluated.
- When the distances are evaluated, apply the formula $A^2 + B^2 = C^2$
- Extract the square root of C^2 to obtain the distance C
- When the distance "C" is obtained, remove the distance "D" *(Radius Thruster)* and "E" *(5 m safety margin)* to obtain the maximum distance of umbilical that can be deployed.
- As the vertical distance "B" of the umbilical is calculated from the centre of the propeller, the distance from this point to the waterline must be added to obtain the depths to be indicated on the drawing. Using the previous example, 5.5 m from the centre of the propeller is 10 m from the waterline (surface of the sea), so the distance to indicate on the reference drawing. Also indicate the distances of the reference point on deck.

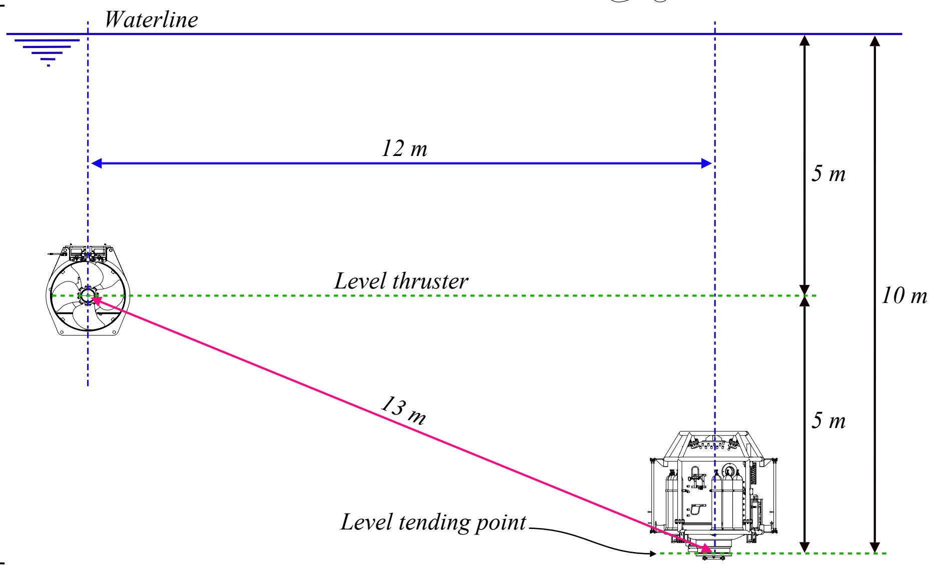
The same method can be used for the calculation of the maximum allowable distance of the rescue diver except that the safety margin is 3 metres instead of 5 m, or by adding 2 metres to the working diver umbilical lengths.

Note that this model does not take into account the fact that the vessel can be ballasted or de-ballasted during the diving operations, which will change the draft of the ship, and so the parameters used for the umbilical length calculation. Because the vertical reference used is the depth of the bell, the hypotenuse can vary as the actual depth of the bell can be above or below the level initially taken for reference. That can be visualized using the following example:

Initial status:

- *The gap between the centre of the thruster and the waterline is 5 metres.*
- *The horizontal of the bell distance from the centre of the thruster is 12 m,*
- *When the bell is lowered at 10 metres, the gap between the centre of the thruster and the tending point in the bell is 5 metres.*

As a result, the length of the hypotenuse is 13 metres.

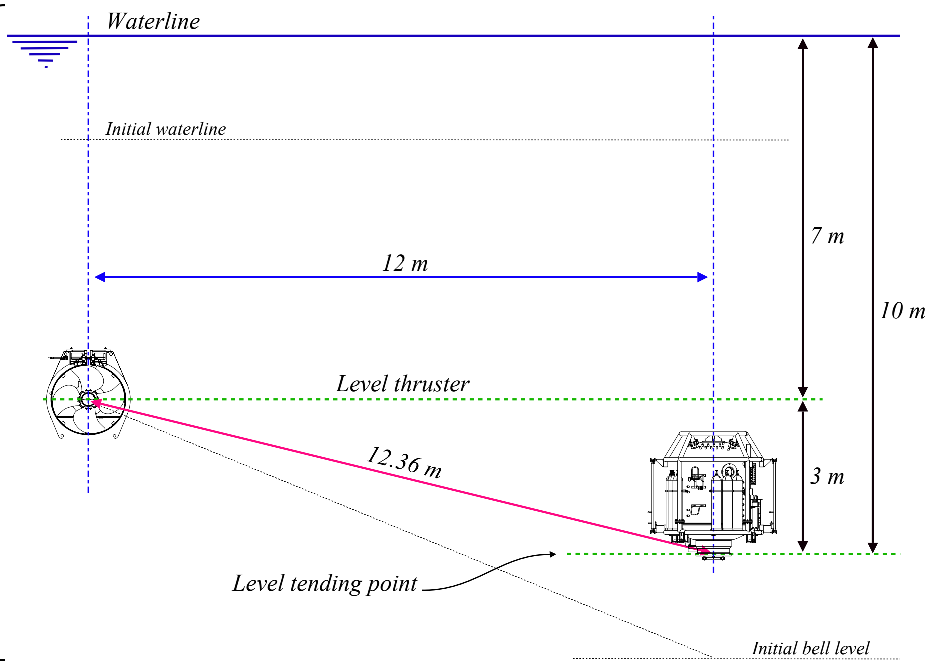


If the vessel is ballasted 2 m deeper the initial status:

- *The draft of the ship is increased of 2 m.*
- *The waterline is 2 m closer to the deck.*
- *The thruster is 2 m deeper.*

Thus, the gap between the centre of the thruster and the waterline is 7 metres, and when the bell is lowered at 10 metres below the waterline, the distance between the centre of the thruster and the tending point in the bell is 3 metres.

As a result, the length of the hypotenuse is 12.36 metres instead of 13 metres. So, the initial distance is longer.

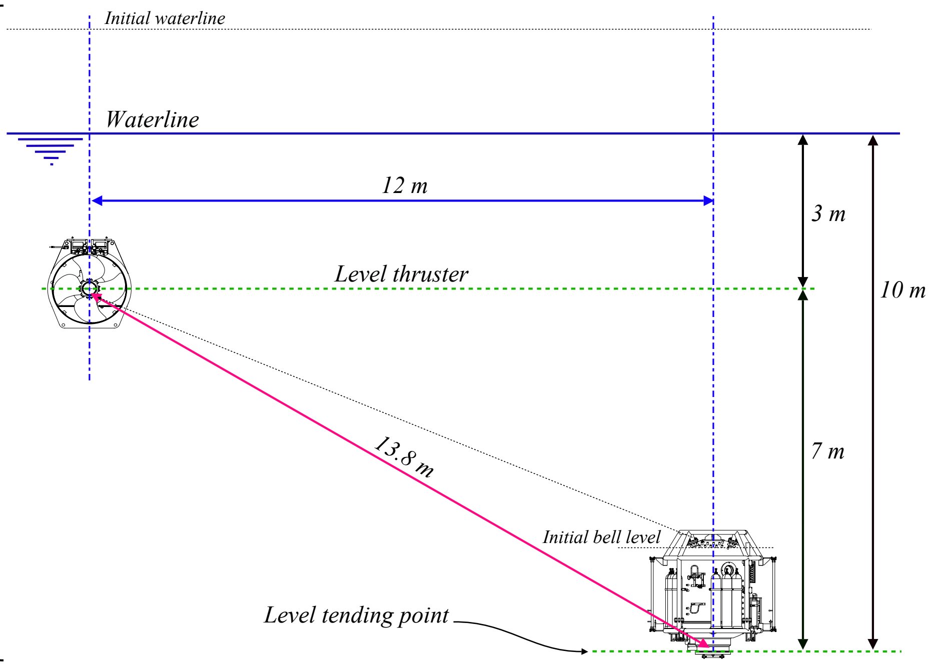


If the vessel de-ballasted 2 metres above the initial status:

- *The draft of the ship is 2 m shallower.*
- *The distance from the waterline to the deck is increased of 2 m.*
- *The thruster is 2 m shallower.*

Thus, the gap between the centre of the thruster and the waterline is 3 metres, and when the bell is lowered at 10 metres below the waterline, the distance between the centre of the thruster and the tending point in the bell is 7 metres.

As a result, the length of the hypotenuse is 13.8 metres instead of 13 metres. So, the initial distance is shorter.



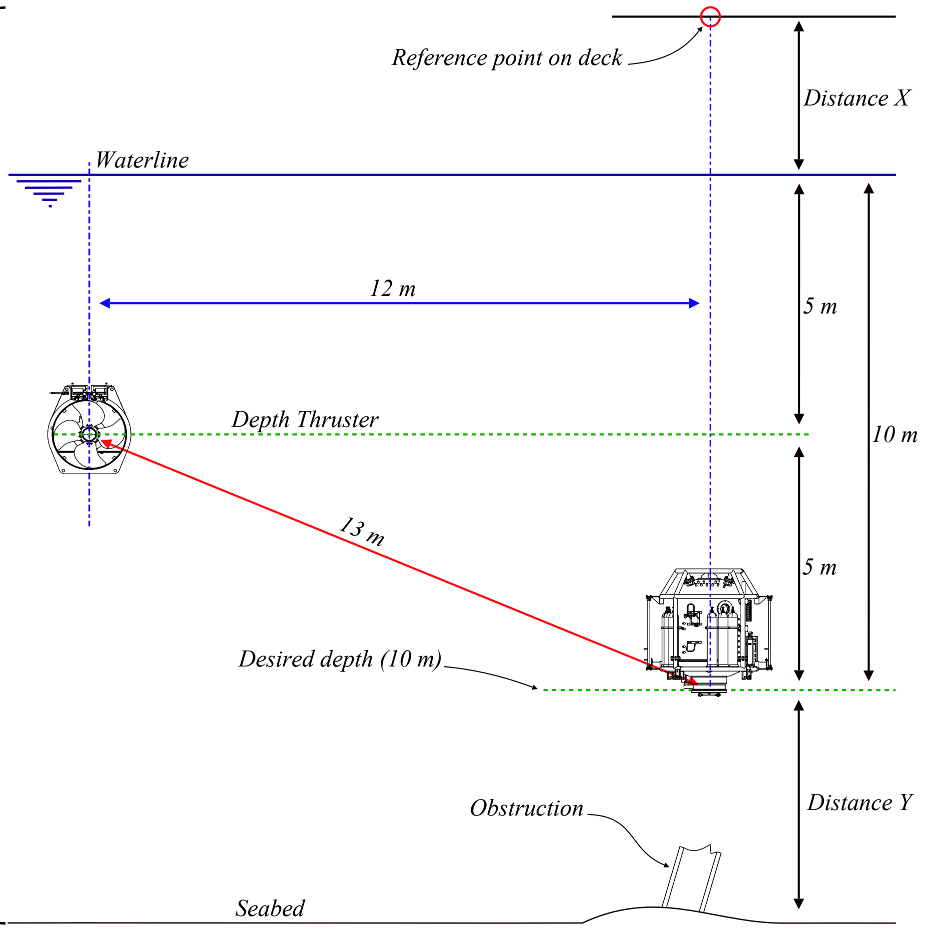
As a conclusion of the above, calculate specific deployment depths for each situation is too complicated and would be confusing for the team. So, the solution is to publish a document that can be used safely, whatever the draft of the vessel. For this reason, when a ship is subject to ballasting and de ballasting, the waterline to select for the calculation of the incremental depths should be the one when the boat is at its maximum draft.

Note that it is usual to check the depth of deployment of the bell using the length of cable deployed from a reference point on deck. However, in the case of a vessel ballasting and de-ballasting, this reference must be adjusted according to the draft of the boat to deploy the bell at the desired depth. If this modification is not implemented, the draft of the vessel varies, and the depth at which the bell is deployed varies accordingly because the length of cable deployed remains the same. As an example, if the vessel is ballasted to have two more metres draft, the reference point on deck is also lowered 2 m, so the bell is 2 metres deeper than calculated initially if it is not readjusted *(see in the scheme below)*. The bell can also be two metres above the planned depth if the boat is de-ballasted 2 m. As a result, the reference on deck is not a valid reference for the depth of deployment of the bell at the desired depth if it remains unchanged.

Initial status:

- *The gap between the centre of the thruster and the waterline is 5 metres.*
- *The horizontal distance of the bell from the centre of the thruster is 12 m.*
- *When the bell is lowered at 10 metres, the gap between the centre of the thruster and the tending point in the bell is 5 metres.*
- *The length of the hypotenuse is 13 metres.*
- *The distance between the thruster and the reference point on deck is always the same. On the drawing , this reference point is 3 m above the waterline (distance X).*

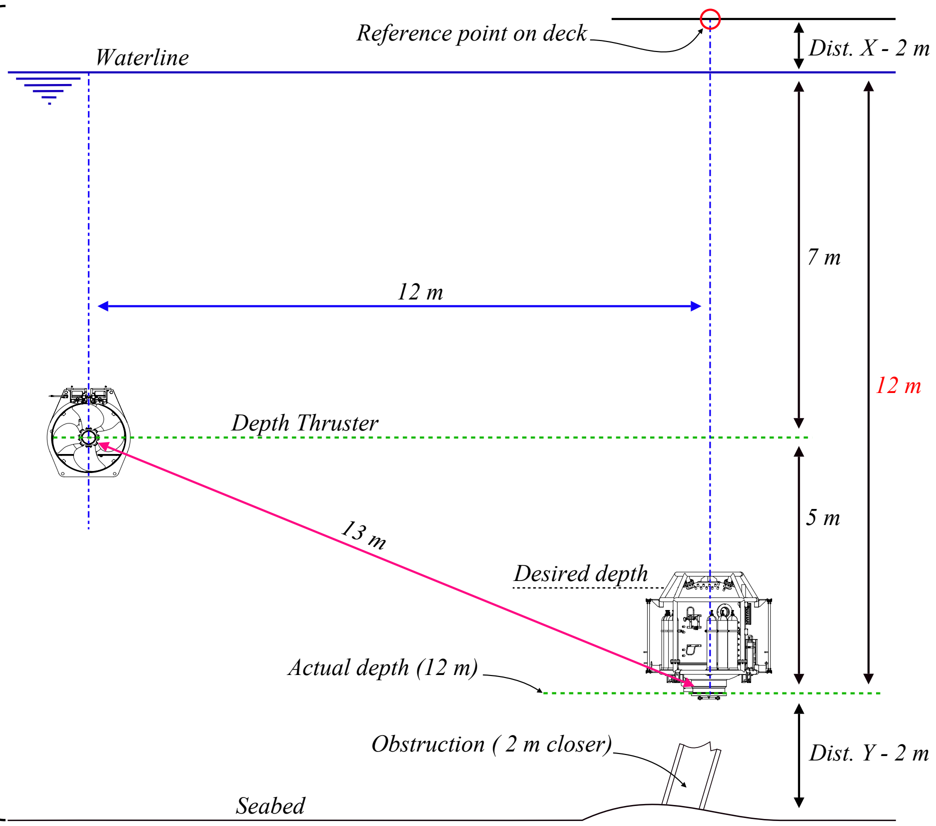
As a result, the bell is deployed at 10 m and its gap from the seabed is the distance Y.



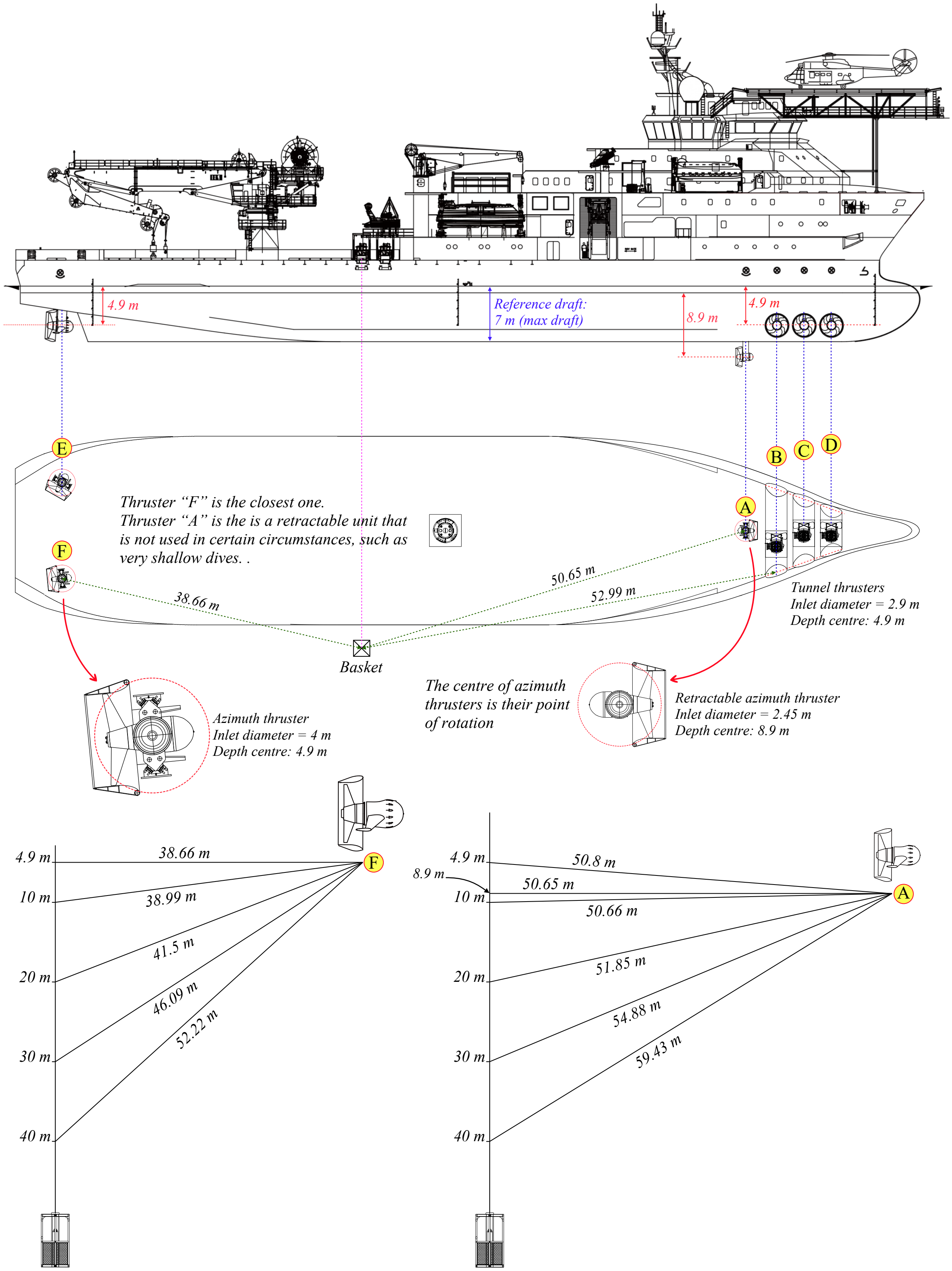
If the draft of the vessel is increased of 2 m:

- *The gap between the centre of the thruster and the waterline is now 7 metres.*
- *The horizontal distance of the bell from the centre of the thruster is unchanged,*
- *The gap between the centre of the thruster and tending point in the bell is still 5 metres.*
- *The length of the hypotenuse is still 13 metres.*
- *The distance between the thruster and the reference point on deck is always the same.*
- *The reference point is now 1 m above the waterline (distance X - 2 m).*
- *As the length of cable deployed is not modified, the bell is now at 12 m instead of 10 m.*

As a result, the gap from the seabed is the distance Y minus 2 m and the bell is closer to hazards.



Another problem that must be taken into account is to verify the exact position of the thrusters to evaluate which one is the closest to the bell/basket.
The lateral view of the vessel is insufficient for this calculation as the thrusters have to be located horizontally and vertically. For this reason, a plan view of the bottom of the ship is to be used to see their exact horizontal position. In complement, the depth of each propeller must be evaluated, so we can have an idea of their position in three dimensions.
As an example, we can see in the plan view below that the thrusters F, A, & B are not aligned with the basket, so their exact distance is to be calculated using the "Pythagorean equation". Note that the point from which the horizontal distance of the azimuth thrusters to the centre of the basket is to be calculated is their point of rotation.
When the thrusters are located horizontally, the depth of the centre of their propeller is to be used to locate them on the vertical axis.
Note that, as indicated previously, the hypotenuses are calculated from the centre point of each device, and the safety limits are added later.



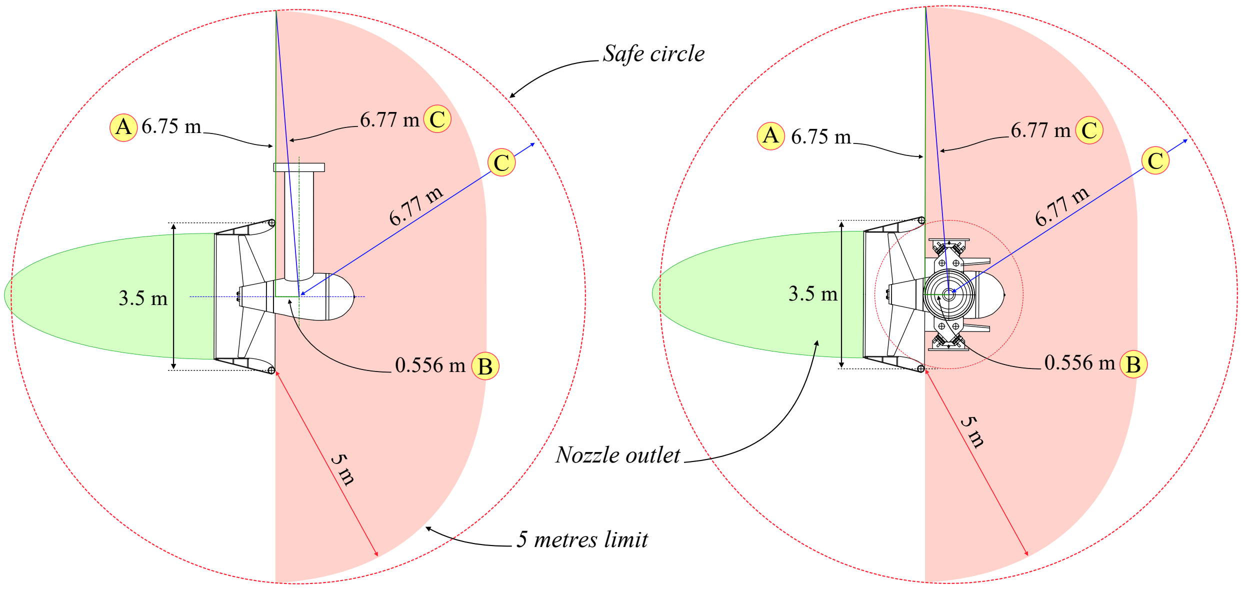
When the thrusters are located, the hypotenuses of the closest thruster are to be calculated for every 10 metres from the first level of deployment and up to the depth where the propellers are too far to represent a danger. This depth also depends on the length of umbilical available in the bell. Usually, the calculation is halted between 60 and 80 metres.

Note that if the closest thruster is retractable, as in the example on the previous page, the nearest unit when this retractable thruster is not used becomes the reference. Also, even though the diver umbilical must be restricted to the closest thruster, it is wise to calculate the distances for the other thrusters as strong currents or sudden vessel moves may push the bell toward them. This problem is more detailed in point 8.4.1.4.

When the lengths axis to axis are calculated, the safety precautions indicated by IMCA and ADCI *(external envelope of the moving parts and 5 m limit),* and mentioned previously must be implemented.
Regarding this point, note that azimuth thrusters rotate 360º around their axis and that their propellers are installed eccentric so that the procedure to evaluate the safe distance from these propellers is different from the one used with tunnel thrusters and fixed propellers. For this reason, the drawings from the manufacturer should be used to evaluate the safe limit into which the thruster can rotate and always be inside a 5 m safety margin as a minimum.
Note that depending on the model of the thruster, the propeller can be installed on the back of the pivoting point, or on the front of it, which influences the procedure of calculation.

- 1 - Procedure for a thruster with the propeller installed on the back of the pivoting point:

- The first step consists of drawing the limit of the propeller "envelope", and the 5 metres safety limit from this "envelope". Note that if the diver is forward the inlet of the propeller, he will be drawn to it. For this reason, the 5 m limit from the inlet of the propeller is outlined in red in the drawing below. However, if the diver is behind the propeller, so roughly in the area figured in green, he will be violently ejected. The spaces between these two zones are sectors that are also to be considered unsafe.
  Note that the 5 m limit from the envelope of the propeller is similar on a vertical and horizontal axis. So we can imagine that the 5 m limit is a flatted half-sphere in which the center point is the crossing of the axis of the propeller with the horizontal rotation axis.
- When the propeller envelope and the 5 m limit are evaluated the circle into which the thruster can rotate without being at less than 5 m from this limit must be evaluated. For thrusters with the propeller on the back of the pivoting point, the proposed procedure is the following:
  - Calculate the distance "A" from the axis of the propeller to the external of the 5 m limit: In the example below, 5 m limit + radius propeller "envelope" (1.75 m) = 6.75 m . .
  - Calculate the distance "B" from the edge of the propeller "envelope" to the pivoting point of the thruster. In the example below, it is 0.556 m.
  - Calculate the hypotenuse "C" of "A" and "B".
  - The Hypotenuse "C" obtained is the radius of the safe circle into which the thruster can rotate.

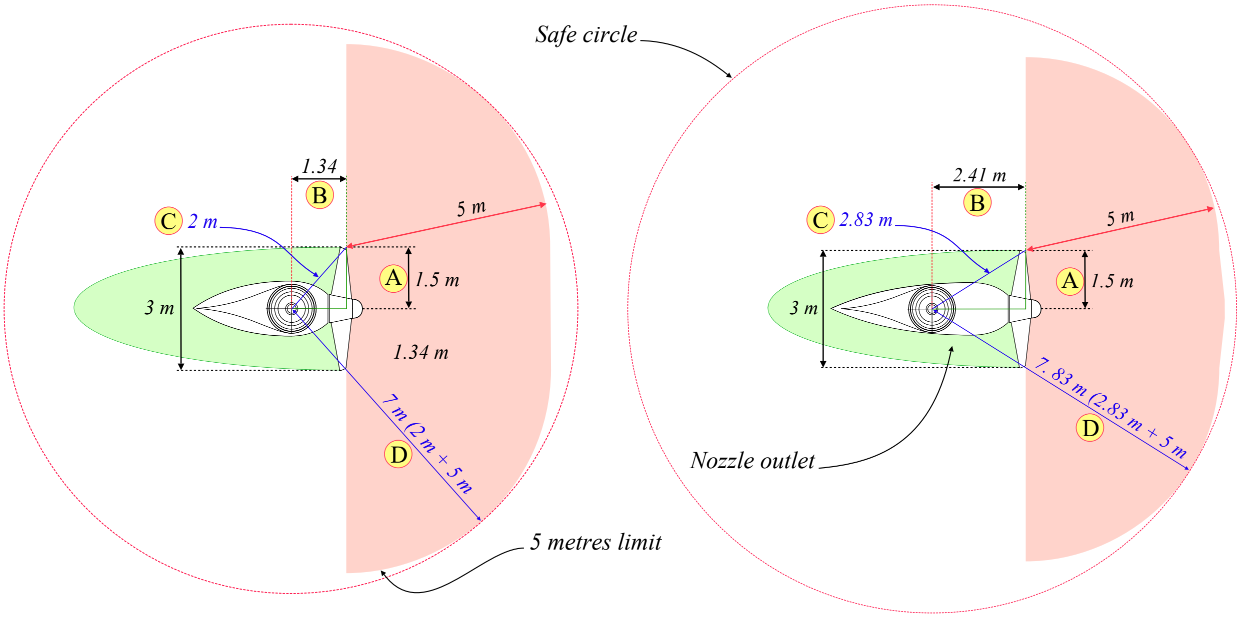


Side view thruster: Vertical axis *Plan view thruster: Horizontal axis*

- 2 - Procedure for a thruster with the propeller installed on the front of the pivoting point:

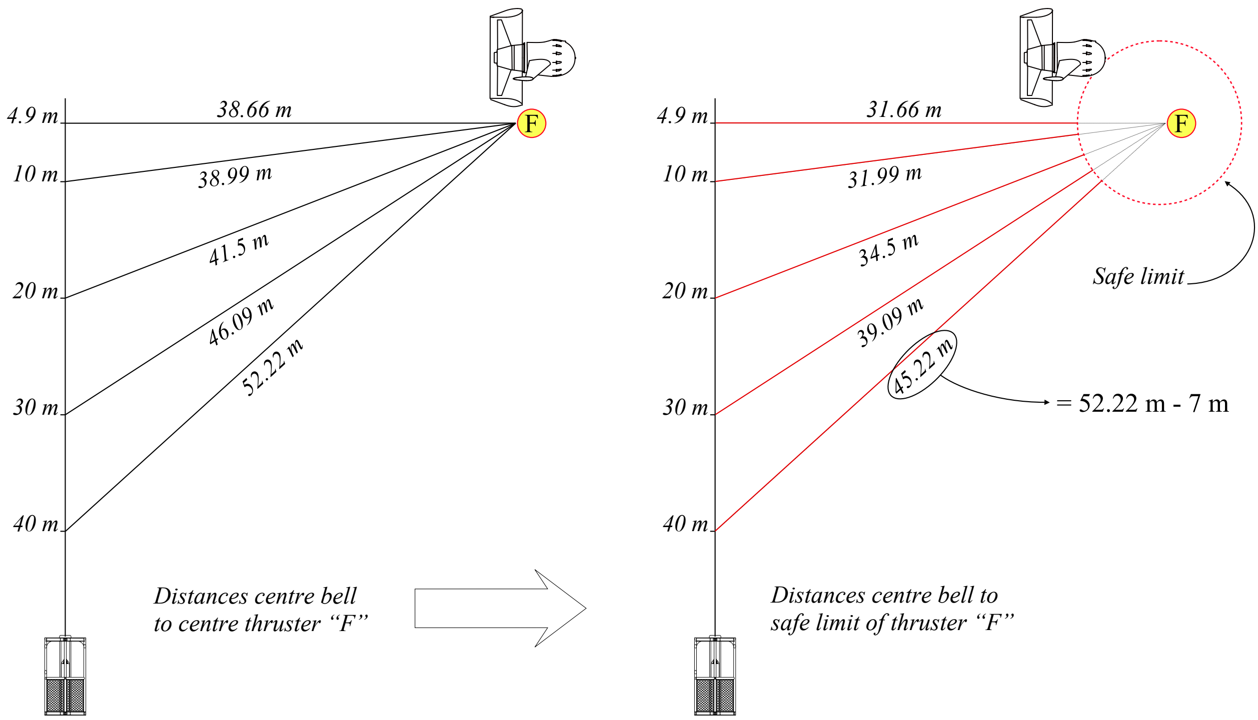
- The first step is similar to the one implemented with thrusters with the propeller installed on the back of the pivoting point. Note that for convenience in the example below, the edge of the blade is taken as reference of the external limit of the envelope of the moving parts.
- When the propeller envelope and the 5 m limit are evaluated the circle into which the thruster can rotate without being at less than 5 m from this limit must be calculated. The proposed procedure is the following:
  - Calculate the distance "A" from the axis of the propeller to the external limit of the envelope of the moving parts: In the example #1 & #2 below, this distance is 1.5 m.
  - Calculate the distance "B" from the edge of the propeller "envelope" to the pivoting point of the thruster. In the example #1 below, it is 1.34 m, and in the example #2, it is 2.41 m.
  - Calculate the hypotenuse "C" of "A" and "B".

- The length of Hypotenuse "C" obtained is added to the 5 m limit: That gives a distance of 7 m in the example #1, and a distance of 7.83 m in the example #2.
- The distance "D" obtained is the radius of the safe circle into which the thruster can rotate.



Example #1 Example #2

When the sphere into which the thruster can rotate within the 5 m safety limit is established, its radius must be removed from the hypotenuse of the axis of the bell to the central point of the thruster, as performed with tunnel thrusters or fixed propellers. As an example, if the radius of the safe circle is 7 m, this distance is merely removed from the hypotenuse as in the drawing below:



When the maximum umbilical lengths are calculated, it often happens that the distances found are precise at the centimetre, and sometimes the millimetre. For practical reasons, these values should be rounded to the immediate shorter decimetre. Example: 49.766 m should be turned to 49.7 m.

The installation of the safety fastenings of the umbilicals should be prepared before launching the dive. The restrictions for the rescue diver are those indicated previously for fixed propellers and tunnel thrusters. Thus 2 m is to be added to the limits established for the working divers. These distances should be shown in the scheme and the table where the maximum umbilical lengths are displayed.

Also, when wet bells are used, it is usual that the bellman acts as the rescue diver. In this case, the classical procedure above is to be implemented as well.

Note that the calculations indicated above should be provided by the manufacturers of Diving Support Vessels. It is, unfortunately, not always the case. The problem is more complicated with boats of opportunity because they are multipurpose ships that are not specifically designed for diving. In case that these evaluations are missing, they must be performed when selecting the vessel as the distance between propellers and the bell is a criterion of selection.

8.4.1.4 - Deployment of divers using in-water tending points

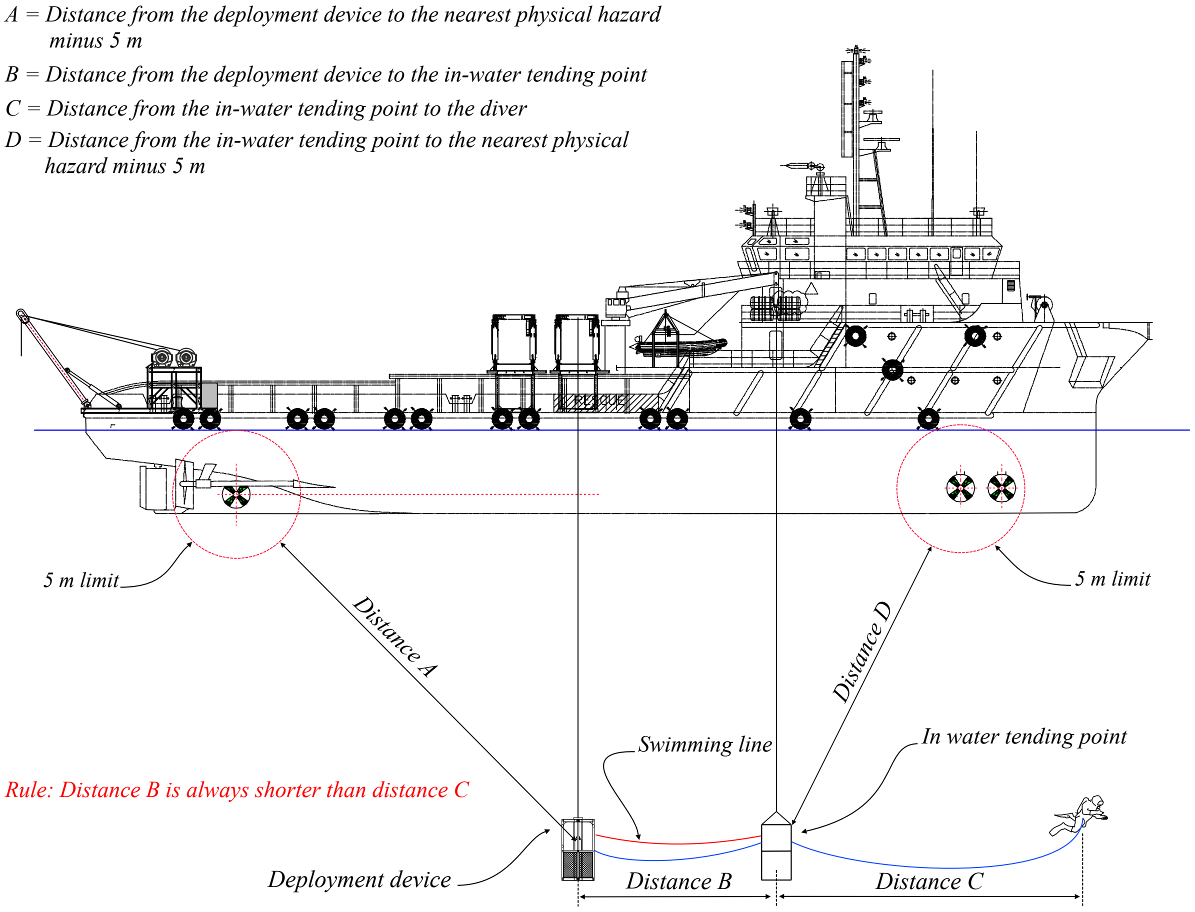
As indicated in point 8.4.1.2, the length of umbilical deployed should be kept to a minimum. So when it is possible to do it, it is preferable to move the vessel above a target instead of extending the umbilicals to their maximum ranges. Also, at depths below 60 m, the distance from the bell the diver can go does not depend on the proximity of the thrusters, but on the length of umbilical available in the bell and on the capacity of his bailout to allow for a safe return to the bell.
However, shallow dives near facilities can be disturbed by problems of access of the boat to some areas due to elements such as platform overhangs, flare towers, lifeboats launching area, bridges, and others.
For this reason, it may be necessary to deploy the divers beyond the calculated safe umbilical length. As indicated in point 8.4.1.2, that can be performed using a 2nd tending point, which can be a basket or a piece of similar equipment such as a squared frame, suspended from a crane, or a similar deployment device located on the vessel. The diver usually passes through this structure to encage his umbilical so that it is secure and can continue sliding. Then, the diver can move forward from this point to the job site *(see the drawing in point 8.4.1.2)* without the risk to be drawn to the closest propeller, despite the extra umbilical length deployed.
The device used to deploy the 2nd tending point must be able to hold a static position when deployed. “A-frame” shaped deployment devices are considered very safe for this reason, and are also simple to implement.

IMCA D 010 provides useful guidelines regarding the methods to be implemented for the safe operation of a 2nd tending point. As indicated in point 8.4.1.2, this guideline classifies the additional tending points into “active” and “passive” tending points, and thus says the following rules:

- 1- Active in-water tending point (manned):

  An active tending point is the arrangement described above with a diver acting in it as intermediate in-water tender. the following criteria should be met:

  - The tending point is held in a static position relative to the vessel that should be confirmed by a beacon.
  - The length of the umbilicals must be restrained as indicated in the previous points.
  - A swim line is fixed between the deployment device and the manned in-water tending point.
  - The working diver’s umbilical is secured to the swim line between the deployment device and the manned in-water tending point at the maximum allowable excursion distance from the in-water tending point.
  - The in-water tender’s umbilical and that of any standby diver is secured to the swim line between the deployment device and the manned in-water tending point at the calculated maximum excursion distance for the working diver from the in-water tend point plus two metres.
  - In the event of the tender becoming incapacitated, the working diver should have sufficient length of umbilical to return to the deployment device without disconnecting his umbilical from the swim line. For this reason, his maximum allowable excursion beyond the in-water tending point is always greater than the distance from the deployment device to the in-water tending point *(see below)*.



- Procedures should be in place to allow for the recovery of a diver in an emergency.
- A risk assessment should be carried out, and the additional measures identified should be implemented.

- 2- Passive in-water tending point (unmanned):

A passive tending point is the arrangement described above but without a diver acting in it as intermediate in-water tender. The procedures that should be applied are the same as those of active tending point except the following:

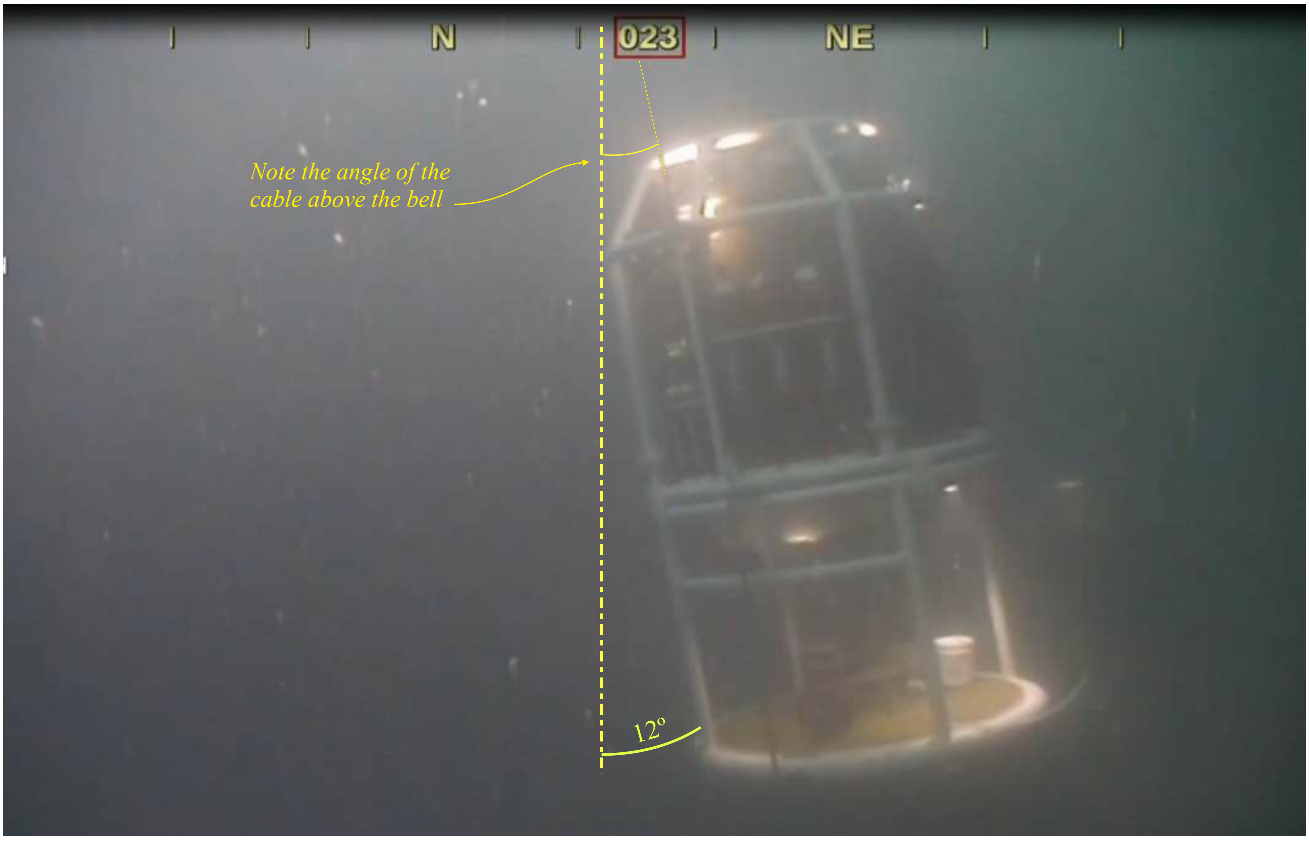
- The bellman's umbilical and that of any standby diver is secured to the swim line between the deployment device and the unmanned in-water tending point at the calculated maximum excursion distance for the diver from the in-water tending point plus two metres.
- If a problem begins to arise when two divers are on passive tending, then one diver should return to the tend point and revert to active tending.

8.4.1.5 - Influence of the underwater currents and sudden moves of the ship on the bell/basket and the umbilicals

Underwater currents that can push the bell/baskets and the umbilicals may establish during the diving operations. Also, due to the density of the water, the bell/basket cannot follow an unexpected move of the boat vertically and thus is hung with an angle during these periods.

The action of the current on the umbilicals can result in large buckles, and an excessive length deployed. This problem is solved with some last generation bell umbilicals that are provided with a dynamic tensioning system that permanently recovers the excess of slack, and maintains it in tension. However most wet bell are not equipped with such systems that are more common with saturation diving bells, and their umbilicals are often partly deployed manually. For this reason, the umbilical of such systems should be secured to the bell wire at regular intervals along its length to prevent it from being attracted by the thrusters. The same procedure should be implemented for the divers umbilicals deployed with a basket. The whips that are used to secure the umbilical should be designed such that they do not damage it and must be able to slide easily along the cable. Also, the distances where these whips are installed on the umbilical must be recorded. Usually, endless soft slings or rope slings with large carabineers that are installed on the main cable of the bell/basket are used for this purpose. The lateral wires can also be used in case of several divers are deployed or the wet bell is used like a basket.
IMCA says that when securing the umbilical along the cable is not an appropriate solution, a risk assessment should identify the maximum safe length of umbilical, which can be deployed in relation to the depth of the bell/basket.

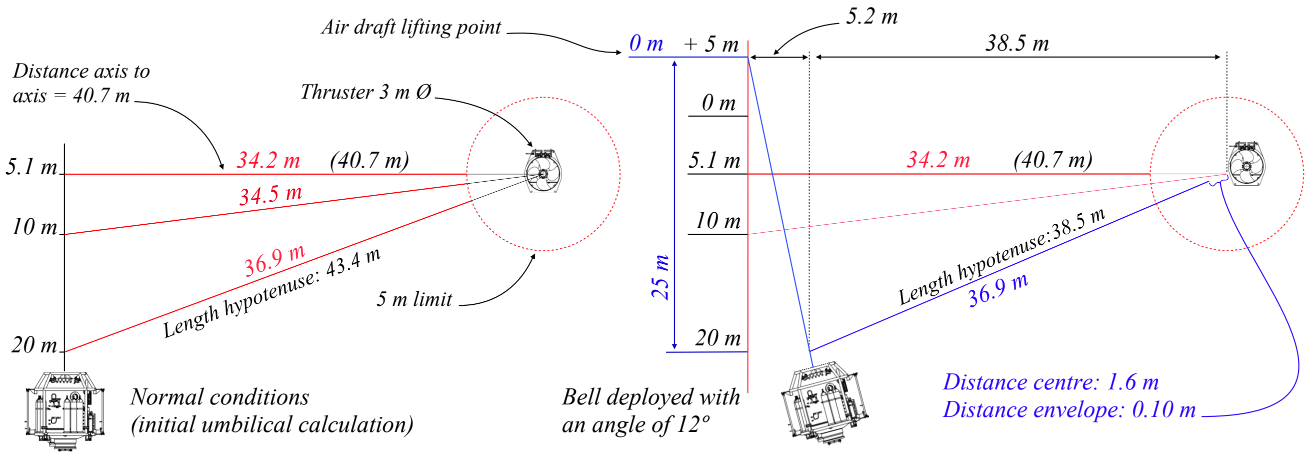
Another problem linked to strong currents is that they can push the bell/basket, which is lowered with an angle as in the photo of the closed bell below instead of vertically. As a result, the bell is not at the planned location, and the initial calculation for the deployment of the divers' umbilicals can be significantly altered. A similar effect may happen in the case of an unexpected violent move of the vessel.



Note that in such cases, the deployment cable usually forms a catenary. However, this catenary varies with the pressure resulting from the current, the depth of the bell, or the force of the sudden pull of the vessel. So, it is challenging to predict its exact curve, and for this reason, only the angle is considered.
Considering the photo above taken at a depth of 50 m, so 60 m below the lifting point, and the visible angle of the bell of 12 degrees, we can evaluate its horizontal distance from the "vertical" of the moon pool to approximately 12.6 m.

The photo of this example has been taken when the bell was descending to a deeper depth where there was no current. So the only problem was to make corrections to be close to the worksite. However, a bell that is not deployed vertically may become a serious problem during shallow dives, due to the proximity of the propellers.
To illustrate it, we can take the example of a bell with a lifting point at 5 m above the waterline, the centre point of the nearest tunnel thruster of 3 m diameter at 5.1 m below the waterline, and a horizontal distance of 40,7 m from the centre of the bell. So, the 5 m safety limit at 6,50 m from the centre of this thruster.

- Under "normal" conditions (initial calculation), the length of umbilical available at 20 m is 36.9 m, and the vertical distance from the pulley of the A-frame is 5 m (air draft)+ 20 m (water depth)= 25 m.
- If the bell is lowered with an angle of 12º from a vertical distance of 25 m, it is shifted 5,2 m from the vertical point. Thus the hypotenuse from this new position to the center of the thruster is 38.5 m.
- If the diver keeps the initial umbilical length of 36.9 m, the end of his umbilical is at 1.6 m from the centre of the thruster and 10 cm from the "envelope". Thus, we can say that this thruster can catch the diver.

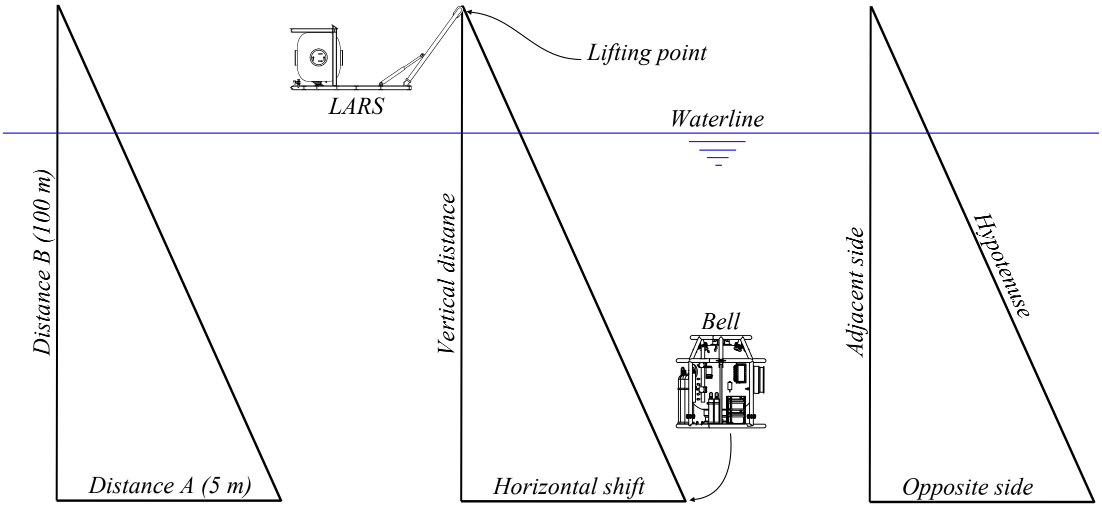


The table below shows the horizontal the deviations resulting from the angles at various distances from the lifting point.

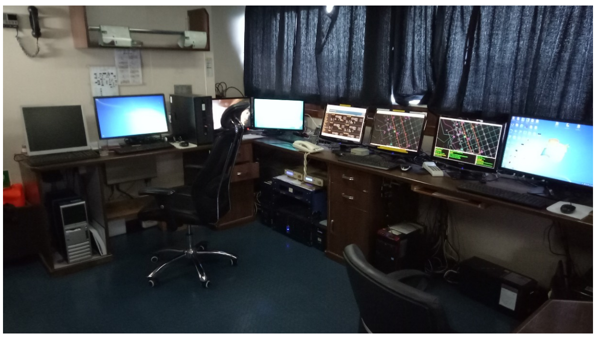
		Angle							
		2°	**4º**	**6°**	**8º**	**10º**	**12º**	**14º**	**16º**
Vertical distance	**5 m**	0.2 m	0. 3 m	0.5 m	0.7 m	0.9 m	1 m	1.2 m	1.4 m
	10 m	0.3 m	0.7 m	1 m	1.4 m	1.7 m	2.1 m	2.4 m	2.8 m
	15 m	0.5 m	1 m	1.6 m	2.1 m	2.6 m	3.1 m	3.7 m	4.2 m
	20 m	0.7 m	1.4 m	2.1 m	2.8 m	3.5 m	4.2 m	4.9 m	5.6 m
	25 m	0.9 m	1.7 m	2.6 m	3.5 m	4.4 m	5.2 m	6.1 m	7 m
	30 m	1 m	2.1 m	3.1 m	4.2 m	5.2 m	6.3 m	7.3 m	8.4 m
	35 m	1.2 m	2.4 m	3.7 m	4.9 m	6.2 m	7.3 m	8.5 m	9.8 m
	40 m	1.4 m	2.8 m	4.2 m	5.6 m	7.2 m	8.4 m	9.8 m	11.2 m
	45 m	1.6 m	3.1 m	4.7 m	6.3 m	8.2 m	9.4 m	11 m	12.6 m
	50 m	1.7 m	3.5 m	5.2 m	7 m	9.2 m	10.5 m	12.2 m	14 m
	55 m	1.9 m	3.8 m	5.8 m	7.7 m	10.2 m	11.5 m	13.4 m	15.4 m
	60 m	2.1 m	4.2 m	6.3 m	8.4 m	11.2 m	12.6 m	14.7 m	16.7 m
	65 m	2.3 m	4.5 m	6.8 m	9.1 m	12.2 m	13.6 m	15.9 m	18.1 m
	70 m	2.4 m	4.9 m	7.3 m	9.8 m	12.2 m	14.7 m	17.1 m	19.5 m
	75 m	2.6 m	5.2 m	7.9 m	10.5 m	13.1 m	15.7 m	18.3 m	20.9 m
	80 m	2.8 m	5.6 m	8.4 m	11.2 m	14 m	16.7 m	19.5 m	22.3 m
	85 m	3 m	5.9 m	8.9 m	11.9 m	14.8 m	17.8 m	20.8 m	23.7 m
	90 m	3.1 m	6.3 m	9.4 m	12.6 m	15.7 m	18.8 m	22 m	25.1 m
	95 m	3.3 m	6.6 m	9.9 m	13.3 m	16.6 m	19.9 m	23.2 m	26.5 m
	100 m	3.5 m	7 m	10.5 m	14 m	17.4 m	20.9 m	24.4 m	27.9 m

There are several methods that can be used to calculate the horizontal shift from the vertical of the launching point:

- The table displayed on the previous page gives approximate horizontal shifts resulting from angles from 2º to 16º, calculated from the vertical alignment of the launching system on deck. Calculating the height of this launching point on deck is very important: It can be found by adding the height of the final pulley of the Launch And Recovery System (LARS), to the air draft of the deck where it is installed.
  This table gives measurements up to 100 m from the point of deployment above the deck. Deeper depths can be evaluated by adding the differential values to the 100 m limit of the table: As an example, for 120 m, add the value for 20 m to the one for 100 m.
- Trigonometry can be used for more precise evaluations. The procedures proposed are similar to those used by carpenters to calculate the slope of a roof. Note that a slope can be displayed in % and in degrees.
  - The procedure proposed to calculate the slope of the deployment device in % consists to divide the horizontal shift by the vertical length, and to convert it in percentage. So, using the drawing below, (distance A / distance B) x 100. As an example, if a bell is 100 m below the last pulley of the LARS, and is shifted 5 m from the theoretical vertical point, the percentage of the "slope" is 5% , which values are 100 (5/100). If the shift is only 4 m, the percentage of the "slope" is (4/100) x 100= 4% .



  - To calculate the slope in degrees, 1st calculate the tangent: Tangent = opposite side / adjacent side, which is in fact the distance of the shift divided by the vertical distance. Thus for a bell that is 100 m below the last pulley of the LARS that is shifted 5 m from the theoretical vertical point, we divide 5 metres by 100 metres to obtain 0.05, which is a value in radians (the real value is 0,0499583957).
    Then, we need to to convert the radians into degrees: To do it apply the formula 0.05 x 180 x 3.14 (Pi). The result obtained is 2.8624, which is the value in degrees with minutes in decimals.
    To covert the decimal value into a sexagesimal value, consider that 2.8624 is 2 + 0.8624. To convert 0.8624, merely multiply it by 60. Thus, 0.8624 x 60 = 51.744, which is the value of the minutes.
    Then, using the same formula, the decimal seconds are converted into sexagesimal seconds: 0.744 x 60 = 44.64. So, the value of 0.05 radians is 2° 51' 44".
  - To find the horizontal shift resulting of an angle in degrees, convert the values in degrees into radians by proceeding the opposite way of the procedure above, and then multiply the value in radian by the vertical distance B.
- The procedures above have some limitations during the diving operations as checking the angle of a cable is not an easy task without adequate tools. As a result, parallax errors may occur. Parallax errors occur when the measurement of an object's length is more or less than the true length because of the eye of the observer is being positioned at an angle instead to be adequately aligned.
  For these reasons, the use of a hydroacoustic beacon seems the best procedure to check the exact position of the bell during the dive. Note that bells are today equipped with such devices and it is also the case of divers.
  Also, surveying and mapping technicians are used to collect data to make maps of the worksite, and provide the position of divers, Remotely Operated vehicle and every item lowered to the worksite. Thus they are highly qualified to indicate the exact position of the bell and its angle of deployment if needed.



Survey station

Hydroacoustic beacons

To conclude on the procedures to be used to calculate the shift of the bell from the theoretical vertical point, it must be taken into account that the underwater current may establish suddenly, or significantly reinforce during a dive and that a failure of the positioning system is unpredictable, despite the improvements manufacturers have made. Also, obliging the diving supervisor to perform such calculations during the operations is a bad idea as he has many things to manage during the dive.

For these reasons, the maximum acceptable angle of the bell and the resulting shift from the theoretical vertical point should be entered into the calculations made for the maximum allowable umbilical lengths taking into account:

- The maximum angle of the bell during diving operations with current speeds conform to those recommended in IMCA D 067, and explained in point 5.8 of this book.
- The maximum angle that may result from a sudden loss of position of the vessel.

8.4.1.6 - To conclude with the preparation of umbilicals

The rules described by IMCA and ADCI regarding the safe distance from propellers and other hazards have probably saved numerous lives. However, these guidelines do not indicate elements such as the possibility to adjust the draft of the diving support vessel, the fact that new ships are equipped with azimuth thrusters that rotate 360 degrees, and that currents and a sudden loss of positions can impact the planned position of the bell and so corrupt the initial umbilical calculations. The main reason is that these guidelines have been emitted since dynamic positioning vessels arrived in the diving industry, and have not been changed from that time. Based on the fact that events that have not happened yesterday may happen one day, it is highly recommended to implement the procedures indicated in this chapter, even though professional organizations publish no modification of the existing rules.

Also, people calculating the umbilical lengths and those managing the dives must have common sense and wiseness.

- When performing umbilical lengths calculations, it is preferable to be a bit restrictive rather than looking to very optimum lengths. It must be considered that the 5 metres and 3 metres limits are the extreme points beyond which the divers are considered endangered. There is no law that forbids giving some more safety margins.
- As indicated, the preparation of the project is an important phase where the umbilical length calculations are to be performed accurately using the construction drawings of the Diving Support Vessel. Uncertainties regarding the design and the position of the thrusters must be solved during this period.
- Also, supervisors should be prudent and avoid using the maximum allowable umbilical lengths during the diving operations. That can be done by an appropriate study of the worksite and the possible movements of the ship, in addition to the option to use a 2nd tending point.
- The design of the vessel used for the operations is also essential: As already said in the previous point, propellers are not a big problem when the worksite is very deep, but they become a hazard during shallow operations. Thus, large boats are preferable for shallow dives. Instead, deep dives can be performed from more reduced surface supports.

Note that there are uncertainties regarding the distances at which the water ejected from azimuth thrusters can affect a diver. That is linked to the power deployed, the diameter, and the rotations per minute of the propeller. However, it seems that no specific study exists at that moment.

8.4.2 - Worksite preparation and selection of the procedures

8.4.2.1 - Main elements to take into consideration

Worksite preparation is a key ingredient for successful diving interventions. Those undertaken from Dynamic Positioning vessels involve precautions that are linked to the fact that these ships maintain their position and heading by using their propellers and thrusters through a computer-controlled machinery and position reference systems that are combined with environmental sensors and controlled from a specific station installed in the bridge of the vessel. Most of these precautions come from the professional organizations previously listed.

- The primary rule is that the vessel and the bell/basket must be positioned in such a way that escape is possible without clashing with existing structures in case of a loss of position or a full blackout of the ship. For this reason, It is recommended to ensure that the bell and its clump weight are always above or out of the way of structures or debris that may catch and damage them. Also, the divers should be ready to be recovered as soon as possible if needed, so they must be informed of all items that may become an obstacle. Note that the structures can be production platforms, mooring buoys, anchor wires, cables, and similar elements that are also hazards for the vessel. For this reason, the following investigations should be implemented before starting the first dive, and preferably during the project preparation:
    - The bottom must be investigated for debris that may harm the bell, or the taut wire if it is planned to use it. the elements found must be logged and indicated on a map.
    - Structures visible from the surface must be precisely logged and investigated underwater. Mooring lines and other items that can be obstructions for the bell must be precisely plotted and represented on the map. Note that dynamic positioning operations in an anchor pattern require particular precautions that are explained in the next point to be able to escape from it safely.
    - Pipelines, electric cables, and their associated structures such as wellheads and PLEMs (Pipe Line End Manifolds) must also be precisely logged.
    - A nav-screen displaying the worksite with the positions of the vessel, the divers and their bell, the ROV,

and any known obstruction together with the vessel's heading and environmental data, should be available to DP operators, diving supervisors, ROV supervisors, Offshore Construction Manager, clients, and every key personnel involved in the operations. The plots displayed must be updated before and during the operations.

- Direction and strength changes of the wind or the currents are likely to cause a sudden variation of the forces acting on the vessel and modify her operating conditions such that operations have to be halted to avoid a dangerous situation.
  The rule is that weather conditions are actively monitored for incoming squalls, change of the atmospheric pressure, and changes in direction and strength of the wind and the underwater currents during the operations. However, tracking the weather also implies studying the prevalent winds and currents in the area during the period planned for the activities as well as atmospheric conditions and records of storms, squalls, and other weather events that have happened during the same period of the year. This investigation has to be done during the preparation of the project.
- The selection of the reference systems that are the most appropriate is of primary importance (refer to the descriptions described in point 8.2.4). Also, precautions should be in place to avoid interferences with other reference systems or some facilities. Among the problems that can be encountered, note the following:
  - Taut wires can be caught by debris on the bottom, conflict with mooring lines, or be snagged to down-lines, or massive objects lowered by the crane. For these reasons, they should not be used in areas where potential contacts with existing structures or debris exist, and their position must be regularly checked by the onboard ROV. In addition, the operations are to be organized such that down-lines must be installed away from them, and lifting operations are not to be performed in their vicinity. Also, down-lines, swimming lines, and lifting areas must be logged on the map of the worksite where the position of the boat is also indicated.
    Another element to consider is that taut wires have some limitations regarding the depths and the weather conditions they can be used for *(see point 8.2.4.2.2)*.
  - Global Navigation Satellite Systems can lose their signal when the vessel is too close to a platform, a Floating Storage Facility, or any massive structure and may have to be replaced by another system (see point *8.2.4.2.2)*.
  - Acoustic systems are subject to interference when the vessel is close to another ship (It is mainly due to the increased thruster wash and noise), or working in very shallow waters.
  - Microwave and laser systems also have limitations linked to weather conditions and their ranges *(see in points 8.2.4.2.3 to 8.2.4.2.6)*
  - Interferences of other systems such as radio reference systems, wind sensors, and communications may happen when the vessel is too close to another one.
- In addition to disturbing the taut wire, down-lines can snag divers, or be broken and be driven into the propellers. For this reason, they must be negatively buoyant and provided with a "breaker" at their end. This breaker must be designed such that it is half the resistance of the down-line. Such small ropes must never be passed in double. Also, Down-lines should be installed only in the areas indicated in the work plan, and handled by experienced people who follow the instructions of the diving supervisor. Such arrangements and procedures are to be organized during the project preparation.
- Divers' umbilicals can be caught by debris or entangled with structures. For this reason, their deployment must be studied during the preparation of the project to avoid obstruction between the worksite and the bell and ensure that the divers will not be injured in case of a pull-off resulting from a sudden loss of position of the ship. Also, IMCA says that when the depth of the worksite puts the diver beyond physical hazards identified by the risk assessment and no restriction on umbilical length is necessary other than consideration of bail-out capacity, then an in-water tending point may be considered to enhance the safety of a working diver who is using an extended umbilical, accessing a structure or working within a jacket structure or manifold.
- It often happens that the divers need to fasten themselves to the structures they are working on to have more stability and not be obliged to fight the currents. In such cases, a "weak link", similar to the model recommended in IMCA D 058, should be used to protect them from a sudden pull off due to the vessel losing position. Note that IMCA says that the means by which the diver's umbilical is prevented from coming into contact with a hazard should not be dependent on this weak link.
- Emergency procedures in place to rescue and recover the divers and the bell/basket are based on those that should be in place when working from an anchored vessel and explained in book #4. However, they should be updated and be adapted to the working conditions and the vessel specifications, Also, a training program should be implemented.

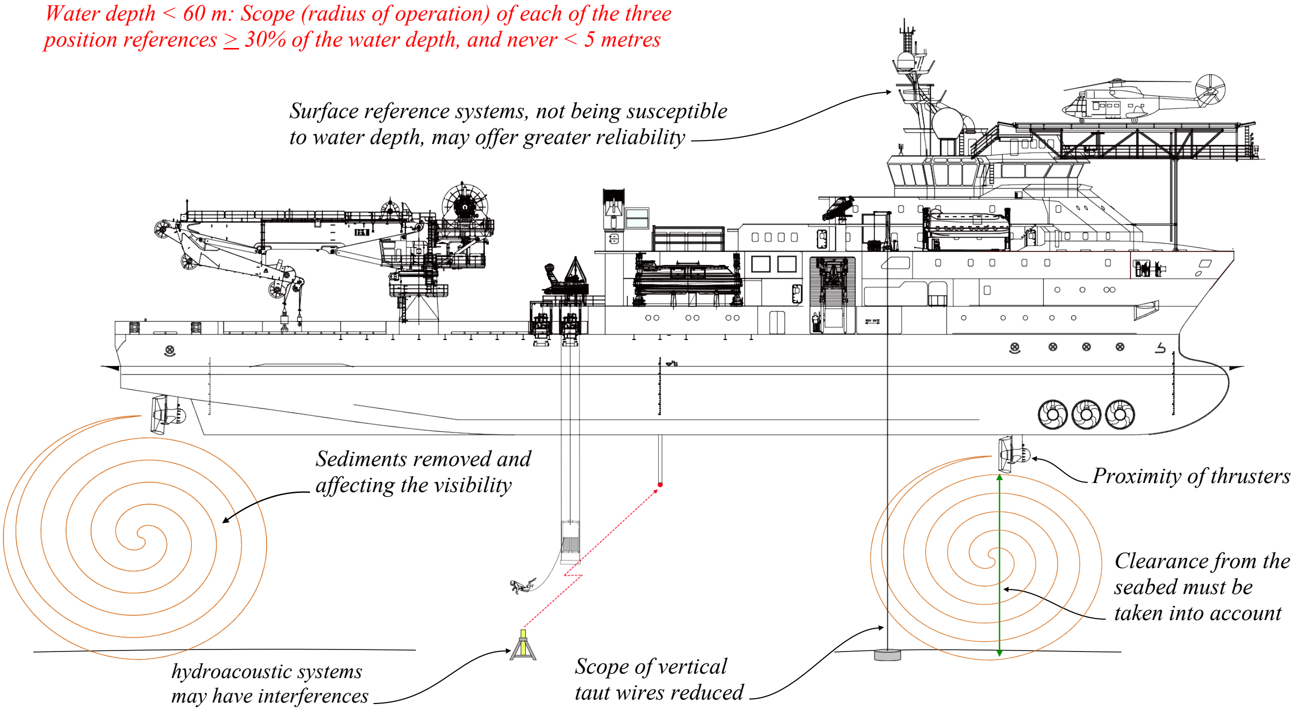
8.4.2.2 - Additional elements to take into consideration for operations in shallow waters

Diving operation in shallow waters have limitations linked to:

- The draft of the vessel and its minimum safe clearance from the seabed, taking into account that thrusters may be deployed below the keel.
- The depth of deployment of hydroacoustic poles, if used.
- The depth needed to deploy the bell/basket and its clump weight.

- The proximity of propellers and sea-chests that are permanent dangers to the divers. Also, their proximity to the seabed may affect the underwater visibility or increase their wash effects, which may disturb the communications of the divers and the acoustic reference systems. Regarding these points, note that the calculations of umbilical lengths are already discussed in detail in the previous points. Also, when vessels are equipped with retractable thrusters, the possibility of not using them when they are very close to the seabed should be taken into account. However, deselecting or isolating a thruster can only be decided by the vessel master. The risk assessment should take into account the reduced thrust capability of the vessel that should remain within the Activity Specific Operating Guidelines (ASOG). Also, the thruster unit which have been deselected must remain stopped and isolated as long as the divers are in the water.
- The effects of bad weather conditions that are increased by the proximity of the seabed. Note that it is also the case of current that may be violent and change direction according to the tide, particularly in estuaries and in areas of high amplitudes.
  Regarding this point, IMCA says that the vessel's capability plots may not accurately give the limiting environmental conditions for shallow water and operators should expect higher thruster and generator loads than for the same wind speed in deeper water and, as a consequence, termination of diving support operations earlier than might otherwise have been expected.
- The height of the tides that may affect the possibilities of escape, or make the vessel vulnerable to underwater structures or reefs, particularly in areas of high amplitudes.
- The accuracy of the underwater reference systems that are reduced. It is the case of the taut wire, which amplitudes are limited, and hydroacoustic systems that may have interferences due to the increased thruster wash. Regarding the procedures to solve this problem, IMCA says that each of the vessel's position references should provide position information accurate to ±2% of the water depth. For example, in 30 m of water, the information provided by the reference systems should have a standard deviation of ±0.6 m. Also IMCA recommends the following:
  - There should always be at least three position reference systems on line of which one should be a radio or surface position reference.
  - When working in water depths of less than 60 m the scope (radius of operation) of each of the three position references should be equal to or greater than 30% of the water depth, and never less than 5 m for example water depth =30 m, radius of operation 9 m.
  - Surface reference systems, not being susceptible to water depth, may offer greater reliability. These may, however, have limitations, the acceptability of which should be assessed, for example the Artemis range may be too great for accurate bearing resolution (The standard deviation of the vessel's natural excursions should not exceed one third of the scope of any position reference.)

The elements listed above should be taken into account for the preparation of operations in shallow waters and added to the elements indicated in the previous point



8.4.2.3 - Additional elements to take into consideration for operations inside subsea structures

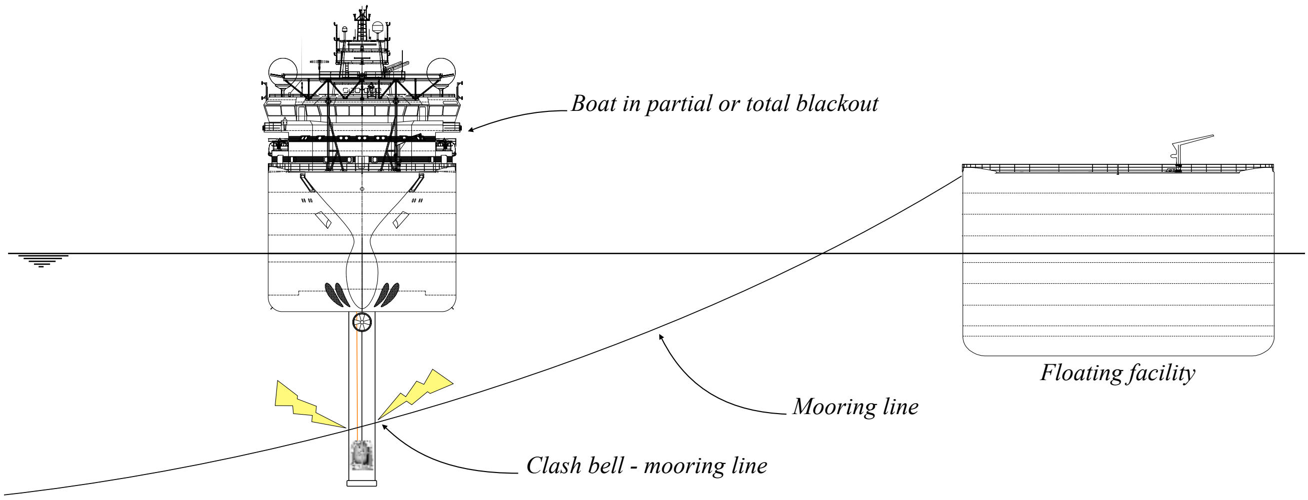
Note that enclosed subsea structures include constructions such as wellheads, Pipe Line End Manifolds (PLEM), and also jackets and platforms.
Entering into confined spaces is not recommended when diving from Dynamic Positioning vessels, as a loss of position of the diving support vessel may lead to a catastrophic event if the diver is stuck inside the structure he is working.

However, such operations may be authorized if appropriate means to ensure the safety of the diver in case of vessel failure are in place. For this reason, a lot of clients require that such operations are performed from a class 3 vessel, or some others require an increased number of reference systems. Also, specific procedures must be implemented for the deployment and the recovery of the divers:

- The structure should be precisely recorded in the operational plot, and its location should be verified by ROV or divers before starting the operations.
- The location and depth of the bell/basket and its clump-weight should be evaluated prior to starting the operations taking into account:
    - The height and the design of the subsea structure and the entry points available to go inside it.
    - The limits given by the mix used and decompression table.
    - The prevalent and actual environmental conditions on site.
    - The vessel’s position reference systems available and its capacity of holding the position within a reduced foot print.
    - The escape way of the vessel in case of a failure and its alignment with the entry point to go into the structure, to ensure that the umbilical of the diver is not stuck or cut in case of a loss of position.
    - The possible leakage of hydrocarbons or other harmful substances. Note that if such risks exist, the wet bell is to be positioned to the side of the structure to prevent the prevailing current from carrying any such substances into it. Also, adequate individual protection should be provided to the divers in addition to a protocol to enter the dome.
- Procedures for the management of the umbilical should be reinforced:
    - Sufficient umbilical length should be provided to allow for minor vessel movement.
    - The diver entering into an enclosed structure should be tended at the entry point by a second diver.
    - During the operations, the underwater tender at the entry point of the structure should ensure that the diver inside the structure can escape from it in case of a sudden movement of the vessel:
        - The umbilical of the diver is away from debris that can damage and catch it.
        - The diver is in the direct line to the entry point.
        - The umbilical of the diver is not in one of the corners of the structure that may trap it and the diver while the vessel is pulling.
        - The umbilical inside the structure should be actively tended. Nevertheless, there should be some slack available at the entrance of the structure to allow for the tender managing the vessel movements.
        - The tender should check his umbilical as well.

8.4.2.4 - Additional elements to take into consideration for operations within an anchor pattern

Diving operations within an anchor pattern are restricted by the presence of the mooring lines to which the bell can be entangled, and the presence of the anchored vessel to which they converge as a funnel. When diving operations are undertaken inside such an anchor lines pattern, the recovery of the divers and of the bell/basket have to remain feasible at all times because the vessel may suffer a partial blackout, which may result in drifting it towards anchor lines. If the bell/basket is not recovered in time, divers' lives can be at risk.



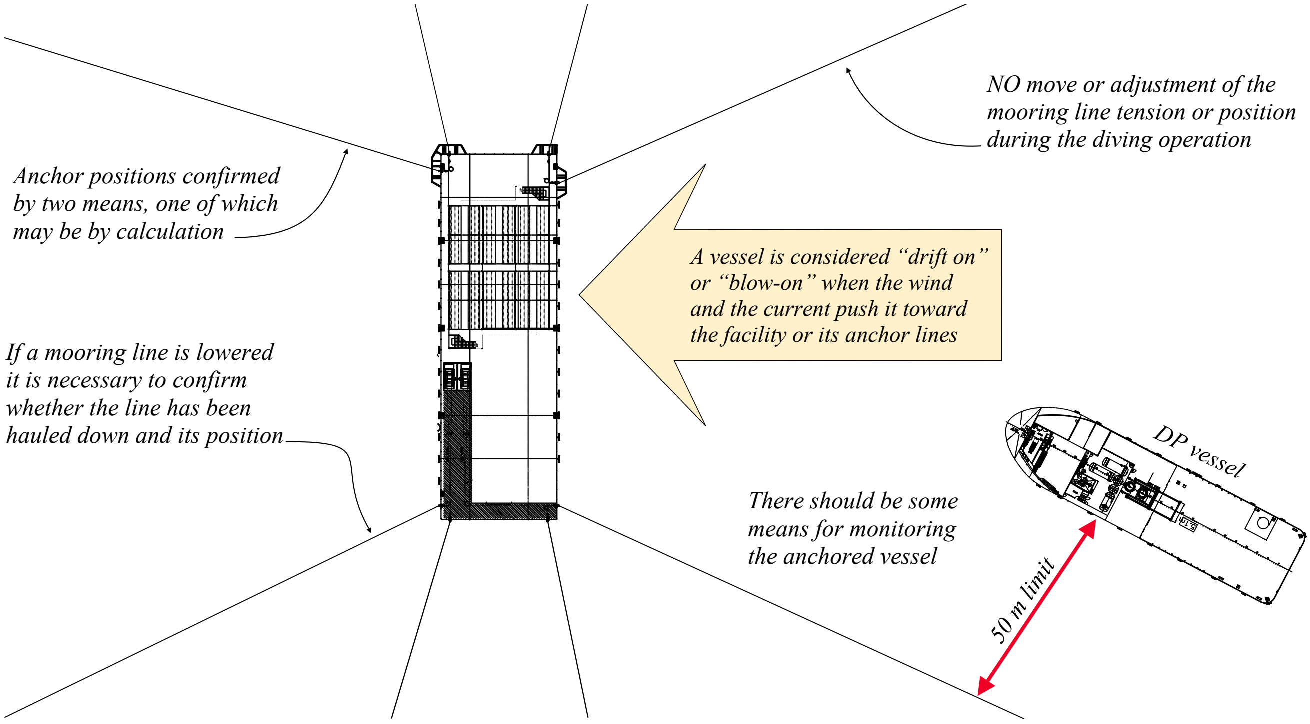
In addition to the clashes of the bell/basket with the mooring line note that incidents such as the collision of the boat with the facility, or The ROV entangled in the mooring lines may happen.
For the reasons indicated above, a lot of clients restrain human-crewed diving operations in their anchor patterns to a minimum. Also, They request that additional precautions such as those described below are enabled:

- Class 3 Dynamic Positioning vessels are mandatory with a lot of companies.
- The anchor positions must be confirmed by the moored vessel, and the location of the mooring lines must be controlled by two independent means, one of which may be by calculation. Underwater inspection and positioning of the mooring lines are usually performed with a Remotely Operated Vehicle (ROV).

Note that the configuration of the mooring lines should be clearly indicated in the working documents and updated on the nav screen.

- The positions of the anchors and mooring lines are valid only one time. It is necessary to recheck these positions in the case that another operation is to be performed in the same anchor pattern later.
- It may happen that a mooring line is lowered to the seabed to facilitate the operations. In this case, it is necessary to confirm whether the line has been hauled down and its new position. Also, reducing the tension of a line may change the stress and the location of the other line that must be checked as well.
- Communications must be in place between the Diving Support Vessel and the anchored facility. Also, there should be some means for monitoring the anchored vessel available to the Dynamic Positioning operators. These means can be radar or laser systems that permanently inform of the distance of floating facility to the DSV.
- When the positions of the mooring lines have been confirmed, they must be frozen for the duration of the diving operations. If readjustment of the lines or the draft of the moored facility is necessary, the master of the Diving Support Vessel must be informed first, and the crew of the moored facility must wait for the recovery of the divers before starting any action. The intention to readjust the lines must be immediately communicated to the diving supervisors, the Offshore Construction Manager, and the client representative on site, and the dive ongoing must be stopped. Then green light to carry on is communicated to the moored vessel. The dives can resume again after a new inspection of the lines and the evaluation of their new catenaries.
- In case the divers have to work on the seabed at the proximity of the touch-down point of a mooring line, precautions to avoid having them caught under the line or having their umbilicals entangled into it should be implemented. If possible, studies should be performed to having the boat oriented to escape from the anchor pattern when the dive is carried out on its edge.
- IMCA says that A horizontal clearance of at least 50 m should normally be maintained between a suspended mooring line and a deployed bell or basket. This nominal distance of 50 m in a “drift on” situation would, in most circumstances, be inappropriate.
  A Diving Support Vessel is considered “drift on” or “blow-on” when the wind and the current push it toward the facility or its anchor lines. In the case of a position loss, there may be a collision with the facility, or the closest anchor line can catch the bell. Note that the Dynamic Positioning Committee says that “even for a vessel operating in DP class 3, the risk of position loss cannot be disregarded”. For this reason, a safe distance that takes into account the time to recover the bell/basket above the lines is calculated:
    - Several recovery drills of the divers to the bell/basket cumulated to the recovery of the bell/basket to the surface must be undertaken. These exercises should be used to evaluate the time that is necessary to recover the bell/basket with sufficient clearance above the lines.
    - A vessel drift test should be performed before entering into the anchor pattern and compiled with the recovery time of the bell/basket to see whether the travel distance allows for the safe recovery of the bell/basket above the mooring lines or not. If the safe recovery is not possible, the dives must not be started.
    - If the drift test is satisfactory, the operations can be resumed. Note that new DP systems, such as an example the K-Pos DP system Kongsberg, provide predicted drift-off and drift-on paths at constant intervals of two to four minutes. Dynamic watch circles are displayed together with the Dynamic Operability Envelopes allowing the operator to position the vessel relative to the target in an optimum way while maintaining required safety margins *(See in the photo below)*.

  - When the first dives are undertaken, several recovery drills of the divers should be performed to ensure that the recovery time calculated is adequate. If it is not the case, corrections should be entered into the software. In case that the new predictions of the software indicate that the safe recovery of the divers is not possible, and so the vessel is outside the Activity Specific Operating Guidelines (ASOG), the dive must be halted and the divers recovered as soon as possible.
  - Note that during the operations, the divers must be recovered as soon as possible in case of a warning from the DP console. For this reason, recovery drills should be undertaken at regular intervals
- Note that maintaining a vessel in an anchor pattern using ropes attached to another DP vessel is not an acceptable practice. Thus, when the vessel is outside Activity Specific Operating Guidelines (ASOG), the operations are merely stopped, and the vessel must standby for favorable conditions to reenter into the anchor pattern. Note that IMCA M 185 "*Considerations about the use of hold-back vessels during DP diving operations*" has been withdrawn and not replaced.
- Regarding the selection of the reference systems, and as indicated before, taut wires may come into contact with the mooring lines if the vessel is very close. The selection of the reference systems should be performed according to the specifics of the worksite. However, IMCA says that if it is technically feasible, a radio or surface position reference should always be used.



8.4.3 - Vessel preparation

8.4.3.1 - International Maritime Organization (IMO) operational requirements

IMO says:

- Before every DP operation, the DP system should be checked according to applicable vessel specific location checklist(s) and other decision support tools such as ASOG (Activity Specific Operating Guidelines) in order to make sure that the DP system is functioning correctly and that the system has been set up for the appropriate mode of operation.
- During DP operations, the system should be checked at regular intervals according to the applicable vessel-specific watchkeeping checklist.
- DP operations necessitating equipment class 2 or 3 should be terminated when the environmental conditions (e.g. wind, waves, current, etc.) are such that the DP vessel will no longer be able to keep position if the single failure criterion applicable to the equipment class should occur. In this context, deterioration of environmental conditions and the necessary time to safely terminate the operation should also be taken into consideration. This should be checked by way of an automatic means (e.g. consequence analysis).
- The necessary operating instructions should be kept on board.
- DP capability polar plots should be produced to demonstrate position keeping capacity for fully operational and post worst-case single failure conditions. The capability plots should represent the environmental conditions in the area of operation and the mission-specific operational condition of the vessel.
- The following checklists, test procedures, trials and instructions should be incorporated into the vessel-specific DP operations manuals:
  - Location checklist *(see the 1st paragraph)*.
  - Watchkeeping checklist *(see the 2nd paragraph)*.

- DP operating instructions *(see fourth paragraph)*.
- Annual tests and procedures.
- Initial and periodical (5-year) tests and procedures.
- Examples of tests and procedures after modifications and non-conformities.
- Blackout recovery procedure.
- List of critical components.
- Examples of operating modes.
- Decision support tools such as ASOG (Activity Specific Operating Guidelines).
- Capability plots *(see filth paragraph)*.

8.4.3.2 - Dynamic Positioning personnel on duty

Note that the competencies and number of persons on duty is also discussed in point 8.3.4 "Training and competencies of personnel". However, to clarify the minimum crew on duty during the operations, note the following:

- Two Dynamic Positioning Operators, capable of operating the system both in DP and manual control without supervision, should be present in the Dynamic Positioning control station on bridge. The Dynamic Positioning committee says that they should have 3 years experience of a vessel engaged in similar operations, at least 6 months of which should have been on the subject or sister vessel. One of them should hold an appropriate deck officer qualification to be in charge of the navigational watch.
  Note that the Dynamic Positioning committee says that the Master should not be considered as one of the required unlimited DPOs for meeting the manning requirements.
  The period of time for which each DPO operates the DP control system should be limited to avoid loss of concentration. For this reason, it is usual that they relay every two hours.
- At least one licensed engineer, with at least 6 months experience on similar equipment and operations, and familiar with the operation of the power plant and the functions of the power management system, should be available at all times, and should be on watch during critical activities.
  Also, appropriately trained technicians, capable of minor fault finding and maintenance of the DP system, should be available at all times as long as the vessel is on DP mode. Some of them must be on watch to control the engine.
  Note that it may be required that an electrician has appropriate high voltage certification, if applicable to the vessel. As with vessel engineers, the electrician/electrical engineer should have at least 6 months experience on similar equipment and operations.

8.4.3.3 - Dynamic Positioning preparation trials and checks

8.4.3.3.1 - Pre mobilization trials:
These trials that are part of the pre mobilization process of a new project are usually carried out by the vessel's crew. They are less rigorous than those of the annual DP trials but more stringent than the field arrival checks. They must confirm the vessel's redundancy concept and station keeping performance after worst-case failure. They must also provide assurance of the integrity of the DP system of the ship and her operational limitations.
Generally, these trials are monitored by a marine specialist mandated by the client.

8.4.3.3.2 - Oilfield arrival checks:
These checks must be carried out upon arrival at the field, and outside the 500 m limit and maybe at a greater distance if required by the onsite manager. Note that the vessel cannot be authorized to enter into the 500 m limit as long as these tests are not successfully completed.
The purpose of these checks is to ensure that the DP system, thrusters, power systems, and others work satisfactory and that the set up of the DP system is correct.
Note that the drift test indicated in point 8.4.2.4 is to be performed at the end of these checks when the vessel is planned entering into an anchor pattern. Also, drift tests may be required by the client for other types of operations.
The onboard client representative usually monitors these trials.

8.4.3.3.3 - Worksite arrival checklists:
These checks should be carried out when the vessel arrives in the position above the worksite. Their purpose is to confirm that the ship is appropriately set up and the elements previously tested work satisfactorily, taking into account the limitations of the position reference.
Regarding this point, ADCI says that in addition to the successful completion of these checks, the vessel must hold station automatically within the defined degree of accuracy until the master and senior diving supervisor are confident that the system is reliably set up before diving operations are permitted to start. That may take at least 30 minutes.
Note that the beginning of the 30 minutes station keeping test must be noted by the diving supervisor and he DP officer.
The onboard client representative also monitors these trials.

8.4.3.3.4 - Pre-dive checklist:
When the 30 minute station keeping test is completed, a series of checks must be performed prior to commencing diving operations. These tests consist to verify that all the visual and audio alarm devices and the main and back up communications are working accurately.
Once these tests are successfully completed, the DPO turns-on the green light of the visual alarms to notify the supervisor that he can launch his dive.

8.4.3.4 - Dynamic Positioning checks performed during the dive

8.4.3.4.1 - Six Hours Status Checklists:
The Diving Positioning Committee say that the purpose of these checks is to record the status of the DP system and configuration. The checks should verify that the vessel's station keeping performance at the working location is satisfactory and, in particular, that the position reference systems are properly set up and operating satisfactorily. No testing is carried out for these checks. The Dynamic positioning Operators should complete the checklist prior to taking over the watch, not during the first few minutes of the watch.

8.4.3.4.2 - Engine control room checklists:
The engine room staff must perform checklists at regular intervals during the operations and keep the DPO on duty informed of the status of the machinery and of any abnormalities that may affect DP operations. Note that it is obvious that these people check the system for all the checklists and trials listed above.

8.4.4 - Elements to take into consideration for vessel movements during the dives

Usual procedures to change of position on the worksite is to recover the divers in the wet bell or the basket, and then to slowly move the vessel to the next location. This procedure is standard when it is necessary to move the divers to a not distant target that is outside the limits of their umbilicals.
However, when the divers are working on a target that necessitates performing long moves, it is often preferable to relocate the vessel instead of giving the divers the maximum allowable umbilical lengths. Also, the Dynamic Positioning Operator may need to readjust the heading or the position of the ship slightly. In such cases, it is common to execute some limited vessel moves without recalling the divers to the bell. The procedures employed are usually based on the one promoted by IMCA provided that the following precautions are in place:

- The Dynamic Positioning vessel is stable and under the full control of the operator.
- The weather conditions allow performing the operation safely.
- Three position reference systems must be online throughout the move.
- The readjustment of the vessel must be organized such that a change of heading and position are not executed simultaneously.
- During the travel, the vessel must not exceed the scope of any one of the three position reference systems. The action must be stopped when any one of them has to be repositioned.
- The DPO and the diving supervisor agree with the move to perform. Also, both of them can stop the operation at any time.
- The move to be performed is identified, and the parameters to execute it safely are entered in the DP system.
- The divers are not far from the bell that can be easily reached. They must be able to be recovered to it at any time.
- The divers are informed of the move to perform and understand it. They also have the power to stop the operation at any time.
- The umbilicals of the divers must be clear and be actively tended during the move.
- The operation can start only when the divers are in a safe location and ready to proceed.
- The move must be executed slowly.
- The DPO must inform the diving supervisor when each phase of the move starts and when it is completed. Such information must be communicated to the divers.

9 - Diving from facilities and self-elevating units

Diving operations from facilities such as jetties, production platforms, and others impose the same rules as working from boats or barges. However, it must be kept in mind the fact that some of these facilities can be in exploitation, which may oblige to implement specific procedures that may be disturbing for the diving team and finally counter productive, or may oblige to stop the other normal activities of the installation for the duration of the dives. For these reasons a close study of the advantages and inconveniences of organizing such operations must be undertaken.

9.1 - Considerations for diving operations

The following elements should be taken into account for organizing diving operations:

- A risk assessment should be made to identify the potential hazards which could impact the planned diving operations and whether some of them may trigger abandonment of the installation.
  Using this risk assessment, the project team must consider whether the project is feasible, and if it can be undertaken while the installation is fully operational or whether the regular operations should be halted while the diving project is in progress. For such an evaluation, The "hazardous areas classification" indicated below must be considered. Note that the operator has to report which parts of the structure are under such classifications.

Zone	Definition	Description	Areas specifics
Zone 0	An area is which a hazardous atmosphere is continuously present.	- Zone 0 classification applies to the internals of process vessels, storage tanks and other similar closed containers. - Any source of ignition in a Zone 0 area would, almost certainly, lead to a fire or explosion	- Please note, hot work is not allowed at any time in Zone 0 or Zone 1 areas. - Because of the presence of hydrocarbons, and the risk of explosion and fire, diving operations cannot be undertaken in zone 0 and 1. - To be acceptable for diving, the area classified as Zone 0 or 1 must be shut down, isolated, depressurized and cleaned, such that the hazard which caused the area to be classified as Zone 0 or Zone 1 is removed for the duration of the work.
Zone 1	An area in which a hazardous atmosphere is likely to occur during normal operating conditions	- Zone 1 classification applies in production areas around process vessels, wellheads, open drains, vents etc. and in all areas where gas is used as the drive material for instruments	
Zone 2	An area in which a hazardous atmosphere is not likely to occur during normal operations.	- Explosive atmosphere is for less than 10 h/year, but still sufficiently likely as to require controls over ignition sources. - In addition to ignition, hydrocarbons are a direct danger to the health of the personnel.	- The control measures over ignition sources must be implemented . - The precautions include fixed & portable gas detectors, audio and visual alarms, breathing apparatus & respiratory escape devices. - There must be a means of escape from the work site, and a refuge at direct proximity. - The dives with decompression can pose a problem of escape and should be minimized.

- The installation of the diving system must follow the same rules as for working from a boat. Thus similar practices such as fastenings inspection and load tests have to be performed.
- The access to the facility and the problems which could be posed by the installation of the diving system must be evaluated closely:

- Installing the system too low can expose it to the waves with no possibility to escape the bad weather. Installing it too high can create an additive hazard, such as the risk of falling at sea increased by the height from which the person is dropping. Also the duration of the recovery of the deployment device from the surface of the sea must be taken into account and minimized.
- Also, the system may have to be installed in areas at the direct proximity of other activities that may be sources of hazards, in addition to the fact that the working zone may be congested. Protections against events such as, but not limited to, mud projections from drilling operations, lifting operations above the dive station, unauthorized personnel crossing the dive station, and others should be organized.

- Electrical supply can be complicated and may oblige the use of generators that are far from the station. That may oblige organizing for people standing by at their proximity during the operations in case of a breakdown. Also, generators must be located in non-hazardous areas. A properly installed and maintained spark arrester that can reduce fire and explosion by trapping the exhaust particles may be mandatory to all thermal engines. Homemade spark arrestors are not acceptable.
- Note that the dive control and machinery rooms should be outside areas where explosive and harmful atmospheres are likely. Also, the client may impose the use of pressurized dive control and machinery rooms in case gas release may happen.
- Another problem is the safe transfer of equipment to these areas that may be complicated. Also, whether the personnel operating the system must be able to access the station without being exposed to hazards arising from the normal activities of the facility. Besides, note that it may happen that the dive system has to be transferred to another part of the facility when several phases of projects are planned.
- The emergency evacuation of the people in the event of failure of the normal evacuation arrangements must be in place with MEDEVAC as well. Training of the diving team should be organized for MEDEVAC and abandonment of the site.
- Procedures for simultaneous operations should be implemented if the facility is active. Also, the diving interventions may have to be interrupted in case of conflicting activities.

- Reliable means of communications, similar to what is normally in place on boats have to be installed:
    - Main and back up communications to the radio room of the facility, or when working on a quay the people who manage it.
    - Main and back up communication to the client representative and the area authority.
    - A reliable dedicated system of alarm installed in the dive station in case of fire and abandon of the facility.
    - Protection from boats transiting in the vicinity must be enforced:
        - The Alpha flag visible. Sometimes it is necessary to install more than one.
        - The lights indicating the work-site applies the same rule.
        - When working on jetties, facilities close to the shore, and zones of traffic, there must be warning buoys, flashing lights, audio warnings (loud speakers), and small patrol boats to warn and push away the vessels and the small fishermen which may sail or fish at proximity. The team must also be briefed and trained to respond quickly to these dangers.
        - The radio operator of the facility must be trained to apply the rules linked to diving operations. He must be sufficiently experienced and "bossy" to manage and keep away the boats that may have to cross the safety area.

Because they do not respect any maritime rule, the small fishing boats are a hazard difficult to manage when diving from a facility.
A preventive system must be in place to ensure that they will not go in the vicinity during the diving operation.

9.2 - Additional considerations for surface orientated diving operations

Note that surface orientated diving may be used to rescue a bell near the surface. That can also be possible at depth if the saturation operations are performed at depths that are reachable to divers deployed from the surface.

- IMCA D 025 says that there must be particular attention to the recompression facilities, which should be located in an appropriate position to facilitate the safe escape of diving personnel in the event of an emergency. Also, note that in case that dives with decompression are planned, this chamber must be reachable within limits indicated in the decompression table in case that planned or emergency surface decompression is to be performed. That means that even though the decompression planned is in the water, surface decompression must be available at all times.
  In complement, when surface supplied diving is to be organized from an active installation, decompression should be minimized or forbidden in the case that the environmental conditions cannot always be under control and that events such as harmful or explosive gas release or a fire may happen and trigger abandonment of the site.
- In addition to the decompression chamber on site, there must be an alternative decompression facility within a reasonable travelling distance from the dive site.
- Gas reserves conform with IMCA D 051 should be connected or at the immediate proximity of the system.
- There must be a means of recovery of a diver adrift at the surface, or personnel fallen at sea.
- The signalization of the work-site must be clear and visible, particularly when working at close proximity to the shore and areas of traffic

10 - Diving with Remotely Operated Vehicles (ROV)

10.1 - Purpose

Remotely Operated Vehicles (ROV) have been developed since the end of the sixties. They are used for any kind of tasks such as the inspection of the seabed or structures, the maintenance, and the construction of facilities, the research of wrecks, the rescue of submarines, and others.
Because they are uncrewed vehicles, they are commonly used to access areas that are not reachable by divers, or for operations where there is a risk to harm them. In parallel to these activities, they are used for diving support tasks such as the inspection of the worksite and the bell, the surveillance of the divers and their surroundings, bell rescue, and others. So, they are today considered indispensable for the monitoring of such operations.
However, depending on the model used, ROV diving support activities may expose divers to potential problems such as for an example:

- Entanglement of the umbilical of the ROV with those of the bell or divers.
- Injury to a diver through collision, propellers, or Electrical shocks.
- Obstruction of the escape way in case of a loss of position of the vessel.

For these reasons, a detailed risk assessment must be carried out to prevent or minimize these potential problems before launching the bell. Nevertheless, to be efficient and not unnecessarily restrict the use of this tool, it is crucial to have a minimum knowledge of it and of the rules that have been put in place by organizations involved with diving operations.

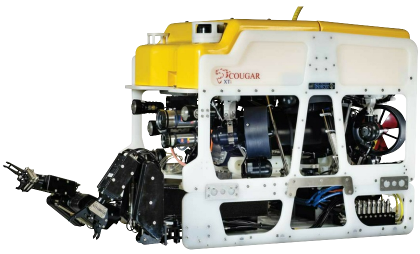
10.2 - ROV classifications

A lot of diving and ROV organizations identify Five main classifications of Remotely Operated Vehicles (ROV), which are those established for a very long time. They remain the main ones, despite that the industry made a lot of new hybrid products that cannot be formally classified in one of these categories.

Class 1 - Pure observation

Pure observation vehicles are physically limited to simple video observation tasks. They cannot undertake any other task without considerable modification and are usually very small machines that can be carried by hand.
The machine in the illustration is a "Seabotix LBV150".

Class 2 - Observation with payload options



IMCA classifies "class 2A" the vehicles that are capable of carrying additional tools such as cathodic protection measurement systems (CP), additional cameras, sonar systems, small manipulators, pipeline and cable detectors, etc… They are capable of operating without loss of their original function when carrying at least two additional sensors.
IMCA classifies "class 2B" the vehicles capable of carrying the same equipment of class 2A plus light working manipulators and tooling skids to be able to perform light construction support, intervention and survey tasks.
The machine in the illustration is a "Seaeye Cougar XTi".

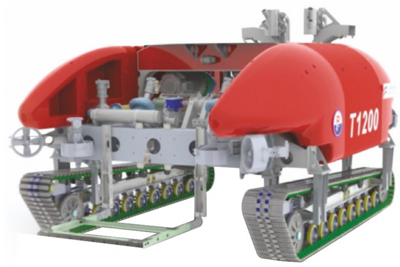
Class 3 - Work-class

These vehicles are large enough to be fitted with additional sensors, and special tools, and have at least two manipulators.
They should have a multiplexing capability allowing additional sensors and tools to be operated without being hard-wired through the umbilical system. Also, the umbilical should have spare conductors to allow operation of payload equipment.

- IMCA classifies Class 3A the machines with less than 200 kg payload and 100 kW power. We can call them "light work class"
- IMCA classifies Class 3B the machines with at least 200 kg payload and 100 kW power. We can call them "Heavy work class"
- Note that NORSOK U 102 uses a similar classification.

The machine in the illustration is a "Forum Perry XLC-C" *(Class 3B Imca)*.

Class 4 - Towed or bottom crawlers



Towed vehicles have no propulsive power, although they may be capable of limited manoeuvrability. They travel through the water by the hauling action of a surface craft or winch.

Bottom crawling vehicles move primarily by exerting ground pressure on the sea floor via a wheel or track system, although some may be able to “swim” limited distances.
These vehicles are often used for the detection or the burying of electrical and communication cables and similar tasks.
The machine in the illustration is a “Forum Perry XT 1200”.

Class 5 or IMCA class 5 and 6 - Autonomous Underwater Vehicles (AUV) and prototypes

IMCA separates these vehicles into two classes: Class 5 for prototypes, and class 6 for AUV. Other organisations use one class only.

Prototypes are vehicles specially designed for a particular project that cannot be classified as above and are not produced in series.

Autonomous Underwater Vehicles (AUV) are not linked to the surface by a tether and can work without requiring input from an operator. They are designed to run on very long distances.
These vehicles are used for tasks such as mapping, video imaging of targets, acoustic pinger searching, black box finding, etc.
IMCA identifies them into class 6A (< 100 kg) and 6B (≥ 100 kg).
The machine in the illustration is an “ECA A18D”.

Particular case of heavy observation class/ light work class

The classification given by IMCA and NORSOK does not provide any minimum performance to ROVs class 2B and class 3A, which results in difficulties in identifying them. To clarify this point, we can say that a "light work class ROV" has two manipulators, can be equipped with additional tools similar to those used by class 3B ROVs, a payload >100 kg & < 200 kg, a power equal or more than 100 kW, and vertical or horizontal thrusters delivering at least 100 kgf.
The machine in the illustration is a "Seaeye Panther".

Hybrid machines

H-ROV

These machines combine several technologies, such as those used for wired class 3 ROV with those of Autonomous Underwater Vehicles (AUV), or those of observation ROV with those of bottom crawlers.
An example of such products is the “ECA H-ROV” *(see the illustration on the right side)*, which is a class 3 ROV designed with an integrated power battery that allows for remote operations through a single optical fiber or fully autonomous intervention supervised through acoustic communication.
Such machines are used for remote or autonomous operations such as seafloor and relief survey, inspection, intervention on wrecks and structures.

Another example from the same manufacturer is a machine named “Rovingbat” *(see the photo on the left side)* that is an ROV designed to inspect and clean vessel hulls and that is provided with crawlers to progress on the support it is glued to by its thrusters. This machine can swim to its target as a normal ROV. Machines for similar applications are proposed by other manufacturers.

10.3 - Description of ROV systems

10.3.1 - ROV classes used for direct support of surface-supplied diving

Remotely Operated Vehicles (ROV) are commonly used to support surface-supplied diving operations. However, opposite for saturation operations performed with single bell systems, surface supplied diving operations are performed with a means of deployment of the rescue diver from the surface. For this reason, ROVs are not considered essential for such operations, even though they should be used to support them.

- Class 1 ROVs do not carry any tools and are not designed for payload. In addition, they are usually very small machines that are not powerful enough to fly in strong currents. They are used for observation only.
- Class 2 machines are designed for all types of inspections, but their payload is limited to less than 100 kg. Also, their power is limited, and some models have difficulties swimming through strong currents. Besides, their tools are usually fitted through an additional frame mounted below the machine and designed only for small tasks such as grabbing small objects and samples, performing small cleaning tasks, or manipulating inspection tools.
- Light work class ROVs are often found. They are cheaper and lighter than class 3-A & 3-B and can perform many tasks. They are powerful enough and sufficiently fitted to recover a wet bell.
- Work class ROVs are powerful machines often used to perform complementary tasks of the divers. They can also be used to rescue a closed bell, and of course, recover a wet bell

10.3.2 - Description of a Class 3 ROV

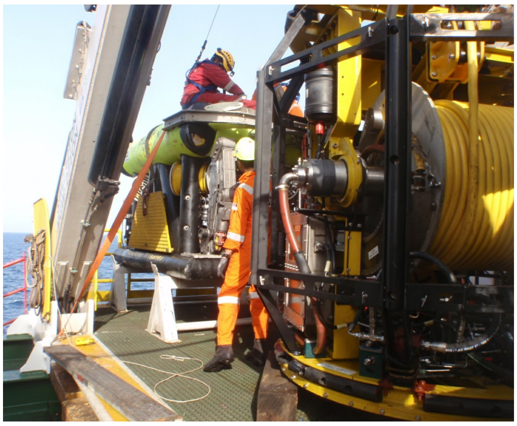
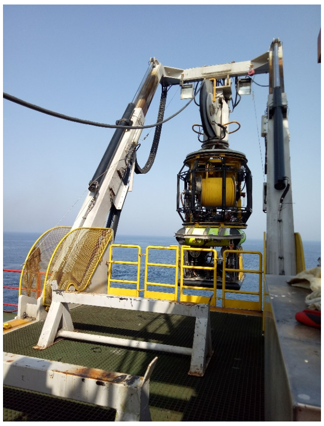
10.3.2.1 - Machine used for this purpose

Describing ROVs is not easy, and the best procedure for providing consistent descriptions is to refer to practical examples of machines that are among the most complex. For this reason, Class 3 ROVs are taken as reference, with a lot of explanations based on models, such as the Merlin WR 200, fabricated and exploited by IKM Subsea AS

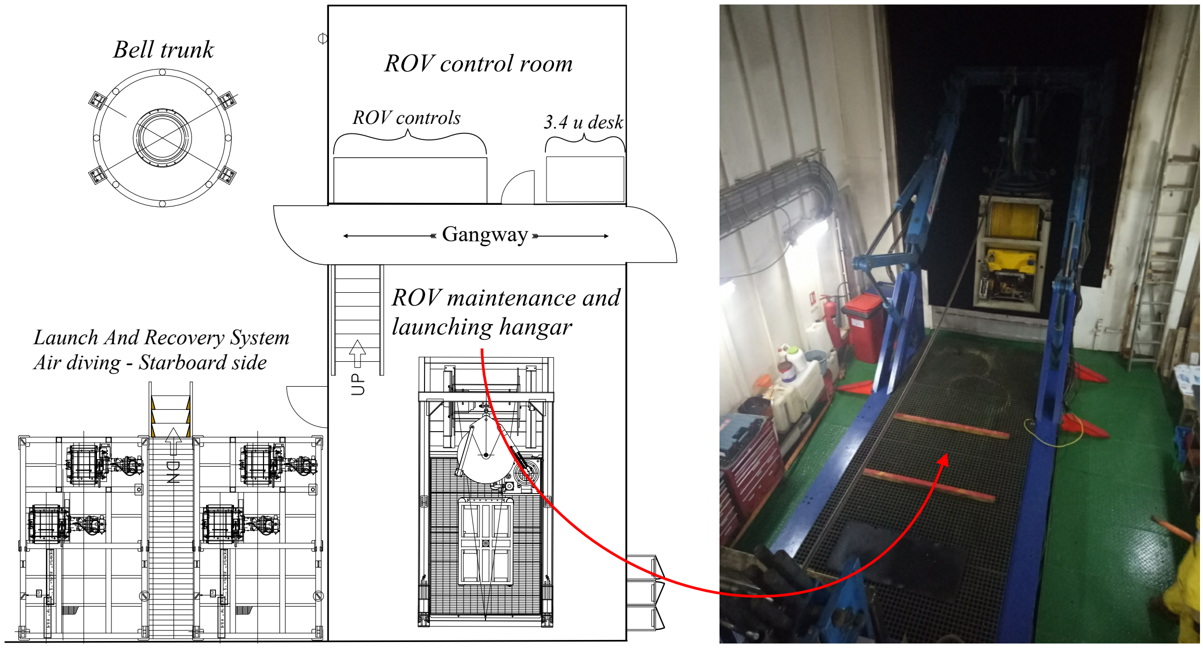
10.3.2.2 - Types of installation

Class 3 ROVs are massive machines whose weight varies between 2000 and more than 5500 kg. For this reason, they cannot be easily manipulated. Two types of installation are encountered that are similar to those of diving systems:

- Transportable systems are designed to be installed on any location sufficiently broad to accommodate them. The control room and electrical devices are protected in containers, and the launching and maintenance interventions on the machine are performed on the deck. Depending on the possibilities, the electrical supply is provided through the electricity supplied by the surface support, or by transportable generators.
  The advantage of such systems is that they can be installed on vessels of opportunity. Their main inconvenience is that the machine and the people intervening on it are not protected from the weather conditions.


- Integrated (built-in) systems are installed inside the vessel. The ROV is deployed from a hangar that is closed by a watertight door when it is not in use, so its deployment and maintenance are performed from a protected area. The inconvenience of such systems is that the replacement of some components can be complicated.

- Note that ROVs can be launched from a moon pool instead of the side of the vessel.

10.3.3 - Electrical supplies

10.3.3.1 - Power supplies

The main power supply of a work class ROV may be provided by the electrical system of the vessel (it is the case with built-in systems) or by customized transportable primary and backup generators (it is often the case with portable systems). Note that generators must be designed to work offshore and be equipped with spark arrestors and earth leakage protection, as described in point 2.3.24 “Generators” of the document “Description of a saturation system”.
The primary input is typically between 400 & 480 Volts/ 50-60 Hz AC, with power between approximately 150 & 380 KW, depending on the machine. As an example, the “Merlin WR 200” system needs 150 kW of 440V/50-60Hz.
Note that in addition to the primary input, an auxiliary input of 220 - 240 Volts is usually provided by the generators for domestic usages.

10.3.3.2 - Power Distribution Unit

The primary input is fed via a junction box to the Power Distribution Unit (PDU), from which it is spread to the elements that compose the ROV system, such as the Launch And Recovery System (LARS), the Tether Management System (TMS), the control room and consoles. Step up and step down transformers are used to adjust the current to the needs of the components listed above.

- A step-up transformer is a device in which the output voltage is higher than the input voltage. That is obtained by the use of more turns in the secondary wiring than the primary one of the device. The reason for stepping up the tension is to overcome line losses through the umbilical of the ROV. Note that power supplies of ROVs are commonly between 100 and 3300 volts AC.
- A step-down transformer uses the inverse principle of work of the step-up transformer to provide an output current with less voltage than the input supply. That can be used to adjust the current to some components. Also, some models of ROV may use low voltages current such as 160 volts AC.

10.3.4 - Control room

10.3.4.1 - Control and sensing systems

A lot of ROVs have their controls and displays grouped in only one control console. However, these elements are split with some last generation work class ROVs, so the pilot is sat in a comfortable armchair where all the controls are provided through joysticks and touch-screens installed on the arms of the seat, and are separate from the main displays.
Note that, the joysticks are usually analog systems that emit varying Direct Current (DC) signals of approximately 5 volts through appropriate resistors according to their position. These signals are then digitalized and multiplexed before being transmitted to the vehicle electronics through the umbilical. The commands operated from the touch screens are digital as they are directly processed through a computer.
To understand the difference between analog and digital commands, note that analog commands emit electric pulses of varying amplitude. Instead, digital systems emit signals into a binary format using zero or one, where zero represents an "off" state, one an "on" state, and combinations of these 1 and 0 are used to create messages.
Also, multiplexing is a method to combine multiple analog or digital signals into one signal over a shared medium.
A "two-way data link" allows transmitting the data from the control console to the vehicle and those from its sensors to the surface. These sensors consist of transducers that convert one form of energy, such as pressure, temperature, or

acoustic, to electrical signals. These analog signals are then converted to digital and transmitted in the same manner as the control signals. The information from the sensor is displayed to the pilot on the control console.
Note that the telemetry system works on the "master/slave principle", the surface electronics being the master, and the vehicle being the slave. As a result, if the vehicle power is switched on before the console power, a situation may arise whereby the slave is enabled but does not receive any command from the master unit, which may damage the telemetry system. For this reason, ROV pilots are taught to switch on the console power first, then the vehicle, and at last the hydraulic system, and to proceed in reverse order to shut down the system.

Video monitors that can be switched are used to show video pictures and information from sensors as required. Liquid Crystal Display (LCD) technology allows displaying video signals on large screens 45" where 17 "monitors were used previously with cathodic tube combos.

As an example of the description above, the Merlin WR 200 is provided with two pilot chairs and a separate desk/space for the supervisor. Large monitors on the wall display essential information regarding the condition of the machine during the operations. Also, the commands and touch screen controls are installed on the seat.

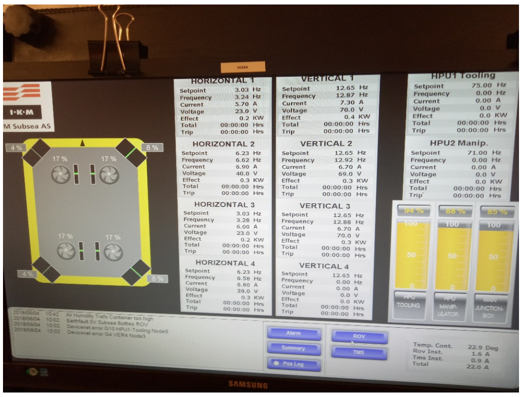
Microphone communications to bridge and dive control

Touch screen control

Control manipulator

Mouse control computer

Joystick control ROV



Display of the power used by the thrusters

As a comparison with the last generation machine above, the photos below show the control console of an ROV of the previous generation where cathodic screens are still used in parallel with LCD monitors. Note the analogic commands composed of classical switches and potentiometers that have been replaced by touch screens on the WR 200.

10.3.4.2 - Protection against harmful and explosive gasses

This system is provided with ROV systems designed to work where harmful and flammable gas releases are likely and within the 500 m limit of all offshore installations of some countries. Its function is to provide a pressurized safe area against these gasses by preventing their intrusion into the cabin and sensitive zones when the team is at work and stopping the machine in case of a failure of this protection.
When the system starts up, the fan of the Room Pressurization System (RPS) pressurizes the cabin to a pressure of approximately 0.75 millibars, and the gas monitoring system prevents any attempts to start the machine during a test period of approximately 20 minutes. If no gas is detected, the ROV can be switched on.
During the dives, the internal pressure of the cabin is maintained above a predetermined minimum pressure. Should it fall below this level (usually 0.25 millibars), the system automatically shuts down the ROV system to prevent the ignition of the flammable gas that may be present in the room atmosphere as a result of an electrical arc.

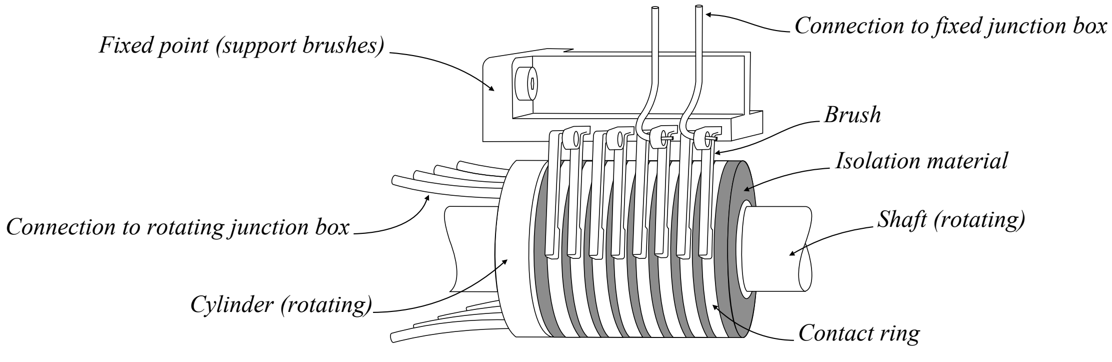
10.3.5 - ROV deployment systems

10.3.5.1 - Launch And Recovery Systems (LARS)

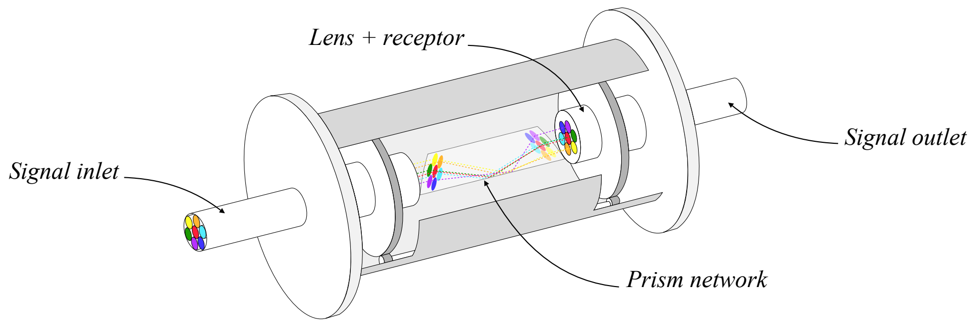
Work class ROVs can be deployed overboard and recovered using hydraulic cranes or ‘A’ frames.

These devices are powered by Hydraulic Power Units that are activated by a 3-phases 300 to 480 volts electric motor, the power for which is taken from the Power Distribution Unit (PDU).
Note that the umbilical that transmits power and data to and from the machine is also used as lifting cable with a lot of machines. In this case, the lifting strength is provided by a steel wire wrap that surrounds the umbilical.
The winch where this umbilical is stored is electro-hydraulic, and designed to provide the pilot with information such as the power delivered and the length of umbilical paid out. Some units are activated by the same Hydraulic Power Units as the jacks, where some others use a separate HPU. Also, to transmit the power and the information to and from the ROV, the system must be equipped with the following elements:

- The fixed junction box, which is a two way junction box that groups power, video signals, and data signals to and from the umbilical.
- The rotating junction box, which is attached to the main drum of the winch and carries out the same function as the fixed junction box.
- The slip rings provide interfaces between the fixed junction box and the rotating junction box. The unit consists of several contacts called brushes mounted on a fixed point above a small cylinder, and connected to the fixed junction box. The cylinder is coupled to the winch drum and rotates. There are several rings made of conducting materials installed around it and separated by isolating elements. These rings are connected to dedicated wires that carry the electricity and data to the rotating junction box. Thus, these rings make physical contact with the brushes attached to the fixed point. As a result, electrical continuity is maintained during the rotation of the winch drum *(see the drawing below)*. Note that some systems use a disc instead of a barrel, but the principle of contact is the same. These systems are called “pancake slip ring”.



Also, light signals from the optic fibre must be transmitted as well. This is done through a prism network and then onto a lens that converges the light onto a receptor in the rotary section of the joint before it is sent down the umbilical. Slip rings used to transmit optic fibre signals are called “Fiber Optic Rotary Joints (FORJ)”.



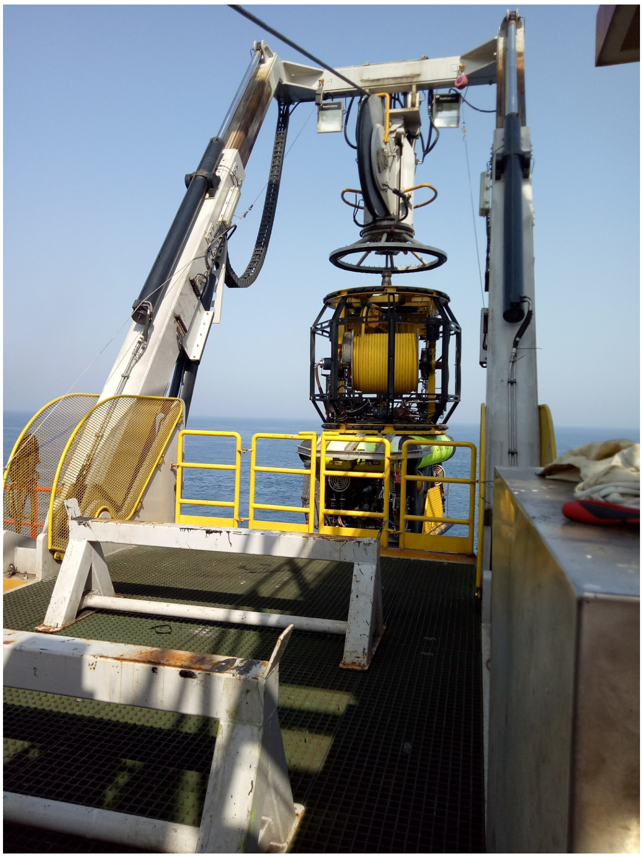
The cranes are usually provided with telescopic booms, which reduce their space on deck and increase their manoeuvrability. Also, the winch is mounted under their jib, so that it can pivot with it.
The deployment of the ROV using a crane usually consists of lifting it above the deck and then rotate the crane laterally

To lower the machine to the water. A latch allows releasing it when it is in the water *(see below)*.

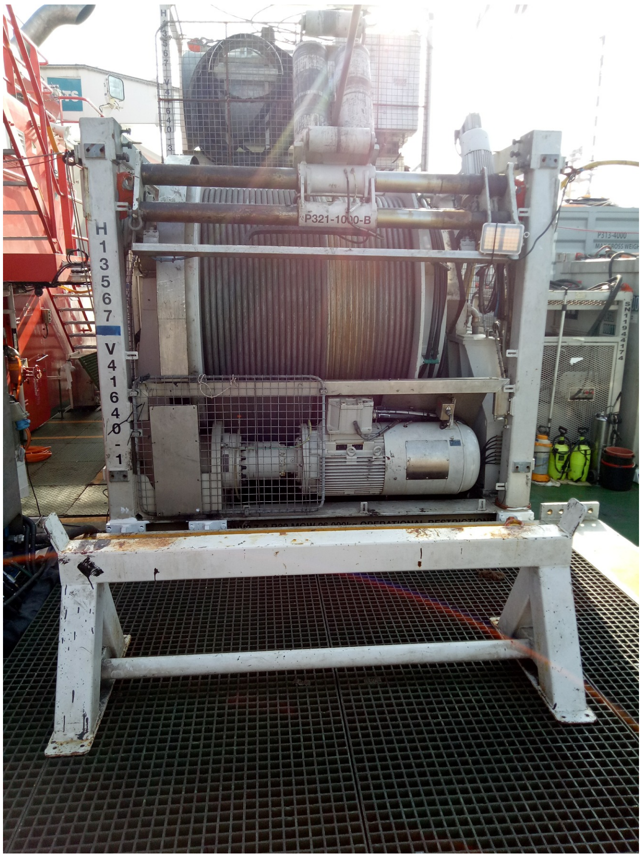
Crane starting to lower a ROV to the water (it is a old model). Note that the umbilical is not used to lift the machine.

Umbilical winch installed below the jib of the crane. Note that the wire winch is on the jib.

'A' frames cannot rotate laterally, so they only pivot to the front or the back to position the load above the water or return it to the deck. The winch is not integrated into the lifting frame and is bolted on the rear of the horizontal chassis on which the 'A' frame is mounted. Note that this system is found with most recent models and particularity those that are integrated into their surface support *(see the photos in* *point 10.3.1.2* *)*.



'A' Frame deploying a WR 200 ROV. Note that the umbilical is used as lifting cable



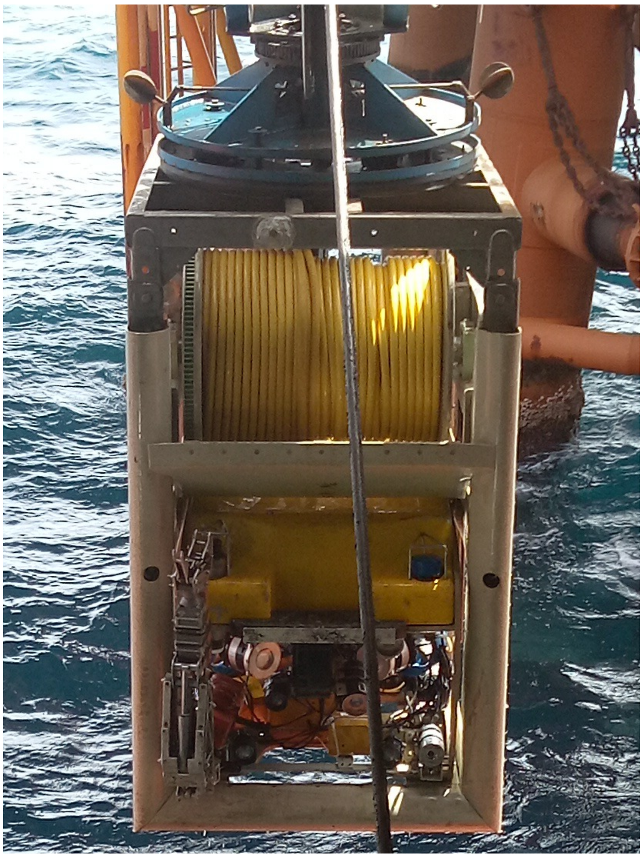
Winch of the WR 200 ROV installed on the rear of the horizontal chassis. Note the steel wire wrap of the umbilical.

10.3.5.2 - Tether Management Systems (TMS)

ROVs with the diving umbilical controlled from the surface are limited in depth and performances due to the drag factor resulting from the lengths deployed. To solve this problem, the vehicle is deployed from a "garage" hanged to the main umbilical of the LARS, and in which the reel of the "ROV umbilical" is installed. The ROV moves outside this garage only when arrived at depth. Thus, it is not impacted by the currents above it. The paying out and reeling in of the umbilical during the diving operation is done by what is known as a "Tether Management System (TMS)" that is controlled from the control room.

"Garage" types TMS are mostly used with small and medium units. Performing the maintenance of an ROV obliges the team to remove the machine from the cage and then reinstall it. Because such handling would be difficult and time-consuming with ROVs of several tons, these machines are often secured to the bottom of a tower called "Top-hat TMS", which contains the Tether Management System and which is hanged to the LARS through the deployment umbilical.

IMCA says that a TMS is mandatory for ROVs of class 2B and above, while a lot of clients request it for all machines.



Garage type TMS: Note the armoured lifting umbilical at the forefront, and the vehicle stored underneath its umbilical reel.

Top-hat type TMS: Note the fixation to the armoured lifting umbilical, and the mechanism of the system.

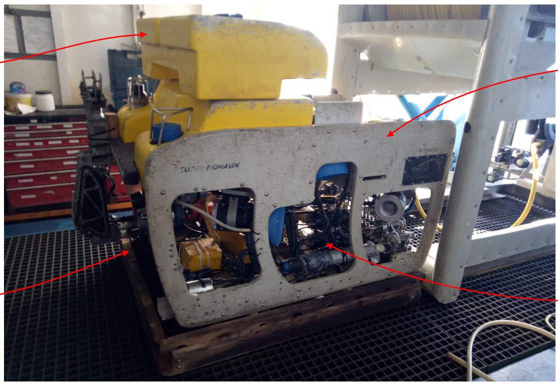
The TMS control signals pass down the armoured lifting umbilical in the same format as the ROV control signals. They are then processed by electronic systems in waterproof containers to control the appropriate hydraulic valves.
The ROV umbilical is housed on a hydraulically controlled drum. From this, the umbilical passes through a system of guides and rollers that maintain the correct tension on the umbilical whilst paying out and reeling in.
A pan and tilt camera is also fitted to the system to aid the pilot when latching and unlatching the ROV.

10.3.6 - ROV vehicle

10.3.6.1 - Frame and buoyancy

The components which make up an ROV are assembled on a frame, usually made of aluminum, plastics, and composite materials.
The problems to solve for the conception of an ROV are similar to those of the aviation industry: Design a vehicle that is not too heavy to save power, and sufficiently strong to withstand the structural stresses from the working operations performed with it, and the effects of the pressure at the maximum depth it is planned to go. Thus, manufacturers usually look for materials that have an excellent weight to strength ratio and good durability. Vulnerable areas, such as the bottom frame, are fitted with replaceable skids of wood, plastic, or aluminum.

Usually, the ROV is designed with a neutral buoyancy that can be adjusted slightly positive or negative according to the needs of the team. Also, it is common that tools have to be added or removed. For this reason, the vehicle must be designed such that its buoyancy can be adjusted.
Modern ROVs designed to have payload are equipped with "hard buoyancy" components, which can be added or removed as required. These components consist of high-density foam that is injected into containers made with composite materials that protect it against water intrusion, shocks, and the crushing due to the external pressure. These containers are designed to fit the shape of the vehicle.



Note that some previous models of ROVs were fitted with air ballasts that were providing the possibility to adjust the buoyancy during the dive. However, this system is not usable at the depths last generation machines are designed for: Note that the external pressure at 3000 m is 300 bar, which is the maximum pressure of a compressed air cylinder.

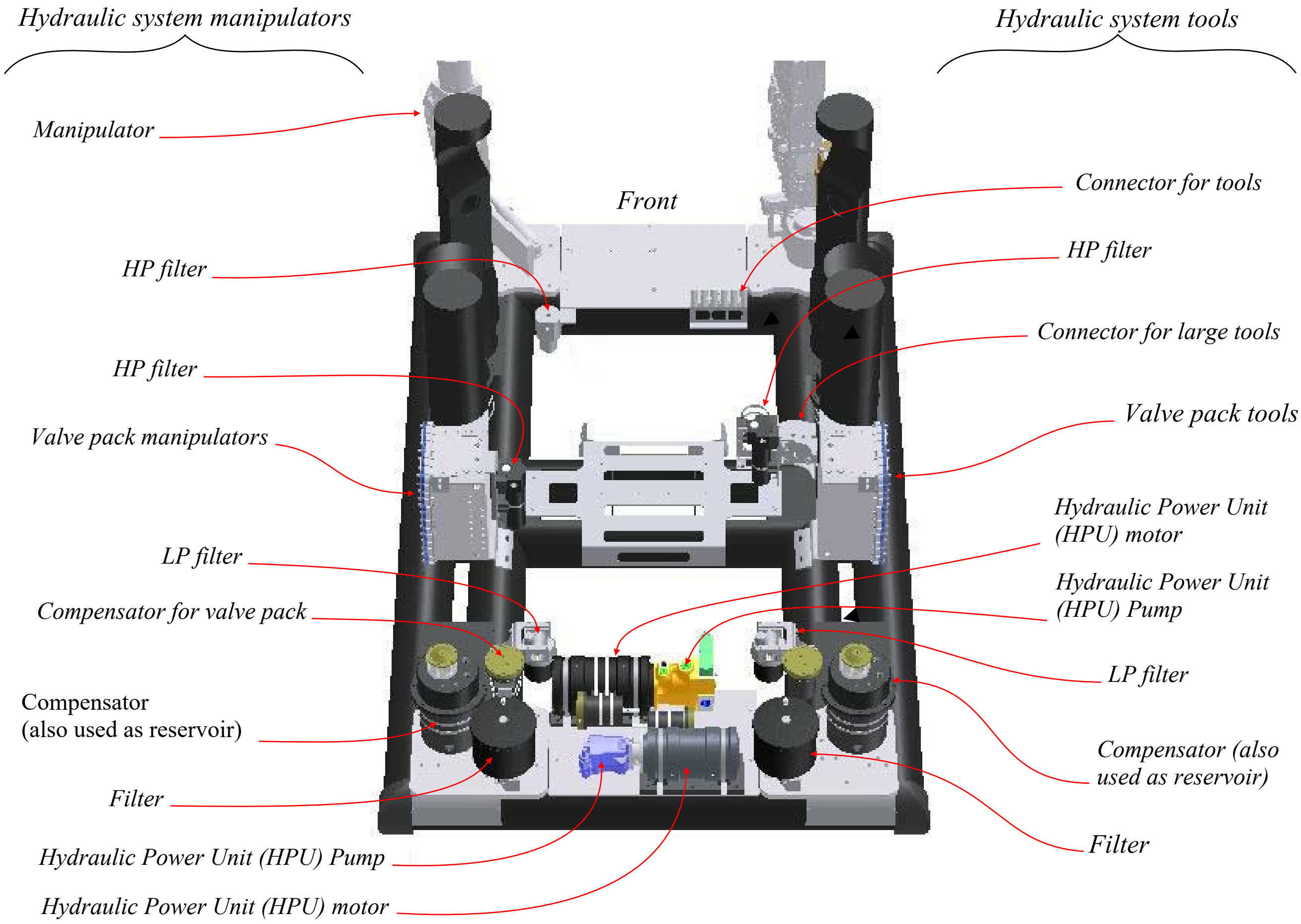
10.3.6.2 - Electrical & electronic components housing

Electric and electronic components are housed in waterproof containers, which are usually installed in protected areas. Some units are kept with an internal pressure below the atmospheric pressure (it is called "void") to ensure they are sealed, some others are oil-filled and pressure compensated to prevent water intrusion that can be detected visually or by sensors. Note that these pressure vessels are also called "electronic bottles" and protect components such as:

- Power distribution systems
- Sensing systems and their connectors
- Gyro compass *(see the description in* *point 8.2.4.3.2**)*
- Sonar system *(It consists of two transducers which transmit an acoustic signal and receives the echo)*
- Camera and lights connections
- Multiplexer *(It decodes the information received from the surface, and encodes those sent to it)*

10.3.6.3 - Hydraulic system

The Hydraulic Power Unit (HPU) provides power to the elements of the ROV that are hydraulically activated, such as tools (grinder, saw, cable cutter, and others), manipulators, and the thrusters with some machines. It is composed of a pump that is driven by an electric motor, a manifold incorporating servo valves controlling the hydraulic circuits and acts as compensator and reservoir, and filters that remove contaminants present in the circuit.
An example of hydraulic circuit is the WR 200 that is equipped with manipulators and tools that are hydraulically driven. This machine has two separate hydraulic systems: One for the manipulators, and one for tooling. Note that the thrusters of this model are electric instead of hydraulic. The models hydraulically propelled have an additional circuit that can be shared or separate.



10.3.6.4 - Manipulators

Manipulators are articulated arms that allow performing various tasks such as:

- Objects and debris recovery
- Equipment deployment and recovery
- Shackle releasing *(these shackles are specific for ROVs)*
- Installation and recovery of transponders

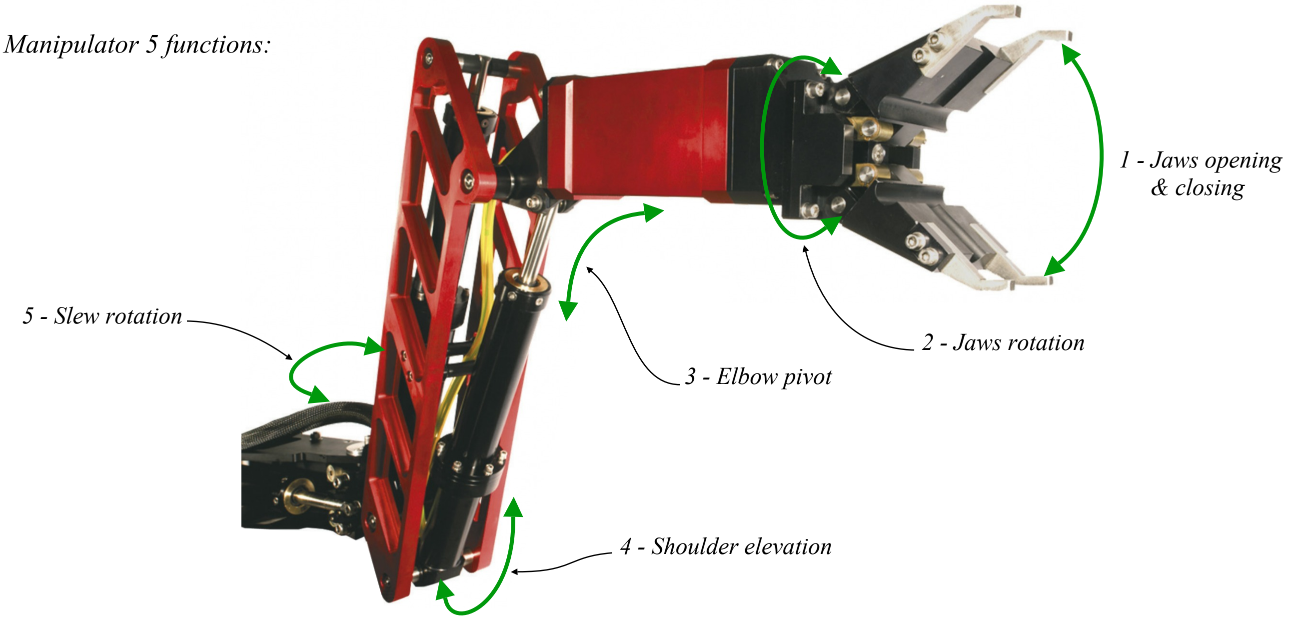
- ROV stabilization while working on a structure
- Handling inspection and cleaning tools
- Operating subsea valves *(through specific connectors designed for ROVs)*

Manipulators can be electrically or hydraulically powered:

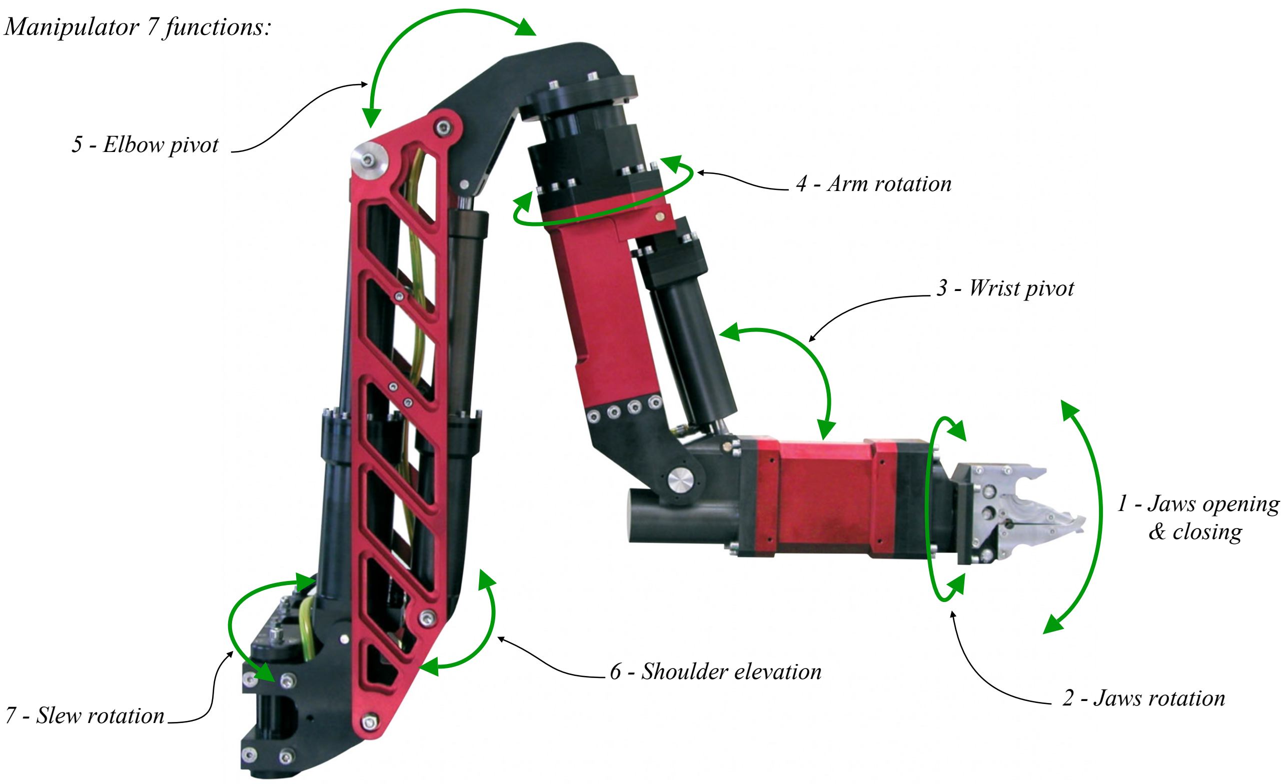
- Electrical units provide the advantage of avoiding the installation of hydraulic systems that are too heavy to be carried by small machines. They are motioned by several electric motors and gears. These systems are found on class 2 ROVs, and can also be found on some work class machines, but the current models are limited to 40 - 50 kg in lift capacity
- Some models of hydraulic manipulators can lift weights of 500 kg. For this reason, they are installed on a lot of work class ROVs designed for works requiring a lot of power. They are motioned by several hydraulic jacks powered by the ROV's HPU *(see point 10.3.5.3)*.

Manipulators are also classified by the number of "functions" they provide. Note that what is called a "function" corresponds to a move that can be performed.
As an example one "function" manipulators can only open or close jaws that are mounted at the end of a fixed arm. They are found on very small ROVs.
Manipulators installed on work class ROVs usually have, but not always, 5 and 7 functions. The two units below, that are designed by ECA - HYTEC, are examples of the moves they allow.

Manipulator 5 functions:



Manipulator 7 functions:



When selecting an ROV for the rescue of a bell, it is essential to check whether its manipulators are sufficiently powerful and articulated for this usage and whether their weights affect the machine.
As an example of a machine that is compatible, the WR 200 from IKM is equipped with one five functions manipulator (”Rig Master”, fabricated by Schilling), and a 2nd unit that allows for seven functions (”Titan 4”, also made by Schilling).

- The manipulator five functions can lift 270 kg maximum and 181 kg when fully extended, its weight is 64 kg in air and 48 kg in the water *(see #1 below)*.
- The seven function manipulator weights 100 kg in air, and 78 kg in the water. It can lift 454 kg and 122 kg when fully extended *(see #2 below)*.

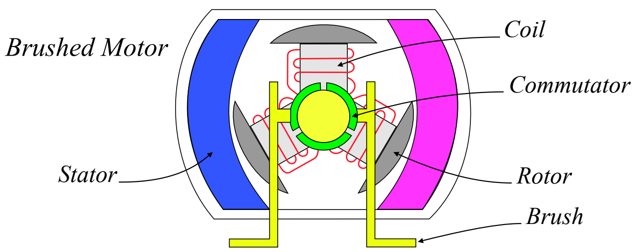
Note that whether the five functions manipulator (which can be four functions) is usually commanded by the pilot *(See point 10.3.3.1)*. The 2nd manipulator is generally operated by another technician (ROV Tooling). The joystick used for this purpose is articulated similarly as the manipulator. So the operator can perform with his hand the moves he wants the manipulator to do *(see #3 below)*.

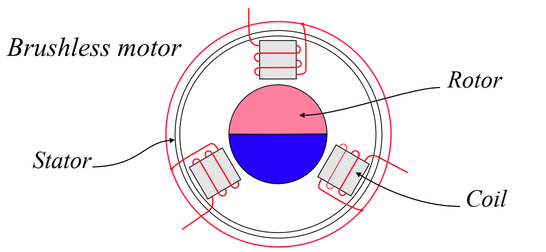
10.3.6.5 - Thrusters

Thrusters are installed to provide the vehicle with horizontal, vertical, and lateral movement. They can be hydraulically powered or electric.

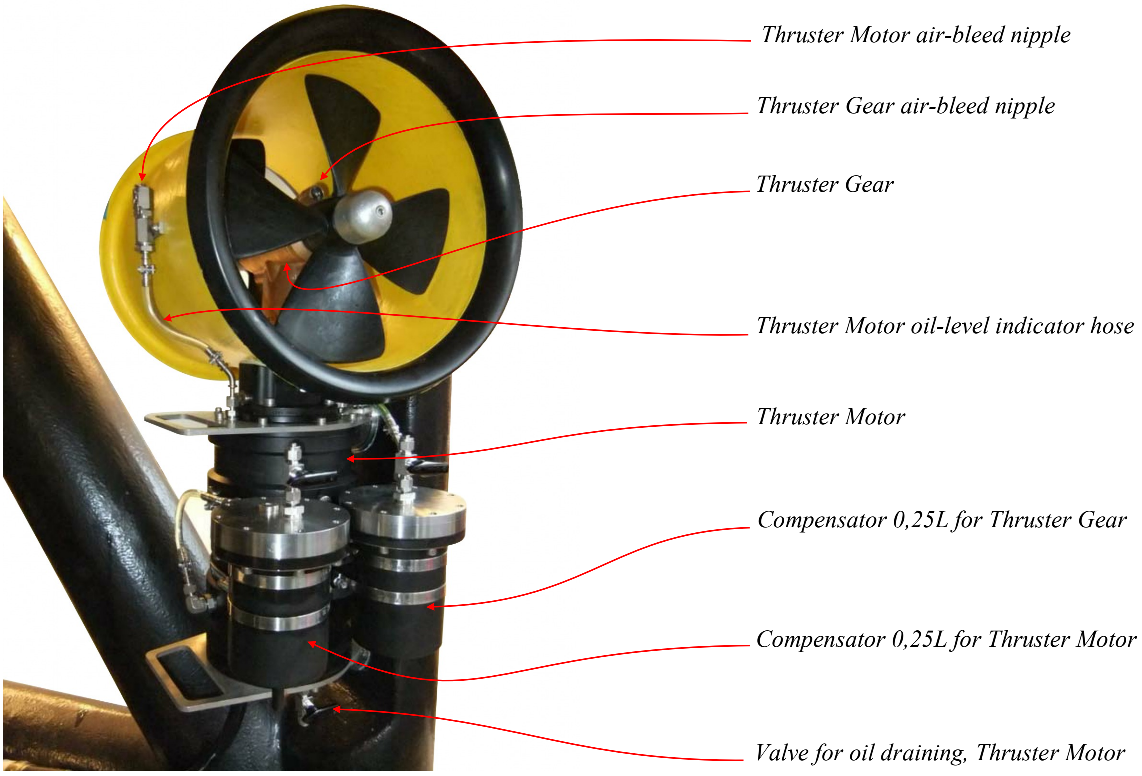
Observation ROVs are usually propelled by electric thrusters. The main reason is that electric thrusters have the advantage not to require a hydraulic system, which is an advantage with machines that are too small to carry this additional equipment without impacting their payload. However, some work class machines of the last generation are also equipped with electrical thrusters.
New models are activated by brushless electric motors powered with AC or DC, housed in pressure compensated vessels that are oil-filled, and usually fitted with gear assemblies. This design provides the advantage to allow the thruster running without damage to the winding or electronic components in the event of a shaft seal failure and subsequent flooding. Thus, it solves the main problem encountered with the previous generation of electric thrusters, which propeller shaft is directly connected to the motor, isolated by only one seal, and so more prone to water intrusions.

The difference between brushed and brushless motors is that with brushed motors the current passes through coils that are mounted on the rotor. This assembly rotates because each coil generates a magnetic field that is pushed away from the pole of the stator of the same polarity and is pulled toward the one of opposite polarity. The power to these coils is supplied through fixed conductive brushes that make contact with a rotating commutator.
With brushless motors, the coils are located on the stator instead of the rotor that is made of two separate polarities permanent magnets. As a result, the coils do not rotate and there is no need for brushes and a commutator.





As an example of last generation electric thrusters described in the previous page, the model below that is used on the Merlin WR 200, is powered by a motor in a oil compensated compartment. This model has the particularity that the motor is separated from the gear and not aligned with the shaft of the propeller. Note that the function of the air bleed nipples is to ensure that the containers are fully filled with oil.

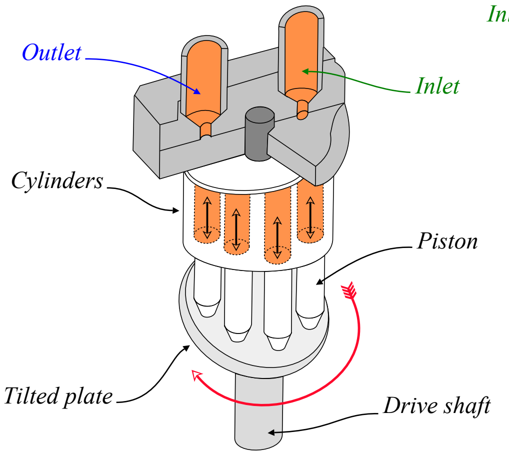


Hydraulically powered thrusters are driven by hydraulic motors that convert the fluid pressure from the HPU into a rotary motion. These motors may be combined with mechanical drives such as gears.

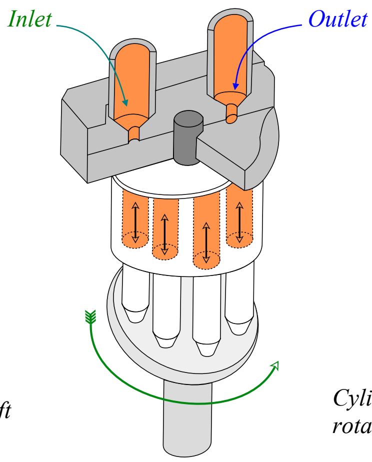
Variable displacement pumps are used in most hydraulic ROVs to save energy and reduce the heating of oil. Opposite to a fixed displacement pumps which amount of flow cannot be changed, and oblige the use of a flow control valve, a variable displacement pump can have its cycle altered so that the displacement will change proportionately to the change in the cycle speed or rate. A common variable displacement pump is the axial piston pump that is composed of several pistons that convert the rotary shaft motion into axial reciprocating motion. They are composed of a tilted plate that rotates, causing the pistons to move up and down, and thus, take the fluid and expel it each shaft rotation. Playing on the orientation of this plate modifies the flow of the pump.

Note that hydraulic motors have the reverse function of pumps, and for this reason, have similar designs. Thus, an axial piston motor is a pump working in the reverse cycle *(see below)*.

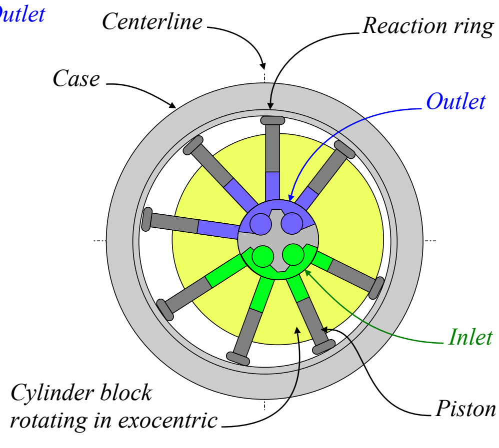
Radial-piston motors are also used. They are composed of a cylinder barrel that contains pistons that reciprocate in radial cylinders attached to the drive shaft. The outer ends of these pistons bear against a thrust ring. The hydraulic oil that is pressurized by the pump flows in the center of the cylinder barrel to drive the pistons outward. As a result, the pistons push against the thrust ring, and the reaction forces rotate the barrel.



Axial piston pump



Axial Piston motor



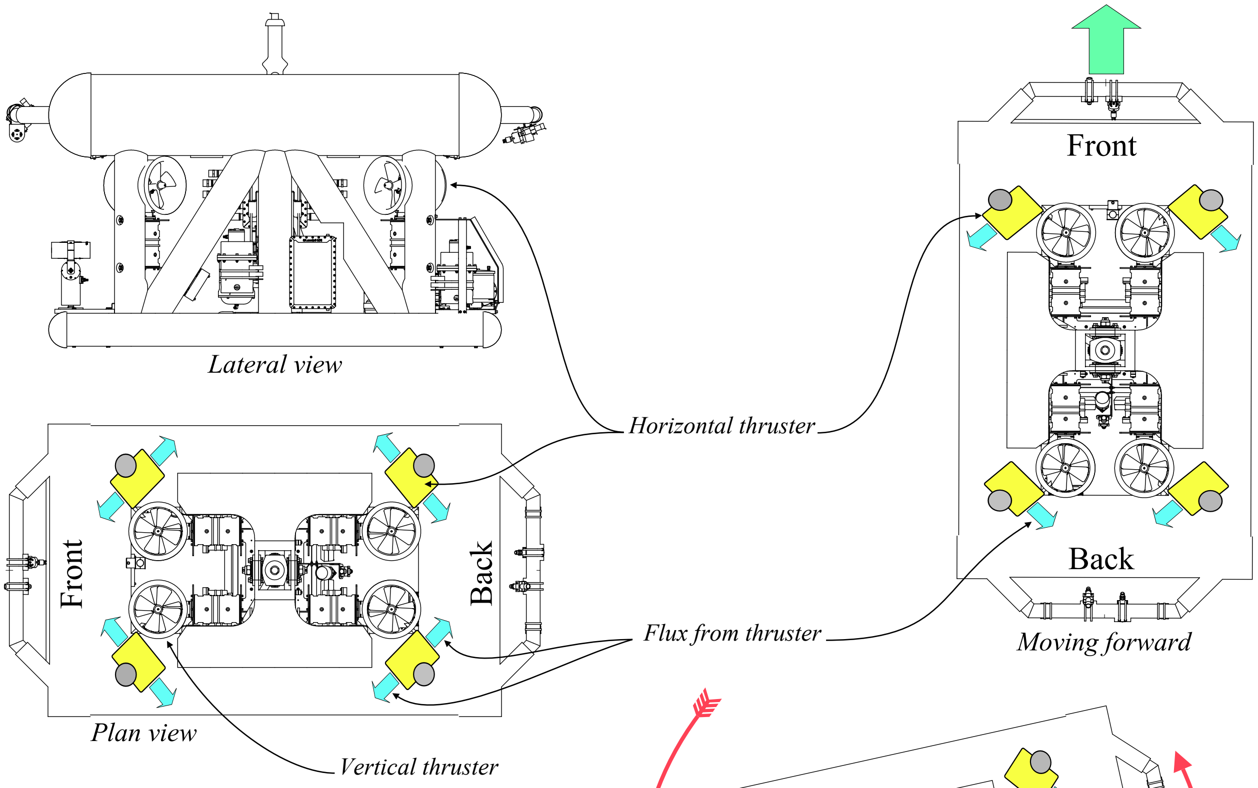
Radial piston motor

Servo valves or similar systems that are paired with the pumps and the motors allow controlling the propellers.

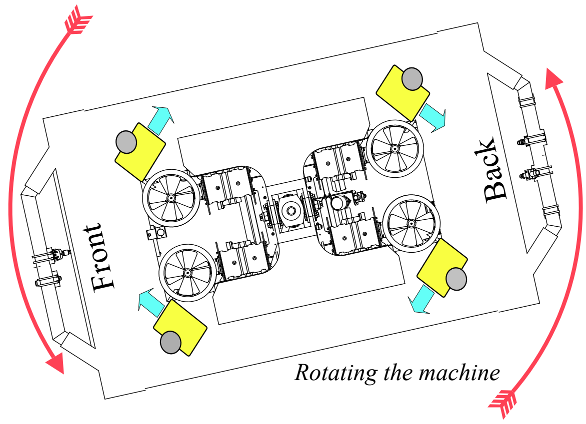
Hydraulic motors are reputed to provide high torques and have a better speed of response than electrical units. It is the main reason they are installed on Work Class machines.

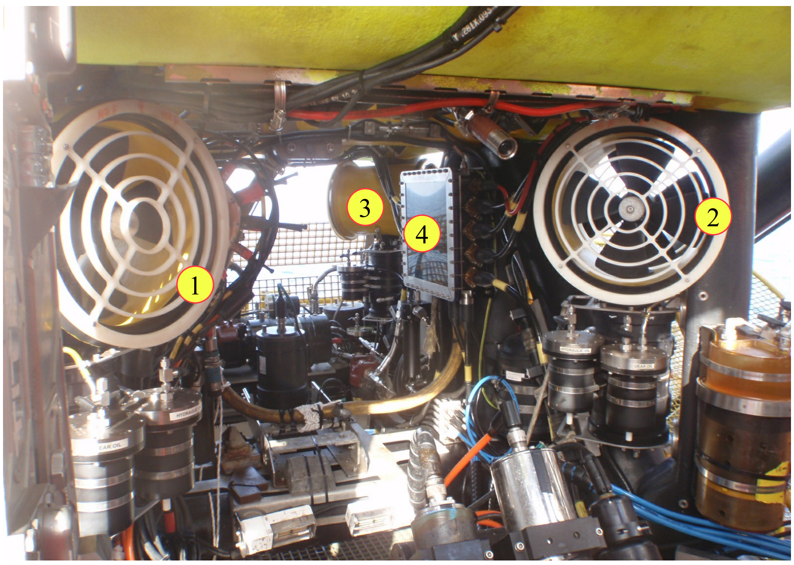
However, some electric thrusters of the last generation, such as the one described above, are now capable of similar performances.

Thrusters are positioned to push the vehicle in any direction. As an example, the Merlin WR 200 has four horizontal thrusters and four vertical thrusters that can work in both directions (rotating & contra-rotating). Its horizontal thrusters are positioned at 45º to move it forward, sideward, or rotate it. This configuration, which is called "X-shaped ", is ideal but the fluxes are not in the axis of the ROV when it moves forward *(see the views below)*.

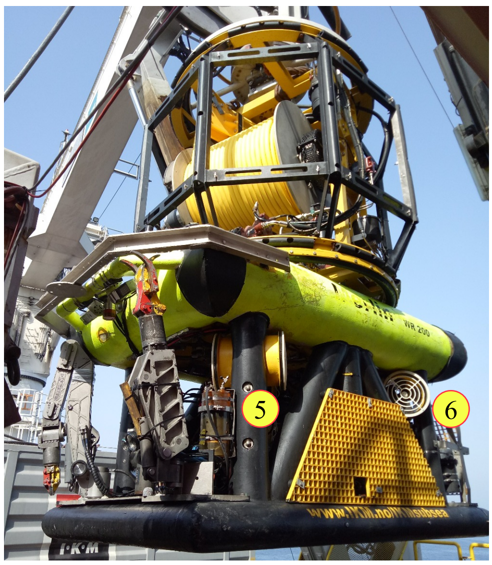


Note that the vertical thrusters of this machine are of the same model of the horizontal units and are organized to work all four simultaneously. This solution that is implemented on a lot of new models gives the advantage to limit the spare parts to be provisioned.
However, it happens that for technical reasons, some machines are equipped with only one or two thrusters of deferent models than the horizontal ones.





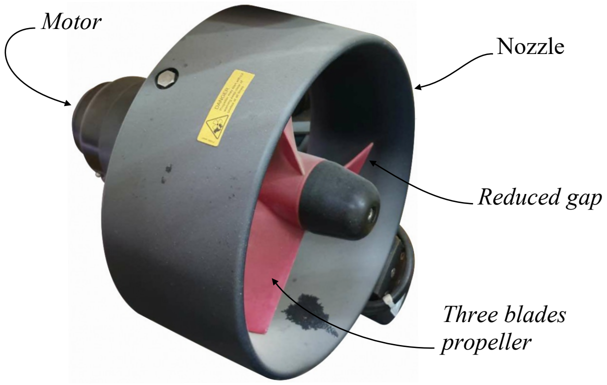
Forward thrusters: #1 & #2 - Stern thruster: #3
Oil filled pressure compensated electrical connection box #4



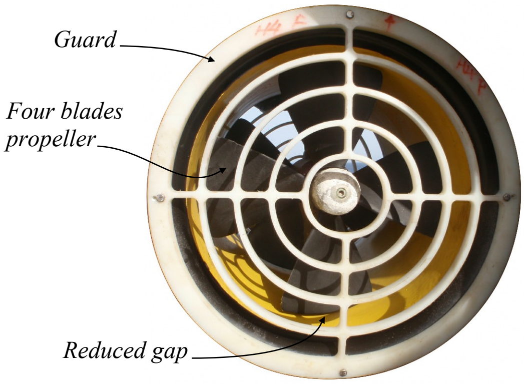
Forward thruster: #5 - Stern thruster: #6

The propellers of work class ROV thrusters are of fixed pitch types, with three or four blades that are installed in nozzles, like in the model on the next page, which is installed on a Seaeye Panther. As already discussed in point 8.2.3.1 of this book, the advantage of the nozzle is that it increases the velocity of the water flow, and so allows for a more efficient thrust than a standard propeller. Also, the very reduced gap with the extremities of the blades eliminates the vortices and the effects of cavitation.

Some propellers, such as those used on the Merlin WR 200 previously discussed are organized in tunnels. The advantage of this configuration is that it allows to house two thrusters, one to move to one way and the other to move to the opposite direction *(see in the right side below)*.
Note that when an ROV is to be used in the vicinity of divers, its thrusters must be fitted with guards to avoid the divers being injured by them. These guards must restrict any hand or finger intrusion *(see the photo on the left side below)*. The inconvenience of these protections is that they impact the flux from the thrusters, and so they lower their efficiency.



Electric thruster with a three blades propeller (Seaeye Panther)



Electric thruster with a four blades propeller (Merlin WR 200 IKM)

The manufacturers express the forward, lateral, and vertical thrusting capabilities of their machines in kilogram-force (kgf) or kilo Newton (kN) (1 kgf = 9.8 Newton). Note that whether the force of the horizontal thrusters in important to move the vehicle in harsh conditions, the force of the vertical thrusters of an ROV is crucial because it provides the ability to operate similarly as a helicopter, and thus lift loads without being obliged to connect the crane or similar devices. The vertical thrusting capabilities of an ROV must not be confused with the payload that can be adjusted by playing on the buoyancy of the machine. Depending on the machine, class 3 ROVs have a forward thrust between 300 to 1100 kgf, a lateral thrust between 290 & 1100 kgf, and a vertical thrust between 200 & 1000 kgf.

10.3.6.6 - Camera and Lights

Cameras are used for numerous tasks such as driving the ROV to and from the target, give an overview of the work site, control the manipulators, provide a detailed view of an object, check the connection to the TMS, verify the condition of the umbilical reel in the TMS. Additional cameras maybe fitted for specific tasks along with still cameras for inspection projects.
These Cameras are paired with powerful lights that can be dimmed and are usually mounted on a pan and tilt assembly. Some last generation cameras have Light Emitting Diodes (LED) around their lens, which provide lighting aligned with the lens of the camera and save the weight of a separate light.

Note that additional cameras are sometimes installed to give views of objects from different angles than the primary camera. The combination of an angled picture with the front one may allow seeing whether the tool is adequately positioned for the task planned. Also, that allows the pilot and the tool operator to cope with the deformation of the picture resulting from the refraction of the water. However, some cameras are now equipped with “dome viewports” that fix this problem and allow for a field of view of 90° instead of 64° with a flat viewport. The spherical curvature of dome viewports allows rays to pass through the surfaces without deflection on their way to the lens. Also, a dome-shaped viewport is better able to withstand extreme pressures than a flat one.

Manufacturers express the performances of cameras as follows:

- Minimum light sensitivity is expressed in “lux”(lx), which is the International System (SI) unit of luminance (light). One “lux” is equal to one lumen per square meter.
  The “lumen” (lm) is the unit used for the total luminous flux in a light beam. For convenience, it is common to compare the lumens emitted by a light beam with the power of light bulbs, so 150 lumens can be roughly correlated with the light emitted by a 10-watt bulb, and 1500 lumens corresponds to the light emitted by a 100-watt bulb. Thus, a 100-watt bulb that fully illuminates a surface of 1 m² is equal to 1500 lux, and 1 lux is equal to the luminescence of a bulb of 0.0666 watts.
  Another simple and practical method to compare the luminance is to keep in mind the following values:
  - Overcast night = 0.0001 lux
  - Star light night = 0.001 to 0.002 lux
  - Quarter moon with clear sky night = 0.01 lux
  - Full moon night with clear sky = 0.1 to 0.4 lux
  - Sunrise or sunset on a clear day = 400 lux
  - Overcast day = 1,000 to 2,000 lux
  - Daylight 10,000 lux
  - Sunlight= 110,000 lux.

  The lower the lux rating the more the camera is able to see in low light conditions.
- The resolution of analog cameras and screens is given in “horizontal lines”:
  The resolution of analog cameras and monitors is calculated in Television Lines (TVL).

- ◦ "Horizontal Resolution" is the number of alternating vertical black and white lines from the left to the right of the screen.
- ◦ "Vertical Resolution" is the number of the alternating horizontal black and white lines from the top to the bottom of the screen.

It is common to use the measure of the horizontal lines to indicate the resolution of a camera or a screen. Note that the highest resolutions are those that have the highest number of lines.

- Digital screen specifications of TV and computers are given in "horizontal" and "vertical resolutions". The "horizontal resolution" corresponds to the number of elements, dots or columns from left to right on a display screen, and the "Vertical resolution" is the number of rows, dots or lines from top to bottom.
  As examples of resolutions that are found with computers and video combos note 1280 x 720 and 1920 x 1080 that are also called 720p & 1080i ("p" means refers to progressive scan, and "i" means "interlaced").
- The resolution of digital cameras and screens is often indicated in megapixels.
  A pixel is a tiny colour square that is assembled to others to create a digital image. So, the more pixels used to represent an image, the more accurate the picture is. Pixels can be plus or less numerous in a picture and used as a unit of measure, such as an example 2400 pixels per inch.
  Megapixel means one million pixels. Thus, a 12-megapixel camera can produce images with 12 million pixels. The formula to calculate the resolution of a digital picture is "Number of horizontal pixels × Number of vertical pixels". As an example, a camera with 4928 by 3264 pixels has a resolution of 16 megapixels.
- Some cameras are also provided with zooms, which are devices that are used to make a subject appear closer. Two systems can be used:
  - ◦ Optical zooms consist of a series of lens and glass elements that are adjusted in or out through a system of screws and miniaturized gears. They are reputed to give the best results of image magnification. Their main problem is that the waterproof housing of the camera may limit their ability to move, so they are limited in performances compared to units not designed to go underwater.
  - ◦ Digital zooms achieve a similar effect to optical zooms, without mechanical work of lenses and glass elements. These systems cut off areas around the target, which is enlarged using algorithms that add pixels to preserve the detail of the magnified image. However, specialists say that this process is imperfect and that some digitally zoomed images may be blurry and smudgy.

  The zoom capability of a lens is usually expressed as the ratio between its longest and shortest focal lengths. For example, a zoom lens with focal lengths ranging from 50 mm to 200 mm is referred to as a x4 zoom lens.

Cameras and display combos of ROVs are essential as they are the eyes through which the pilots and the persons observing the scene for inspection or diving monitoring purposes can see. Clients and organizations usually request a low light navigation camera and a colour or a high definition camera as a minimum. Nevertheless, manufacturers of class 3 ROVs equip them with more units than this minimum and provide connectors to add additional units, as indicated previously. As an example, in addition to low light and colour cameras, the Merlin WR 200 is initially equipped with two other colour cameras on the front, plus one unit on the rear and another one for the TMS docking.

- Low light cameras are sensitive enough to show detailed pictures in a dark environment where most cameras show only black. The pictures of these analogic cameras are usually in black and white. However, some new digital models that provide images in colour are proposed.
  Such cameras are mostly used for navigation. However, they can also replace colour cameras when the water turbidity does not allow for the use of lighting without being dazzled by its reflection on particles.
- Colour analog cameras are used for all kinds of works, including inspection, and are often fitted with a zoom. These cameras are also used to navigate when the water turbidity allows. These models have not evolved so much these last ten years; the main improvements are their housings, which some of them allow dives up to 6000 m.
- High definition digital cameras, which some are equipped with zoom, can be used for the same operations as analog models, and tend to replace them. The manufacturers continuously improve their performances that have been multiplied by 10 since the first models. Besides, these cameras are designed to store photos and films at the quality they have been taken, which allows them back up (this point is mandatory with Norsok U102).

The quality of the image displayed is essential, and for this reason, clients and organizations also require minimum performances. The requirements of NORSOK U102/2016 are indicated below. However, they are based on more than ten year old references and may change in the next revision. For this reason, it is better to refer to last-generation devices and select the highest performing equipment not to be affected too fast by the obsolescence of standards.

	Low light camera		*Colour camera*		*High Definition camera*	
	Norsok	*Last generation*	*Norsok*	*Last generation*	*Norsok*	*Last generation*
Sensitivity	0.03 lux	0.000,05 lux	1 lux	0.9 lux	0.1 lux	0.1 lux
Resolution	> 400 TVL	570 TVL	> 400 TVL	550 TVL	2,1 megapixels	>20 megapixels
Field of view	60°	77°	–	90°	–	90°
Depth of focus	150 mm to inf.	150 mm to inf.	–	–	–	–
Zoom	–	–	–	x 36	–	x 30

Lights are the complement of cameras and should be powerful enough to illuminate the worksite perfectly during optimal conditions. Due to the absorption of the light by the water, the more powerful the lighting, the better it is. However, the number of floodlights that can be installed is often limited by the number of fixation points available on the machine and the electrical power that can be supplied.
Most lights that are manufactured for ROVs are today made of Light Emitting Diodes (LED), and use 24 to 48 volts DC or 110 - 120 volts AC. These lights are more efficient than traditional bulbs.
As a reference of lighting provided on class 3 ROVs, the Merlin WR 200 can be equipped with four lights 7500 lumens each and a spotlight 4366 lumens mounted on its front, Plus one spotlight 4366 lumens at the rear and another one of the same power for the TMS docking. Thus, the machine can provide a maximum of 34366 lumens at its front, which is the approximate equivalent of the light emitted by 229 bulbs of 100 watt each.
Lights may not be usable at their full power for the reasons linked to water turbidity already described. For this reason, manufacturers provide a system that allows dimming them.

Note that whether some cameras and lights are mounted on fixed points, some others are installed on “pan and tilt units”. These devices enable the pilot to remotely drive the cameras into position to give the best views while moving or holding the vehicle stable. There are several different types available, from cylinder driven rack and pinion units to rotary vaned and multi-thread piston actuated units. At a minimum, they should allow moving 90º vertically and 120º horizontally.

1 - floodlight

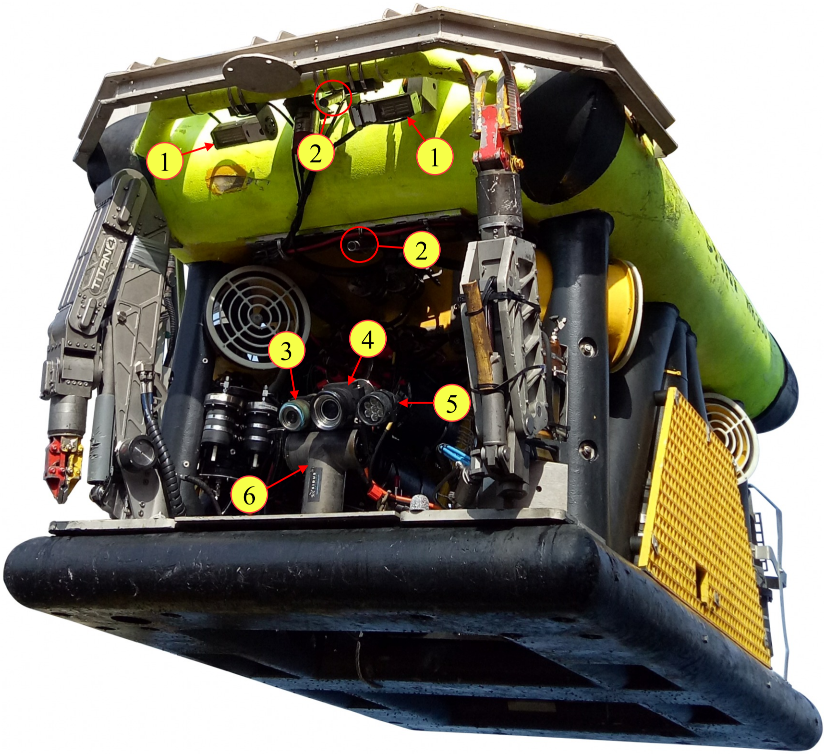
2 - HD camera

3 - Low light camera

4 - Colour camera

5 - Spotlight

6 - Pan & tilt unit



10.3.6.7 - Umbilical

As previously said, a typical ROV umbilical carries the control signals from the control console, information from the vehicle sensors, and the electrical power required to operate the ROV.
Depending on the system used it may be only one length terminated at the winch junction box on the Launch and Recovery system (LARS), previously described in point 10.3.4.1, or be composed of an armoured length that is reeled in the surface winch of the LARS and hold the Tether Management System , and of a 2nd umbilical which is reeled on the winch of the TMS and which the other end s connected to the ROV. In the case that the ROV umbilical is terminated in the TMS, Intermediate junction boxes similar to those described in point 10.3.4.1 are mounted on the winch of the TMS.
The umbilical is organised as below:

The umbilical is organized to protect the most fragile components:

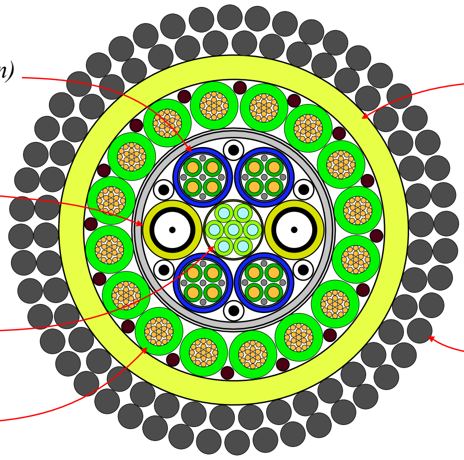
1 - The fibre optic bundle is in the center

2 - The communication cables are around the fibre optic bundle.

3 - The power cables are organized at the periphery of the umbilical, so they rigidify it.

The external sheath provides insulation and protection. It is the latest layer of standard umbilicals not designed to lift the ROV.

The armour is part of umbilicals with lifting capabilities. Thus, the umbilical from the surface to the TMS.



Note that umbilicals must be secured such that the connections in the junction boxes are not under stress. For this reason, they are secured to the frame of the machine through a “Chinese finger” that is usually inspected every day. The umbilicals are also secured to the reels of the winches. Also, it is recommended to always let a minimum of 5 turns on these reels.

10.3.7 - Navigation and technical aid systems

These functions are usually indicated in the description of the machines provided by the manufacturers and the operators. Note that some terminologies

10.3.7.1 - Navigation aids

- Gyroscope & gyro compass:
  A Gyroscope detects and measures the angular motion of an object relative to an inertial reference and has the orientation of its axis unaffected by tilting or rotation. So, it measures the absolute motion of an object without any external infrastructure or reference signal. These devices that were initially mechanical systems mounted on a gimbaled support are today replaced by electronic sensors. A gyrocompass is a navigational device that is built around a gyroscope movement. They are used for functions such as auto heading and must have a resolution better than 1°.
- Auto heading:
  This function allows entering a pre-determined heading to which the machine always moves to as long as the pilot does not deactivate it. As said above, it uses the gyroscope that is monitored continuously and acts in such a way as the thrusters are automatically directed to maintain the vehicle in a fixed direction.
- Auto depth:
  Depth is the distance of the ROV from the surface. This function works on a voltage that is derived from a pressure sensor is compared to a reference signal. The resulting signal is applied to the vertical thrusters which act in such a way as to counteract the change in depth. Note that depth sensors should have a precision of at least 0.1 m.
- Auto altitude:
  Altitude is the distance of the ROV from the seabed. The system utilises the gyro to detect any change of altitude and make an adequate correction using the vertical thrusters. The altimeter should have an accuracy of 0.1 m.
- Inclinometers:
  It often happens that the ROV rolls and pitches during the operations, which may result in a disorientation of the pilot. For this reason, instruments are mounted to show the angular movements of the vehicle, that are often graphically displayed on the screen with the degrees of roll or pitch and an artificial horizon. Their accuracy should be better than 1°. Note that some machines are equipped with automatic correction systems.
- Navigation SONAR
  SONAR stands for “Sound Navigation Ranging”. The sonar assembly consists of a transducer that transmits an acoustic signal and another one that receives the echo. This device that operates horizontally, and may be mounted on a hydraulically operated tilt mechanism, is used to look for obstacles that are not visible through cameras. The display of the sonar is usually on an adjacent screen. Clients often require a range from 1 to 150 metres.
- Imaging SONAR
  It is a particular type of SONAR enabling a photographic type view of the sea bed, that allows the positioning of topographical features, structures, and debris on the worksite in the absence of visibility and from long distances. These sonar can also be used to take pictures of items such as flanges in waters of high turbidity.
- Doppler Velocity Logs (DVL):
  A “Doppler Velocity Logs” is a sonar system that emits sound bursts angled downward in various directions, that are returned to the receptors of the emitting vehicle. These returned echoes carry a change in pitch called “Doppler effect”. Combining these readings tells how fast the ROV is moving and in which direction.
- Trim controls:
  The function of the "trim control" is to free the pilot from permanent corrections with the joystick in case of established currents that push the ROV, or in the case of a modification of the buoyancy. So, this function allows the pilot to focus on his task as the ROV is making the asked corrections.
  Depending on the machine, the trim function is activated through a switch, a potentiometer, or a button on the touch screen near the pilot. When enabled, the system maintains a control signal to the vehicle that automatically applies corrections according to the control selected.
  Among the functions available, forward/reverse, vertical up/down, and lateral port/starboard are the most common.
- DP systems
  DP systems for ROVs are new applications that can be optional with some last-generation machines and are still experimental and under evaluation by a lot of manufacturers and competent organizations. The purpose of these systems is to provide significant levels of automatic control functions such as absolute DP (ROV dynamic positioning regardless of ship motion) or relative DP (ROV dynamic positioning relative to ship motion).
  ROV dynamic positioning applications can be achieved with Gyro based Inertial Navigation Systems (INS), depth sensors, Doppler Velocity Logs (DVL), and acoustic positioning systems such as Ultra Short Baseline System (USBL) and Long Baseline System (LBL).

10.3.7.2 - Technical aids

- Main display:
This display provides the picture from the video camera in use. Also, it provides essential information such as the ROV heading, depth and altitude, pitch and roll, oil pressure, temperature, and others. However, note that several displays are used for this function with class 3 ROVs *(see in point 10.3.3.1)*.

- Multiplexer data:
This function allows visualizing whether data are transmitted through the multiplexer.

- Water intrusion and current leakage sensors:
Sensors are provided to inform of water intrusion or condensation in the system, and some others of current leakage.

- Power used by thrusters:
The power that is used by the thrusters is displayed graphically and in percentages on the main display or an additional screen *(see in point 10.3.3.1)*. That allows adjusting their output or the piloting to preserve them.

- TMS bail count:
It is a system that allows the pilot to know how much length of umbilical is off the TMS. This distance is displayed on the main or an adjacent screen.

- Vehicle turns count
It often happens that during some operations, the pilot pivots the ROV several times around its axis in one direction without realizing it. That may exaggeratedly twist the umbilical and damage it. The vehicle turns count system allows the pilot to visualize how many turns the ROV made on itself to one direction and thus return it to zero to preserve the umbilical. This function is usually displayed on the main panel.

- Self diagnostics program:
The "Self diagnostics program" continuously monitors the circuit boards of the system. Should a fault occur, then a surface computer allows the operator to step through the system and locate the affected circuit board.

10.3.8 - Emergency locating and recovery equipment

ROVs carry battery-operated transponders, which aid in the locating and recovery of the vehicle should the umbilical break. Also, they are used for navigation purpose and allow to locate the ROV permanently through the survey system of the vessel. For these reasons, these systems are the most employed and the most required by clients.
ROV teams usually install a transponder on the ROV and another one on the TMS system, to precisely locate them on the nav screen. note that the batteries of these systems should allow for several days of autonomy.
Also, it must be taken into account that work class ROVs operating at the proximity of divers should be equipped with such a system, so the diving supervisor can see where it is on the nav screen.
Note that some units are equipped with a "responder", which is a system similar to the transponder, except that the "interrogation" signal that triggers the answer by an acoustic pulse through the water is sent through the umbilical.
Some models of ROVs are equipped with a pinger in addition to transponder or responder. Pingers, that are mandatory on diving bells, are devices that repeatedly emits short pulses of acoustic emissions at a set frequency. They allow locating a lost ROV by triangulation of the emission.
Also, the ROV should be equipped with a flashlight that is powered by independent batteries. This device usually starts when it reaches the water and automatically stops when the machine is back the deck. The flashlight is essential for visually locating the ROV.

In addition to the locating equipment, an appropriate rigging should be ready for the recovery of the machine by the crane. It is prudent to plan for slings and shackles that are designed with a safe working load allowing lifting double the weight of the ROV in the air in the case of a complicated recovery. Soft slings are the preferred option.

10.3.9 - Tools used for various manipulation and cutting tasks and also diving bell recovery

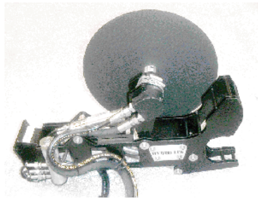
A class 3 ROV must be equipped with minimum tools to perform various manipulation and cutting tasks and also rescue wet or closed diving bells.

- Four, five, and seven functions manipulators:
Manipulators are explained previously. Four and five functions manipulators are generally used to grab objects and/or maintain the ROV in position. The seven positions manipulators are designed to perform all the movements which could be possible by a human arm and perform more delicate tasks.

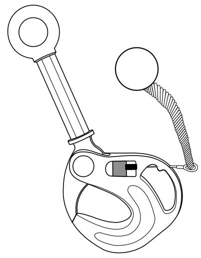
- Water jets and brushes:
These tools are used to perform cleaning operations. HP water jets and cavitation jets (see #1) are usually energised by a pump that is part of the ROV. It is also the case of rotative brushes (see #2) that can be motioned hydraulically or electrically.

- Cable & umbilical cutters:
  These tools use the principle of the guillotine and are typically installed at the end of one arm. The unit selected must be capable of cutting the main and the guide wires of the bell. Also, note that some models are designed to cut umbilicals up to 270 mm diameter.

- Grinder:
  This tool can be used to cut metal and concrete and the umbilical of the bell if necessary. Diamond disks with diameters sufficient to cut the objects in one pass are recommended.



- Hook:
  Only hooks specifically designed for handling by an ROV should be provided in case of lifting operations. Also, they must be included in the tool kit to rescue a diving bell. They can be grabbed and orientated using the five positions manipulator of the ROV and opened or closed using the seven-position manipulator. The locking mechanism is often integrated with the body of the hook, and a ball connected to the latching system by a small cable allows the ROV to trigger its opening.



10.3.10 - Video display & recording, and communications & alarms

10.3.10.1 - Video display & recording

The video signals from the cameras are sent to the control room through the multiplexer. Then the signals are converted to the format of the displays and the recorders.
In addition to the displays in the ROV control room, the video signal of the camera in use is transmitted to the screens of the diving supervisor, the bridge, the Offshore Construction Manager (OCM), and the clients.
The pictures displayed should indicate essential information such as the date and time, the name of the pilot, the project and location, the task performed, the heading, the depth, the altitude, the roll & pitch. Some clients may require more elements.
Note that video displays from the divers should be in place in the ROV room. So the pilot can have a picture of what the divers see.

Video recorders are the complement tools of cameras. Safety organizations and clients ask that two units are provided in the ROV control. Also, the recording of dives should be kept at least 24 hours. Regarding this point, the new systems allow storing them for a longer time, and most teams transfer them to external media where they are saved forever when the project is completed.
The last generations of video recorders are digital systems installed in dedicated racks. They are provided with functions that allow adding overlays and annotation in addition to logos and information about the job. Screen splitters are also provided to allow viewing several cameras on the same screen.
New systems also provide tools to isolate photos or part of a video recording as well as anomaly clips with their logs. The full logs can also be introduced in the records. The files are typically edited in formats that are common to every computer and digital video reader.
These systems are provided with hard disks where the video files are saved, and that can be accessed through a data bank. Also, USB (Universal Serial Bus) connectors are provided to transfer these files to external drives or download those kept in the cameras.
Note that clients commonly request recorders with the functions described above.

Also, because new video recorders are in fact computers, some software developers propose to adapt classical laptops and desktops to this function.

10.3.10.2 - Communications and alarms other than video

Wired communications must be in place with the Launch And Recovery System (LARS) for the launching and the recovery of the ROV, check the machine (Function tests), and ensure that the machine is cold when performing maintenance tasks.
Diving support is a particular ROV task that requires that the ROV pilot works in symbiosis with the diving supervisor and the bridge. For this reason, he must be in permanent communication with both, and the primary link used for this purpose must be hard-wired, immediately available, and unable to be interrupted. If the dive is organized from a facility, the Offshore Installation Manager (OIM) room must be connected through this channel
Note that this link must be organized such that it cannot be interfered with by other communications.
Backup systems must be in place in the case of failure of the primary system. They can be a second intercom system, the phone, and radio communications if relevant.

Key people such as the Offshore Construction Manager and the clients must have the possibility to contact the ROV control room and be reachable if needed. It is usually done through a dedicated intercom. Communications with some parts of the vessel such as the conference room should be possible.

In the case that loads have to be transferred, there must be direct communications with the crane operator. They must be of the same type than those used with the diving supervisor, bridges, and OIM room.

There must be a direct communication with the survey team, and a display that indicate the position of the ROV and the divers on the worksite must be in the ROV control.

DP alarms must be in place when the ROV operates from a DP vessel. The system and procedures is the one described in point 8.2.7.2.

Vessel alarms must also be installed in the ROV control. There must be the possibility to mute them

10.3.10.3 - Summary of communication and alarms required by clients and various organizations

Competent bodies emit guidelines regarding communication systems that are the minimum to be in place. However, numerous clients have more stringent requirements that cannot be ignored. The table below summarizes the requirements from IMCA and other organizations and clients, and gives additional recommendations.

No	*Description*	*Requirements IMCA*	*Requirements from clients and other organizations*	*Additional information*
1	Hard wired communications to and from the bridge *(dedicated intercom)*	Mandatory	Mandatory	The primary link must be hard wired, immediately available, and unable to be interrupted.
2	Wired secondary communications to and from the bridge	Optional	Optional	The secondary link can be hard wired, or a dedicated radio channel.
3	Hard wired communications to and from the OIM room *(Operations from a facility only)*	Mandatory	Mandatory	It is only when the operation is organized from a facility. The primary link must be hard wired, immediately available, and unable to be interrupted.
4	Wired secondary communications to and from the OIM room. *(Operations from a facility only)*	Optional	Optional	It is only when the operation is organized from a facility. The secondary link can be hard wired, or a dedicated radio channel.
5	Hard wired communications to and from the launch and recovery console *(dedicated intercom)*	Not clearly indicated	Mandatory	These communications can be verbal if the console is in the same room as the supervisor.
6	Hard wired communications to and from the crane *(dedicated intercom)*	Nothing indicated	Mandatory	Radio is no more accepted as main communication with the crane
7	Hard wired communications to and from the saturation diving control room *(dedicated intercom)*	Mandatory	Mandatory	The primary link must be hard wired, immediately available, and unable to be interrupted. Verbal communications are accepted if the ROV pilot is in the same room as the diving supervisor (It is unusual with class 3 ROVs)
8	Hard wired communications to and from the surface orientated diving control room .	Mandatory	Mandatory with most clients and contractors	Surface orientated divers may be involved to rescue the bell. Hard wired communications have the advantage to be dedicated and not interrupted.
9	Hard wired communications to and from the survey control room (Intercom)	Nothing indicated	Mandatory with most clients and contractors	See above
10	Hard wired communications *(Intercom)* to and from Offshore Construction Manager (OCM) office	Nothing indicated (It can be the phone)	Mandatory with most clients and contractors	See above
11	Hard wired communications *(Intercom)* to and from the conference room	Optional (It can be the phone)	Optional (It can be the phone)	Onboard new vessels, this office is generally connected to the ROV control by hard wired communications
12	Hard wired communications *(Intercom)* to and from the inspection office	Optional (It can be the phone)	Optional (It can be the phone)	See above

No	Description	Requirements IMCA	Requirements from clients and other organizations	Additional information
13	Radio communications to boats cruising within the vicinity of the vessel	Nothing indicated	Optional	This system is optional, but required by a lot of clients and contractors.
14	Radio communications to key people or used as 2nd means of communication	Nothing indicated	Mandatory	The radio can be used as a 2nd means of communication with areas that have primary hard-wired communications
15	Phone (wired) communications to the areas indicated before and other parts of the vessel	Nothing indicated	Mandatory with most clients	Onboard new vessels, office and cabins are generally connected to the ROV control by phone communications
16	Video signal from the launching and recovery areas and appropriate working areas	Nothing indicated	Mandatory	ROV controls are usually in the dark when operating the machine, so the pilot needs a camera to see what happens on deck.
17	Video signal from the saturation dive control	Mandatory	Mandatory	The picture shows the display from the helmet cameras of diver #1 & #2.
18	Video signal from the surface orientated dive control	Not indicated	Mandatory with most clients	Surface orientated divers may be involved to rescue the bell. For this reason, the ROV pilot must have a visual of what is carried on
19	Data from survey control to combo screen.	Not clearly indicated	Mandatory with most clients	A data screen indicating the position of the vessel, the divers, the ROV and its TMS is common today and usually mandatory.
20	Video signals to the saturation diving control room	Mandatory	Mandatory	A video screen that displays the ROV camera to the saturation diving control room is mandatory.
21	Video signals to the surface orientated diving control room	Mandatory	Mandatory	A video screen that displays the ROV camera to the surface orientated diving control room is mandatory.
22	Video signals to the bridge & DP console (if relevant)	Mandatory	Mandatory	A video screen that displays the ROV camera to the bridge and the DP console is mandatory.
23	Video signals to OIM control room (Operation from a facility only)	Mandatory	Mandatory with most clients	A video screen that displays the ROV camera to the OIM control room should be mandatory when the operations are organized from a facility.
24	Video signals to the Offshore Construction Manager	Not indicated	Mandatory with most contractors	A video screen that displays the ROV camera to the OCM is mandatory with most contractors.
25	Video signals to client office	Not indicated	Mandatory with most clients	A video screen that displays the ROV camera to the client office is mandatory with most clients.
26	DP alarms	Mandatory	Mandatory	The ROV pilot must be able to mute the alarm to maintain clear communications.
27	Vessel emergency alarms	Not indicated	Mandatory	Fire alarm, abandon ship, personnel falling to the sea, gas release, etc. This alarm can also be muted.

10.3.11 - Maintenance

10.3.11.1 - Planned maintenance system

ROVs are complex machines, and each model has some design weaknesses that may affect its reliability during the operations. To avoid having the ROV in breakdown and all operations halted, the ROV team must perform the maintenance operations indicated by the manufacturer, and inspect the system regularly. Also, the operations of maintenance should be logged in the planned maintenance system that should be used to identify additional weaknesses not seen by the manufacturer and implement corrective measures.

The Planned Maintenance System (PMS) allows ROV operators to carry out the maintenance of their systems at scheduled intervals according to the requirements of manufacturers, classification societies, IMCA, and other diving or safety organizations. Also, note that this equipment management system is mandatory by most of the organizations indicated above, the clients, and also in International Maritime Organization (IMO) that says in the International Safety Management Code (ISM):

The Company should establish procedures to ensure that the ship is maintained in conformity with the provisions of the relevant rules and regulations and with any additional requirements which may be established by the Company. In meeting these requirements the company should ensure that:
I. inspections are held at appropriate intervals,
II. any non-conformity is reported with its possible cause, if known,
III. appropriate corrective action is taken, and
IV. records of these activities are maintained.

Because ROV systems used offshore are onboard vessels, we can say that the implementation of the planned maintenance system of ROVs is mandatory for all companies working at sea.

The implementation of this system with ROVs is similar to the one used with the diving systems that is explained point 3.4 of the document "Description of a saturation system".

10.3.11.2 - Workshop

A workshop which is provided with the necessary set of tools to perform the maintenance of the ROV system is mandatory.
This workshop should provide a dry zone where the technicians can intervene on electrical components. Its illuminations should be between 1500 and 2000 lux, and the electrical installation (usually 220 volts) should be provided with a personnel ground fault protection. Also, fire protection must be provided in the form of extinguishers, water deluge system, smoke and flame detectors.
In the case that the ROV is planned to work in areas where harmful and flammable gas releases are likely and within the 500 m limit of all offshore installations of some countries, this workshop must be provided with a protection against harmful and explosive gasses *(see point 10.3.3.2)*.
Depending on whether the ROV is built-in or a transportable system, the workshop is in a room near the hangar in which the ROV is stored, or in a specific container installed at the proximity of the ROV. In the case that the workshop is in a container, the interventions on the machine are performed in the open air.
Note that interventions on the ROV may oblige to move the vessel outside the 500 m limit of facilities likely to emit hazardous gasses.

10.3.11.3 - Consumable and spare parts store

Consumables such as oil, tape, degreaser, and others should be provided in sufficient quantity to complete the project and face unplanned breakdowns.
Their storage should conform with the rules regarding the Control of Substances Hazardous to Health (COSHH), and similar fire protection as above should be provided.

Also, a store where the most sensitive spare parts are provided is mandatory. As an example, IMCA R 006 says that major or critical spares such as those listed below must be available in sufficient quantities:

- Tether
- Slip ring unit for winch
- Slip ring unit for TMS or garage
- Thrusters complete lateral
- Thrusters complete vertical
- Thruster motors complete
- ROV electric motor
- ROV main hydraulic pump
- ROV auxiliary hydraulic pump
- TMS drive motor
- Compensator complete
- Complete set of serviceable PC boards
- Main system computer
- Set of connectors and cables at or above standard quantity
- Rotary actuator or pan-and-tilt unit
- Spare hydraulic hoses, or the facility to make up assemblies as required
- LARS HPU motor and pump
- LARS gearbox
- Spare cameras
- Spare lights for ROV and TMS
- Optic fibre and electrical termination kits

An inventory system that allows locating the spares should be available. Most teams use specific software for this purpose and regularly edit lists that are printed.

Additional spare parts to those listed by IMCA may be provided according to the detected weaknesses of the machine.
It is the responsibility of the ROV supervisor to ensure that the sensitive spare parts are on board in sufficient quantities, and the responsibility of the manager of the ROV department of the company to list them according to the failures detected through the planned maintenance system and according to the recommendations of the manufacturer.

10.3.12 - ROV audit

10.3.12.1 - Purpose

The planned maintenance system allows making sure that the ROV is correctly maintained. However, this system is not sufficient to ensure that the ROV is in perfect condition and fits the best standards. For this reason, it is common to thoroughly audit the system to detect parts of the system that do not conform to the best practices and need to be improved.
Also, the audit is a document the contractor can use to prove to the client that the equipment proposed for the project is in perfect condition. It is the reason most clients require this document.
Note that this audit can be performed internally by the ROV team or by a third party auditor, which is the solution usually selected by the clients. IMCA says that the audit should be performed in the following circumstances:

- Before mobilization or load-out from the onshore facility;
- Following mobilization but before offshore operations;
- During operations, for example, onboard a host installation or vessel.

In most cases, the client requires that this audit is performed before or during the mobilization and every year for systems used on long term projects or integrated into the ship. Thus, because the rule for a diving system is to perform an audit every year and at each mobilization, we can say that the one for an ROV should be the same, particularly for the machines that are involved in diving support.

10.3.12.2 - IMCA audit R 006

IMCA (International Marine Contractors Association) has developed the "Standard ROV Audit Document R 006 " to provide the members of the association a procedure of auditing that is easy to implement. This document, which is also employed by companies and organizations that are not affiliated with IMCA, can be downloaded at this address: https://www.imca-int.com/publications/164/standard-rov-audit-document/.
This guideline explains the following topics:

- ROV System Audits: Background and Rationale
  This point explains when and by whom the audit is to be performed *(it is the point explained above)*.
- ROV System Audit Process
  This point details procedures for:
  - Planning the Audit - IMCA says that the audit should be planned in advance and the document prepared in such a way that anticipates the scope required by the audit and its originator.
  - Assessing - IMCA explains that the audit must not be subjective, but answer to questions which answers should be "yes", "no", or "not applicable".
  - Recording and Reporting - IMCA says that the report should be unambiguous and recommends to classify the findings into the following categories:
    - "Category A" is an unacceptable non-conformity that requires immediate corrective action.
    - "Category B" is a non-conformity that can be addressed within an agreed and practical timescale.
    - "Category C" is an observation in which corrective action is at the discretion of the owner of the ROV.
  - Closeout - The guideline says that what is important is that the findings of the audit are actioned and a formal closeout agreed.
- Competence
  This point explains the profile of the auditor that should conform to IMCA's definition of competence, which is: *"The combination of appropriate training, current skills, knowledge, and experience so that a person consistently applies them to perform tasks safely and effectively. Other factors such as attitude and physical ability can also affect someone's competence"*.
  Note that the guideline recommends that the auditor is at least ROV supervisor, or has a level of competence that is appropriate to undertake such an audit. This point refers to the guidance IMCA C 005.
- Sample Template
  A template, which is designed to most ROV systems, is provided in the appendix of the document. IMCA R 006 says that a lot of service providers and contractors have their own ROV auditing process and that this template is provided as an example for members who have not such a process in place and need to implement it. This audit template that is organized under the form of questions to which the auditor answer as explained above covers the following:
  - Audit overview and executive summary;
  - General ROV system information;
  - Control room or container;
  - Workshop including system spares;
  - Deployment system (LARS, winch, HPU, etc.);

- ROV;
- TMS;
- Support analyses, documentation and procedures;
- Optional functional wet test;
- Detailed audit findings.

- References
  This point indicates the following documents that are downloadable at this address: https://www.imca-int.com/divisions/rov/publications/
  - IMCA R 004 – Guidance for the safe and efficient operation of remotely operated vehicles
  - IMCA R 005 – Guidance on safety procedures for working on ROV high voltage equipment (above 1kV)
  - IMCA R 008 – Terms and conditions for ROV support services
  - IMCA R 009 – ROV mobilisation
  - IMCA LR 011/IMCA R 011 – The initial and periodic examination, testing and certification of ROV launch and recovery systems
  - IMCA R 013 – Contract for the provision of ROV, support vessel and associated work
  - IMCA R 015 – Code of practice for the safe use of electricity under water
  - IMCA R 021 – Remotely operated vehicle load testing and inspection
  - IMCA C 005 – Guidance on competence assurance and assessment: Remote Systems & ROV Division

10.4 - Preparation of the ROV for diving support

10.4.1 - Organization of the team

10.4.1.1 - Minimum team and qualification

The duties of the ROV team is explained in point 3.2.

IMCA and NORSOK consider that a minimum crewing level of three per shift is necessary for a class 3 ROV and can be reduced to two people for ROVs class 2 and 1.
Also, it is recommended that the members of the team have complementary skills and sufficient hydraulic and electrical knowledge to be able to maintain the machine.
The ROV supervisor should ensure that there are sufficient personnel for the launching and the recovery of the ROV. Besides, it may be necessary to have specialised personnel for operating additional sensors and equipment if other tasks than divers assistance are planned.

Organizations require that the members of an ROV team have minimum experience and training to be accepted to an upper level of their position. As an example, the table below summarizes IMCA and NORSOK requirements:

Requirements IMCA	
Position	***Experience***
Pilot grade 2	Entry level
Pilot technician grade 2	Entry level
Tooling technician grade 2	Entry level
Pilot technician grade 1	- 180 days offshore as pilot grade 2 - 100 hours piloting of which 40 hours can be on simulators.
Tooling technician grade 1	- 180 days offshore as grade 2
Senior pilot technician	- 360 days offshore, and 100 piloting hours as grade 1
Senior tooling technician	- 360 days offshore as grade 1
ROV supervisor	- 180 days offshore as ROV Senior Pilot/Technician + assessment competencies
Tooling supervisor	- 180 days offshore as ROV tooling technician + assessment competencies
ROV superintendent	- 180 days offshore as ROV Supervisor + assessment competencies

Requirements NORSOK	
Position	**Experience**
Pilot	Entry-level - 9 days training course in a specialized school with 5 hours simulator + two weeks offshore with an ROV system
Pilot technician	ROV pilot level + 200 hrs experience with relevant ROV operations + 5 days training course in a specialized school
ROV supervisor	3 years Experience as ROV Pilot/Technician
ROV superintendent	2 years as ROV supervisor

Regarding this point ADCI says that the qualifications of ROV personnel are determined by training, experience and actual evaluations of the individual by the employer.

The petroleum companies usually ask that ROV teams operating on their oilfields have an experience that is above the minimum required by organizations above. The table below is an example of what they commonly request.

Position	Experience
Pilot technician	Proof of competency + three years experience
ROV supervisor	Proof of competency + five years experience with ROV offshore operations with a minimum of three years experience from a DP vessel as ROV Pilot.
ROV superintendent	Ten years experience with ROV offshore operations with a minimum of five years experience from a DP vessel as ROV Supervisor.

10.4.1.2 - Shift and piloting periods

IMCA and NORSOK say that the working time of ROV personnel is limited to 12 hours followed by a rest period of the same duration. We can say that this rule is recommended by all safety organizations.
IMCA also says that the maximum number of hours that a member of the ROV team pilots an ROV should not exceed six hours in every 24 hours under normal circumstances. The assistance of the pilot, the launching and recovery of the machine, and various maintenance works, are parts of the other tasks pilot technicians perform during their shift.
A meal break of one hour in the restaurant of the ship should be organized at approximately the mid-shift period as well as refreshment breaks that can be taken at the work station. Also, facilities such as toilets should be at the proximity of the ROV station.
It may happen that for operational reasons or unfavourable weather conditions the working periods indicated above cannot be applied. Regarding this point, IMCA says:
Members of the ROV team should not be asked to work or be on standby for more than 12 hours without having at least eight hours of unbroken rest during the previous 24 hours. However, in some circumstances an ROV team may have been on standby for a number of hours before an operation begins and, in such circumstances, this can be taken into account in extending the hours worked. In such cases, extreme care should be taken and allowance should be made for the effects of fatigue.
Based on the above rules, the ROV manager must ensure that sufficient qualified and experienced personnel are available at all times to be able to face any problem that may happen.
Also, extended work periods should be performed exceptionally, and not become a habit. So such a situation should be limited to two days maximum followed by a long period of normal working conditions (> 2 weeks), except in conditions where lives that are threatened depend on the intervention of the ROV.

10.4.2 - Elements to take into account when preparing the risk assessment

10.4.2.1 - Electricity

Note that the effects of electrical shocks in the water and at the surface are explained in Book #4 “diving accidents” of this manual.

ROVs are powered by electricity flowing through its umbilical, connection boxes, and equipment, which a leakage may harm the diver at different degrees, depending on whether he is in the sea or freshwater.
“Conductivity” is the measure of the ability of fluids and solids to pass an electrical current. Note that the ability to carry current is better at warm than at cold temperatures.
The distilled water does not contain dissolved salts and it does not conduct electricity. Thus, the conductivity of water is

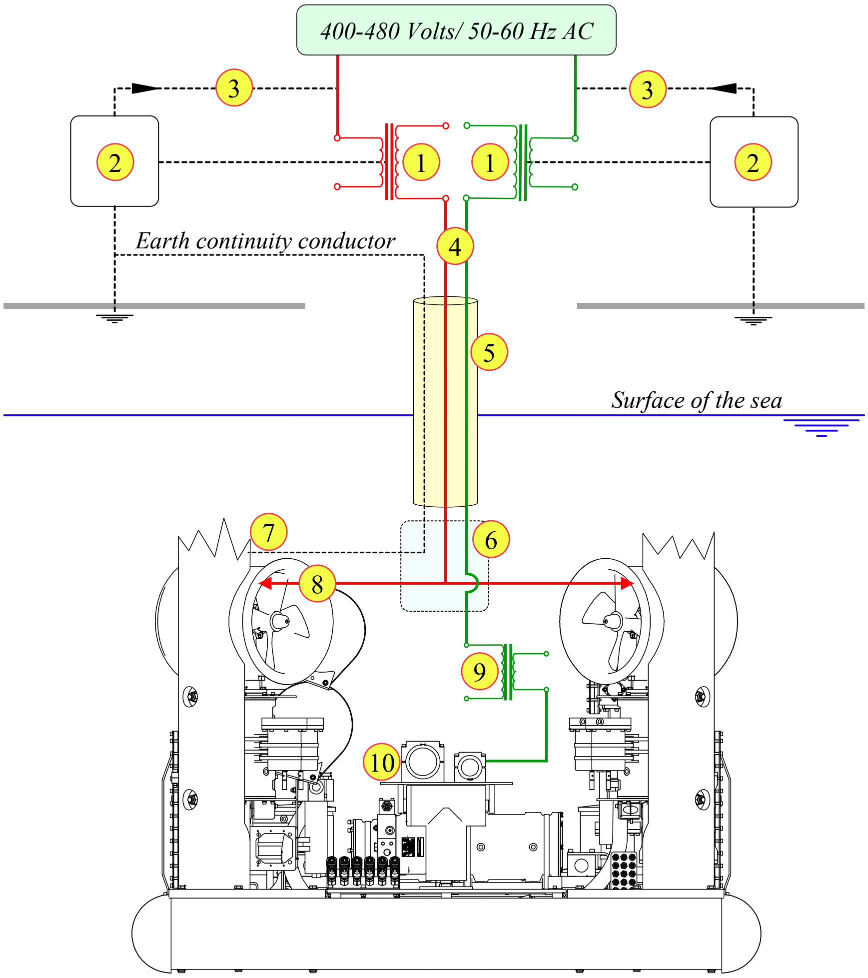
dependent on the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminium cations (ions that carry a positive charge). Because the sea has about 3.5% of dissolved salt in addition to other particles, it has a low electrical resistance. In contrast, fresh water, depending on the particles in suspension, has a relatively high electrical resistance, so, a low conductivity.
Referring to what is indicated, a leak of electricity in salt water will be transmitted to the ground, and a leak of electricity in freshwater will not easily pass to the ground. As a result, a diver in saltwater should feel the electrical field before being affected. Three progressive states are commonly described:

1. The diver starts to feel the electrical field, and this sensation becomes more potent as he goes closer to the source to become uncomfortable progressively.
2. A more harmful problem can be a diver caught in an electrical field sufficiently powerful to cause some of the muscles to contract involuntarily. This phenomenon that is commonly called "let go level", is known to result in the inability of the person to open the hands and move. That is not considered very hazardous if the current is switched off immediately. However, that may become harmful if the breathing muscles are contracted during a too long period. In saltwater, such effect may happen if the fault develops when the diver is in its direct vicinity, or if he continues to approach despite the warnings of state #1.
3. The most severe effect is an electrical emission that causes fibrillation of the heart (fibrillation is a rapid, irregular, and inefficient beating of the heart), which results in the blood not circulating anymore. As above that may happen if the diver is at the direct vicinity of the fault when the problem starts, or if he continues to approach despite the warnings of state #1.

Opposite to saltwater, the diver in freshwater may not feel the electrical field and may become the link to the ground if he enters it as the human body is composed of salted fluids through which the electric current can find its path to the ground. As a result, he may be in scenarios #2 and #3 without any notice.

There are some technical considerations to take into account regarding ROVs, such as the fact that the primary power is derived from the vessel's 400-480 V/ 50-60 Hz AC that is stepped up through an isolating transformer to provide up to 3000 volts to the machine via the umbilical. This current supplies the motors of the thrusters or the motor of the hydraulic pump that activates them, depending on whether the thrusters are electric or hydraulic. Depending on the model of ROV, other separate electrical supplies may be provided to supply the lights and other functions. These supplies are monitored by Line Insulation Monitors (LIM), connected to an alarm, and other protection devices *(see the explanations below).*

1 - Step-up isolating transformer
2 - Line Isolation Monitor (LIM)
3 - Circuit breaker
4 - Current up to 3000 volts
5 - Umbilical to ROV
6 - Distribution box
7 - Earth connection
8 - Supply to thrusters' motors or pump
9 - Step down transformer
10 - Lights 120 volts (or low voltage)



Regarding the line protection device indicated above and similar systems, note the following:

- A Line Isolation Monitor (LIM) is a device that continuously monitors the integrity of the insulation between live conductors and an earth return circuit to provide a status of the insulation. It triggers an alarm and cuts out

the supply if the insulation value falls below a set level.
IMCA R 0015 / D 0045 says that the response time of some devices may be too slow to protect the divers. Also, because of the length of cable, there may be the possibility of a high charge being stored in the umbilical and the circuits monitored, which can therefore be potentially harmful to a diver.

- A Residual Current Device (RCD), also called Residual Current Circuit Breaker (RCCB), or Ground Fault Circuit Interrupter (GFCI), is a device that compares the current between the supply and returns lines of a circuit to detect earth-leakage. If a difference is detected, the equipment quickly breaks the electric source to prevent electric shock.
- A trip unit is the part of a basic circuit breaker, RCD, or LIM that opens the circuit in the event of a thermal overload, short circuit, or ground fault. These devices have different response times that depend on their function. Based on CEI/IEC/TS 60479 studies, it has been considered that systems designed for short circuits or ground fault with an operating time of 20 ms or less provide an acceptable response.

IMCA R 015/D 045 is a document that has been published to provide guidelines regarding the safe use of electricity underwater. These guidelines, that are based on the publication CEI/IEC/TS 60479 from the International Electrotechnical Commission, mostly discuss dives at sea. Nevertheless, the document indicates the problems that may arise from fresh water.
This guidance provides an analysis of several devices used in the offshore industry, among which ROVs, that is based on the Ohm law: *Safe voltage = Safe body current (mA) x Body Resistance (Ω - ohms).*
Note that the result of this calculation is expressed in millivolts that must be converted to volts. Also, based on the results of experiences explained in CEI/IEC/TS 60479, the following values are selected:

- The body resistance is 500 ohms for voltages over 50 ohms and 750 ohms for low voltages (< 50 ohms)
- 500 mA is considered a safe value of current

Based on these calculations, IMCA provides tables, which the one dedicated to ROVs gives the following results that can be used to visualize harms linked to electricity with such a machine:

Description	***Safe body current in milliamperes (mA)***	***Body resistance in ohms (Ω)***	***Safe maximum voltage in volts (V)***	***Safe nominal voltage in volts (V)***
Alternating current with trip device.	*500*	*500*	*250*	*220 (See in notes*)*
Alternating current fed from an isolating transformer with a non-earthed secondary. Using a LIM with circuit breaker.	*Not applicable*	*Not applicable*	*In this case, a single fault does not present a hazard and thus no maximum voltage needs to be stipulated provided the protective devices are able to prevent the occurrence of a second fault constituting a hazard.*	
Alternating current fed from an isolating transformer with the secondary earthed through an impedance to limit fault current to 1A and trip device.	*Not applicable*	*Not applicable*	*No voltage limit is stated as the diver is protected by the fault current limit and the associated trip device.*	

Notes *:

- The nominal voltage is the specified system voltage of the supply circuit to which a device may be connected.
- IMCA says that the values of safe distance in water depend on the ratio of fault current (I_o) to the safe body current (I_b), and that the approximate safe distance in sea water (Ss) in metres is calculated according to the following formula: $S_s = (I + \{(I_o \times 10^{-4})/ I_b\})^{½} - I$.

It must be noted that even though the guideline above provides a useful means of analysis, the method proposed has its limits and should be employed as a means of reflection instead of a precise means of calculation for safe distances:

- Calculations with the formula given above can be corrupted if some values are inexact.
- It is difficult to evaluate in advance the amount of current leaking in the eventuality of a fault occurs, and it is not prudent to base such a calculation on a minimum leakage. Also, note that using a machine that is known not to be utterly isolated is not an acceptable practice.
- People working in deltas and their vicinity may operate in waters in which salinity varies at all times. Regarding this point, it must be remembered that deltas of large tropical rivers have an influence on the environment at distances that are up to 200 km from their mouth. That often results in layers of salt and fresh water crossing.
- The evaluation of the safe distance is a complex process that should be performed by trained and experienced people only. However, even though the calculations produced may give results close to reality, the uncertainties described above cannot be removed entirely.

Using the elements above, elements such as those listed below should be taken into consideration:

- The electrical power supplied to the ROV and how this supply is monitored and controlled should be documented. An isolating transformer with the secondary earthed through an impedance to limit fault current to 1A and a trip device must be in place and be able to respond within 20 milliseconds or less.
- Electrical shock protection devices should be tested before each ROV dive, and warnings stickers provided.

- Calculations of the possible electrical leakages and the safe distances from the machine should be provided by the ROV manufacturer or a recognized specialist and presented in a format that is easy to understand and be implemented by people at work. It must be considered that to be utilizable, a guideline must be easy to apply, especially when complex computations may be the sources of fatal mistakes, and the environmental conditions may frequently change and oblige to review the initial estimate. An example of complex calculations that are made exploitable to everyone is the decompression tables.
- The diver should not have any physical contact with the ROV when the machine is activated. For this reason, procedures such as direct tools transfer to the divers should not be used. Instead, when some tools are to be transferred to the divers, the ROV picks them up and deposits them in a dedicated place where the divers can access when the machine is away.
- In case of a breakdown of the ROV, and a diver is asked to intervene, the electricity must be fully isolated, and the machine checked for residual current before the diver can approach it.
- There is no reason to approach the ROV very close to the divers during diving assistance. The typical closest distance of the ROV from the divers, which is empirically applied by the teams, is approximately 5 m, even though calculations may allow it to be closer. Note that regarding this point IMCA indicates 4 m. This distance is to be increased if an estimate proves that it is too nearby. Note that 5 m is also considered a safe limit to avoid collisions by a lot of ROV teams.
- The ROV should approach the divers very slowly, so an undetected fault can be felt by the divers sufficiently on time in saltwater in addition to avoiding a collision.
- An ROV that is known to have electrical leakage should never be at the proximity of divers: Any electrical fault detected should result that the machine is withdrawn from the worksite, and is sent back only when the problem is repaired. Note that such events must be reported.
- As previously said in point 10.3.7, ROVs operating at the proximity of divers should be equipped with transponder and a flashing light, so the diving supervisor can see where it is on the nav screen, and the divers can also visualise it.

10.4.2.2 - Entanglement & collision

Entanglement may happen with the umbilical of the bell, the divers' umbilicals, the downline, positioning systems such as taut wire, and other lines that may be deployed.

- Entanglement with the bell umbilical may result that the bell, and the ROV cannot be recovered.
- Entanglement with a diver's umbilical may result that the diver can be injured, be unable to return to the bell, and may be drawn at the direct proximity of the ROV that is still active.
- Entanglement with the taut wire of the Dynamic Positioning vessel may result in a loss of position, and the ROV that cannot be recovered.
- Entanglement with downlines and other lines may result that the ROV cannot be recovered.

Entangled umbilicals can be freed by the ROV team when possible, except with divers umbilicals that should be disentangled by the divers. Regarding this last point, IMCA R 020 says that switching power off to the ROV is to be avoided, as without power the ROV could be swept into the diver and cause injury. This guideline says that the ROV monitoring and instrumentation system should give any indication of potential electrical failure and priority to keeping control of the ROV.
For the other scenarios, if the situation is too complicated, the divers may have to intervene to recover the machine.
Note that, as previously said, for divers intervention on the ROV or its tether, the ROV must be stopped and its electrical supply deactivated. The solving of the problem by the divers may result in the ROV umbilical being cut, and the machine recovered to the surface using the crane. In such a case, the ROV team must ensure that there is no residual current, and the ROV must be loaded to ensure that it will not return to the surface unexpectedly.

Collision with divers may result from a loss of control of the machine or the ROV traveling while there is no visibility. Note that collision with lines, debris and structures may also happen.

- A collision with a diver may result in the diver being seriously injured and unable to return to the bell.
- A collision with debris, stricture, or a line may result in the ROV being damaged, or entangled or stuck. Such damages may prevent the ROV from being recovered by itself.

A diver injured and unable to return to the bell has to be rescued. During this time, the ROV must be stopped and de-energized.
An ROV damaged that cannot be recovered may have to be recovered by the divers. In this case, the rules regarding electricity and the recovery by crane have to be in place.

The prevention of entanglement and collision is based on a safe distance between the diver and the ROV:

- The ROV pilot should be aware of all lines and structures in the water, and of the position of the bell and the divers as well as the position of the TMS. A document that explains the worksite configuration should be provided, and the nav screen should be updated.
- There should be a tracking device on the ROV, the TMS, the bell, and the divers to identify their position on the nav screen.
- IMCA says that the launch and recovery of the ROV must be considered a lifting operation, and that appropriate procedures should be implemented. For this reason, the ROV should be sent first and recovered after the dive.

- The ROV deployment system should be situated at the maximum possible distance from the diving bell and taut wire launch positions to minimize the probabilities of entanglement of its umbilical.
- IMCA also suggests that, if possible, the TMS/garage is located within the limits of excursion of the divers such that a diver would not be carried beyond his excursion limit should he become entangled with the ROV tether.
- The positioning of the ROV related to the divers and the bell should be taken into account in case of a total break down of the machine. For this reason, it is preferable to position the ROV downstream and away from obstructions.
- Note that the ROV should be static when the divers go outside the bell and the divers aware of its position. However, it is recommended to keep the divers in view.
- There must be a strobe light on the ROV to indicate visually its position to the diver. A good practice is also to turn on the lights. The ROV pilot must also see the divers. For this reason, he may have to dim his light and require the divers having their helmet lights on. It is also a common practice to flash the divers' lights.
- The thrusters should be fitted with guards to prevent the ingress of a diver's fingers, umbilical or equipment.
- The ROV should not, for any reason, be flying in a no-visibility situation with a diver in the area.
- The intervention of the ROV is authorized by the diving supervisor only, who needs to be informed of the intention of the pilot. Also, the ROV moves must be indicated to the divers.
- Five metres from the divers is considered a safe limit to avoid collisions by a lot of ROV teams, as already said, IMCA authorises 4 metres. Five metres is also the distance below which the supervisor loses any panoramic view of the divers. Note that when the ROV is at this limit, zoom cameras can be used to see more details. Also, as indicated above, the ROV should approach the divers very slowly, and the divers must be aware of it.
- Uninterrupted communications must be established with the dive control, the bridge, and the survey team.
- The ROV tracking device should not be used as a reference of the positioning system of the vessel.
- Members of the diving and ROV teams should be aware of the hazards and operational constraints of simultaneous operations.

10.4.2.3 - Environmental conditions

Variations of the environmental conditions may affect the ROV operations or prevent them from starting:

- Variation of the salinity of the water may affect the buoyancy of the machine. That commonly happens in estuaries where layers of saltwater and freshwater superpose.
- In addition to the change of buoyancy, the variations in salinity is known to affect the acoustic tracking and positioning systems. It is also the case of differences in temperature and parasite noises.
- Reduced visibility may affect the operations and may oblige to keep the machine in the TMS. Also, activities near the seabed may stir up fine sediments that remain in suspension and reduce or erase visibility. However, some ROVs can be equipped with Imaging SONAR enabling a photographic type view of the sea bed; Such a system can allow the ROV to move in an environment where the visibility is reduced and perform some simple tasks.
- Saturation diving support is usually performed at depths that are unaffected by the weather conditions at the surface. Thus the main problem is the deployment of the ROV over the side of the vessel. Note that DP vessels can be positioned to protect the launching stations when they are not alongside facilities that may reduce their capacity to change their heading. Such possibility is not available with barges and four-point mooring ships which movements are limited by their mooring.
  In the case of shallow saturation dives, the weather may affect the water layers nearby the surface, and the ROV may not be able to fly correctly.

The fundamental rule to apply is that when the ROV is the only means for the rescue of the bell, the dive must not be launched if the ROV cannot be used adequately to rescue the bell safely.

10.4.3 - Documents that should be onboard

Clients require that documents such as those listed below are on board. Note that, depending on the client, more items may be asked.

- Proof of competencies of ROV team members.
- Quality Assurance (QA) and Health, Safety, and Environmental (HSE) manuals.
- Technical manuals for the ROV system, including the additional sensors and tools used.
- ROV project plan with the task plans for all activities of the relevant contract and their risk assessments.
- Emergency response plan for the project planned.
- Build certificates for the ROV system main components.
- Valid Lifting certificates (rigging and machine).
- ROV audit IMCA R 006 or similar *(see point 10.3.11.2)*.
- Calibration certificates for all sensors.
- Operational activities logs.
- Planned maintenance system *(see point 10.3.10)*.

Note that the emergency response plans, working procedures, and task plans should be published sufficiently in advance to let the team study and discuss them and that in case changes are necessary, the management of change procedure can be followed.

10.5 - ROV operations for surface supplied diving support

10.5.1 - Chain of command

The elements regarding the authorities, which some are indicated previously should be clearly established and understood by people involved, so an efficient chain of command is in place:

- The diving supervisor has authority over the ROV supervisor (and the pilot) when simultaneous operations are being carried out.
- Related to above, the ROV should be deployed only when authorized by the diving supervisor and the bridge (or the OIM control room) while diving operations are in progress.
  ROV movements must be allowed by the diving supervisor and passed to the bridge.
  The ROV can leave the worksite only when it is authorized to do so by the diving supervisor.

10.5.2 - Elements to consider in the checklist

Safe practices impose to check any equipment intended to go in the water, and particularly those used for diving support. These checks must be performed before each dive.
The ROV and its Launch And Recovery System (LARS) must be strictly inspected before turning on the power supply to detect potential or existing problems. This inspection focuses on structural issues such as cracks or unsecured elements, in addition to a close check of the junction boxes, slip rings, cameras, connectors, lights, etc. Then the vehicle is powered, and the commands are controlled as well as alarms, data displays, lights, and cameras. In addition to usual checks, the ROV team preparing a dive support operation should focus on the following vital elements:

- The devices that must be in place to protect the personnel against electrical shocks should be tested. Regarding this point, IMCA says that the Line Insulation Monitor (LIM) systems should be physically tested and recorded as part of the pre and post dive checks and repeated on a 24 hourly basis during long dives when supporting diving operations.
- Also, the tools that may have to be used and are described in point 10.3.8 should be checked and function tested. Note that other tools than those described in this point, which are the minimum to be provided, can be used. It is the case of inspection tools, specific manipulators, etc.
- Localization tools such as beacons should also be tested, and their batteries should be full. The surveyors are responsible for the calibration and the batteries of these devices.
- Regarding the buoyancy of the ROV, IMCA recommends that it is ballasted negatively buoyant to eliminate the risk of divers being moved out of their excursion range by the ROV returning to the surface in case of a total break down with their umbilicals entangled. This buoyancy should be adjusted such that the ROV trimming does not require excessive thrust to maintain position or manoeuvre in the water column.
- The thruster guards should be closely inspected as well as the cables and hoses that may come into contact with the divers that must be secured.
- The thrusters should also be function tested and checked for oil leaks, the presence of fishing lines, shocks, etc.
- The operational procedures should be understood by the ROV team.
- The diving supervisor must ensure that the ROV team understands the emergency procedures for recovering the diving bell/basket.
- The procedures for the recovery of the ROV should be understood by the diving staff.
- As previously indicated, the communications with the dive control and the bridge, and also those to the survey team, must be carefully checked with the Dynamic Positioning alarm system (if used)

10.5.3 - Organization of diving support operations other than diving bell rescue

ROVs are employed to various supporting tasks during a diving project that are not limited to only diving bell rescue, and it is the responsibility of the Offshore Construction Manager and the diving superintendent to organise such operations that must be indicated in the diving project plan.

10.5.3.1 - Operations with two ROVs

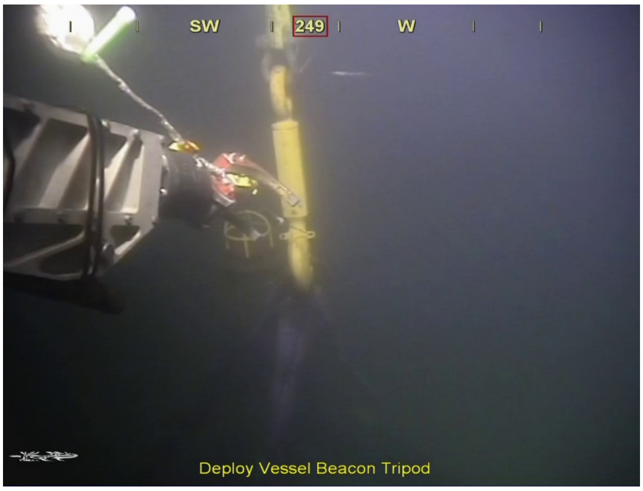
Depending on the project plan, a second machine may be planned for the project.
If the 2nd ROV is a class 2, it is preferable to use it to monitor the dives as these machines are less dangerous in case of a collision with a diver than a class 3 ROV as the result of the difference of mass and power.

If it is planned to employ a machine to simultaneous tasks, they must be organized not to conflict with the diving job scheduled, and the chain of command indicated in point 10.5.1 is to be applied:

- The diving supervisor has authority over all ROV supervisors and pilots.
- The ROVs must be deployed in the water before the bell and recovered to the surface after the bell. This procedure, which is already indicated in point 10.4.2.2, is to avoid an ROV deployment above the divers and the bell.
- The launching station of the ROV used to monitor the divers should be the closest to the bell and the diving worksite. Also, the launching station of the ROV planned to perform the simultaneous task should be sufficiently far from the other stations to avoid conflicts such as umbilicals entanglements.
- The worksite of the ROV should not be upstream of the worksite of the divers. Also, this ROV must be ballasted negatively buoyant as the ROV used for the surveillance of the divers for the same reasons.
- Direct communications must be installed between the 2nd ROV station and the dive control and the bridge. Also, displays from the 2nd ROV should be provided in the dive control and the bridge.

10.5.3.2 - Acoustic transponder installation

When the project is planned to use acoustic positioning, the ROV is usually employed to install the transponder and remove them at the end of the operation. The installation of the transponders is normally performed using the crane, as surface positioning systems have to be used for a precise localization. Thus the operation performed by the ROV is to disconnect it from the frame that holds the beacon. However, if the ROV is sufficiently powerful, it can be used to recover the transponders at the end of the project or if the device must be changed. For this reason, it is an advantage of having a powerful ROV instead of one that is too limited in power for these tasks.
Note that it often happens that vessels are provided with only an observation class ROV that is only used to perform inspections and monitor the divers. In this case, transponders can be installed by another vessel equipped with work class ROVs. This organization of the job may pose problems of scheduling that may impact the project, as the Diving Support Vessel is dependent on the availability of another ship. It is also common to lower the transponder to the seabed using a davit or a crane. In this case, the vessel's movements will be restricted by the cable securing it.



Beacon installation: Disconnection from the crane

Beacon recovery using the 5 functions manipulator

10.5.3.3 - As-found and as-built surveys

These inspections were previously commonly done by the divers, and it can be the case today. However, a lot of teams prefer using the ROV, because it avoids exposing lives when there is a risk of hydrocarbons or other dangers.
Also, a lot of clients require as-found and as-left inspections performed by ROVs instead of divers for the safety reasons indicated above and because some elements they may use, such as the depth, altitude, heading, the geographical position, and others are displayed on the screen.

As found survey: General view of the structure

As found survey: Detailed view of the structure

10.5.3.4 - Bell/basket checks

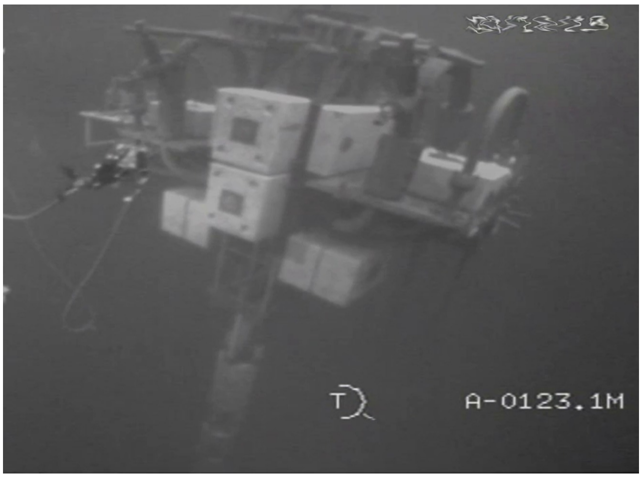
The inspection of the bell/basket at its arrival at depth and before its recovery is a standard procedure.

1. The ROV is launched to the worksite first and waits for instructions in the TMS or near the worksite.
2. When the clump weight of the bell is deployed *("clump weight" is explained in point 2.3.2.2 "Anti gyration systems" of the document "Description of a saturation system")*, the diving supervisor asks the ROV pilot to check its position and whether it is sufficiently far from obstructions.
3. At the end of the inspection, the ROV returns to the TMS or stay in a safe place (it should be downstream), waiting for instructions.
4. When the bell is launched, the diving supervisor asks the pilot to position the machine near the clump weight to monitor the arrival of the bell/basket at depth. The ROV gives a visual of the final descent of the bell/basket and the distance of the bell to its clump weight (which is also confirmed by the divers).
5. When a wet bell is used, the ROV quickly inspects the dome and the main umbilical before returning to the safe place from which divers in and outside the bell/basket can be observed. This inspection should not interfere with the launching of the divers that usually happens upon the arrival at the working depth due to the limited bottom times allowed for surface-supplied diving operations techniques.
6. At the end of the dive, the supervisor asks the pilot to position the machine near the bell/basket to ensure that it can be safely recovered (this inspection is also made by the divers). The same process is to be used to retrieve the clump weight at the end of the diving operations.
7. When the clump weight is retrieved, the ROV can return to its TMS and being recovered to the surface when authorized to do so.

10.5.3.5 - Divers observation

The observation of the divers is performed between tasks 5 and 6 discussed above.
The advantage of using the ROV to observe the divers is that it gives a panoramic overview of the scene, and thus a better appreciation of the situation to the diving supervisor. That allows seeing dangerous conditions that may not have been detected by the divers, so making sure that they work in a safe condition at all times.
Also, the diving supervisor can ask the ROV to approach within the maximum safe limit when he needs to have a more detailed view of the operation ongoing *(see below)*.

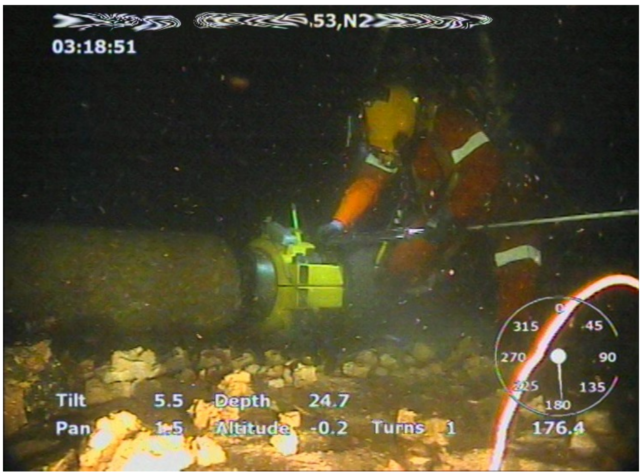
Close view of divers during a load transfer



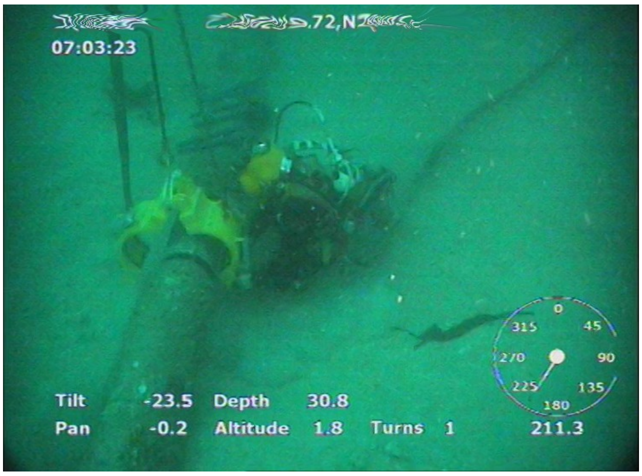
Panoramic view of the worksite

Note that the ROV can be used to light up a diver. Also, when working near the seabed for long periods, it is preferable to sit the ROV on it instead of flying around the divers *(see the photos below)*.

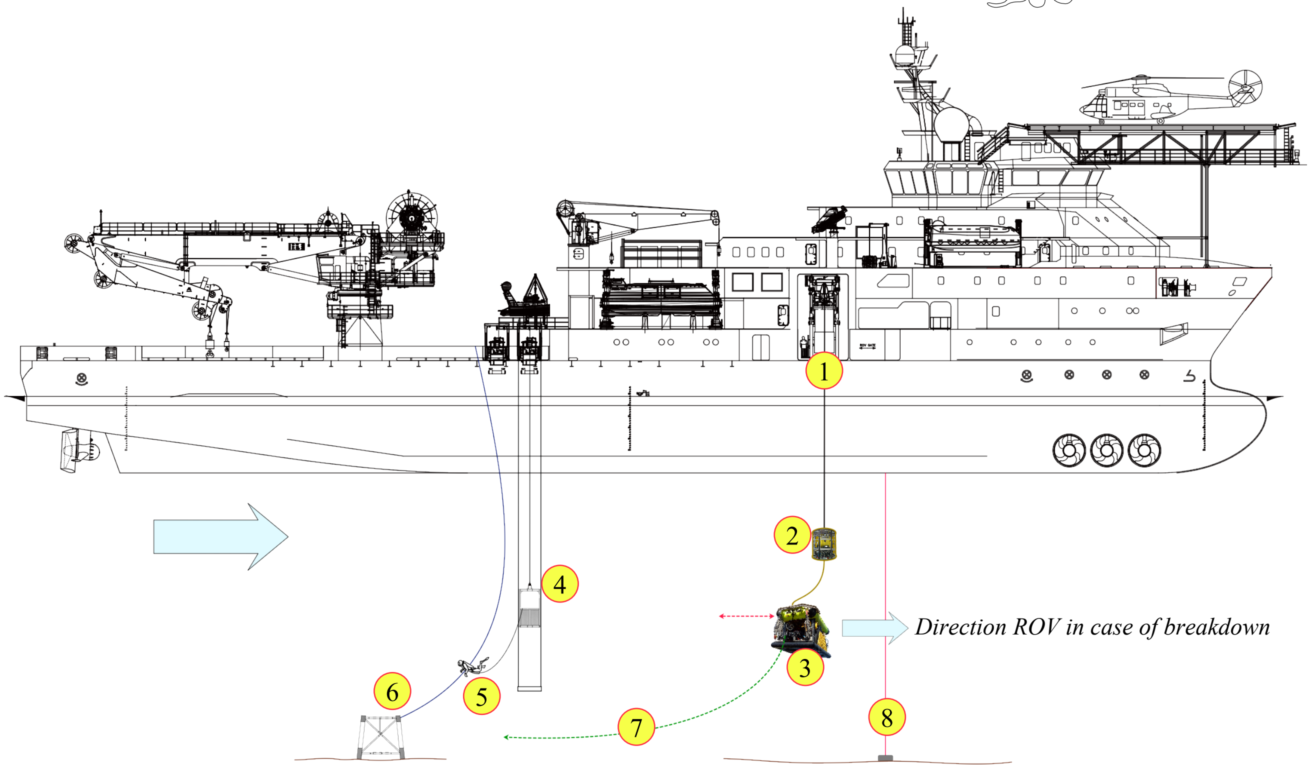
Important: The precautions listed in point 10.4.2 must be in place and always taken into account during these operations.



ROV sat on the seabed lighting up a diver (see Altitude = 0)



Panoramic view of a load transfer



1 - Launching station ROV	*Situated starboard side in this example. It should be the closest station to the job site*		*5 - Diver*	*Equipped with a beacon, a helmet camera + a helmet light. Closest distance to ROV = 5 metres.*
2 - TMS	*Equipped with a beacon and a warning light.*		*6 - Worksite & downline*	*They must be indicated on the nav screen.*
3 - ROV	*Equipped with a beacon and a warning light, + adjusted negatively buoyant. Closest distance to divers = 5 metres Positioned downstream of the job site.*		*7 - Travelling ROV to the worksite*	*Travelling on the starboard side of the bell and the tending point, and sufficiently far to not be entangled with the divers and any deployed device.*
4 - Diving bell or basket	*Equipped with a beacon and a warning light. Deployment through a moon pool at the center of the ship*		*8 - Taut wire positioning system vessel*	*Deployed from Portside in this example (the other side) for not being in the way of the ROV and being entangled. It must be indicated on the nav screen.*

10.5.3.6 - Precautions to be in place when working with a new ROV team or pilot

It is usual that the ROV contractor employed on the diving project is a sub-contractor of the diving company or that a trained pilot used to work with the diving team is replaced by another one.
As already discussed in point 10.4.1.1, clients usually request minimum experience and training. However, what is written on logbooks is one thing, and the reality can be something else.
For this reason, when new people are employed, it is prudent to limit the approach of the ROV to the divers to 10 metres during the first dives to ensure that the machine is entirely under control. After evaluation, the new pilot can be authorized to approach at 5 metres when asked for by the diving supervisor.

11 - Documentation and certifications

The superintendent and the supervisors must be able to solve any problem linked to diving or working procedures and to comply with good practices, rules, laws, and also wishes from the client. For this reason, there must be valid soft and hard copies of relevant company manuals and procedures immediately available or displayed on walls of the dive control and strategic points.

11.1 - Manuals

11.1.1 - Company organization & working procedures manual

There are many things to take into account to prepare the working procedures of the divers, and the team must have relevant information to develop aspects of the project other than diving procedures, but directly impacts them. For this reason, there should be:

- A document that describes the quality management system of the company.
- A manual that describes the health and safety system of the company.
- A document that describes the tools used by the divers and the procedures to minimize the hazards arising from these tools.
- A manual that describes the best practices of rigging and lifting.
- A document that describes the surface support and the elements to take into account to make sure of the hygiene onboard during the diving operations.
- A document that describes the elements to be in place for an efficient and safe mobilization and demobilization.
- A document that explains the forms used to manage the company and the procedures for reporting.

11.1.2 - Diving manuals

Of course, the surface supplied diving manual of the company must be available. Note that this manual should provide standard and emergency procedures.

Also, the company may use saturation diving procedures where surface-supplied divers are to be used in case of bell rescue. For this reason, the relevant surface-orientated diving procedures to rescue the closed bell should be available with a description of the saturation bell.

11.1.3 - ROV *(remotely operated vehicle)* procedures manual

ROVs are commonly used in conjunction with divers. For this reason, the ROV manual with procedures to work in the vicinity of divers should be onboard. The bell rescue procedures must be included in the ROV manual.

11.2 - Audit diving system

It is essential to ensure that the diving system is in perfect condition. For this reason, the system must be regularly examined and maintained.

Note that this topic is explained in point 4.5.2 “Organize an audit based on IMCA Diving Equipment Systems Inspection Guidance Notes (DESIGN)”. As a reminder, note the following:

IMCA says that the saturation diving system should be audited by a qualified auditor.

For permanent installations that are part of the boat, this audit must be performed every year. For mobile systems installed onboard rented surface supports, the inspection must be done at the mobilization and every year. Note that a lot of clients require that such inspections are carried out by an independent organization.

Please, remember that the IMCA DESIGN documents to be used for surface supplied diving operations depend on the diving operations performed and so the system to be used:

- D 023 surface orientated air and Nitrox diving
- *D 037* surface supplied mixed gas diving systems
- D 040 mobile/portable surface supplied systems *(scuba replacements)*

In addition, the following documents should be available for the audit:

- The classification certificate (or certified copy) of the diving system issued by a classification society member of IACS (international association of classification societies). The classification of surface supplied diving systems is optional with most organizations. However, it is mandatory with a lot of clients, particularly the members of the International Association of Oil & Gas Producers (IOGP).
- The periodic maintenance system and records (indicating what is maintained, by whom, when, and the date of the next inspection/function test).
- The emergency procedures of the diving system with the FMEA. Note that it is said that a risk assessment can be used as FMEA with air diving systems. However, FMEA are in fact risk assessments.

- As already discussed, heave compensators are not commonly used with wet bells and baskets. Nevertheless, the operational and maintenance procedures should be part of the documentation if it is the case.
- A plan showing where the gas and the electrical supplies are situated must be displayed on strategic walls
- A notice of use must be displayed on compressors, generators LARS, winches…
- A board with the records of the contents and pressure of each cylinder or quad. These records must be updated daily when the system is in use.

11.3 - Power supplies and machines not covered by the IMCA documents

The IMCA documents D 023, D 037, & D 040 focus on the diving system they describe only. Machines like industrial compressors, generators, electrical panels, welding machines, hydraulic power packs, and others which may be used by the team are not covered by this audit. For this reason, for each external machine used by the team there must be:

- A certificate of conformity. Note that this certificate must indicate that the machine is approved for offshore work in the oil & gas industry. Meaning that the machines using thermal engines must be diesel, have a spark arrestor, and accessible emergency shut down devices. Also, the electrical equipment must be equipped with a suitable trip devices such as earth leakage protectors sufficiently fast and sensitive to protect from electrical shocks.
- Certificates of conformities and audits of the elements used with these machines such as industrial air hoses, hydraulic hoses, electrical cabling, and other associated elements.
- Records of maintenance and audits

Warning:
Clients are often rigorous regarding the conformity of the machines working on their fields, and they often use their company auditors to check the real condition of the devices before entering the 500 m. These technicians do not hesitate to reject any machine that does not conform to their requirements.

11.4 - Small tools & lifting devices

The small tools and lifting devices used in water and on deck must have a certificate of conformity from the manufacturer plus records of maintenance and audits. The categories concerned are (but not limited to):

- Impact wrenches, drillers
- Tensioners
- Welding and burning guns
- Grinders, hydraulic saws
- Jaw winches (Tirfors), lever hoist, chain blocks
- Lifting slings (soft or wires), shackles, carabineers
- Electrical tools used on deck (grinder, drillers, cutters, portable lights, electrical extension wires…)
- Underwater inspection tools (CP meter, UT meter, ACFM, etc.)

11.5 - Safety

- The safety policy of the company must be displayed on strategic walls.
- HSE manuals covering the points not covered by the diving and working manuals must be available
- The emergency response plan must be available. The charts and lists and means of contact of the diving medical specialists must be included on this document and displayed on the walls.
- The radio channels and the cabins /office phone numbers must be displayed near the phone and/or intercoms.
- If the vessel operates on DP then a diagram of all thrusters and other obstructions must be displayed in the dive control. There must also be a diagram of the maximum permitted lengths of divers umbilical for each depth for the specific dive station position(s) onboard. These diagrams must be near the supervisor.
- The maximum ranges allowed by the bail out must be displayed. The diagram must also be close to the supervisor. In addition, the colour code of the umbilical must be displayed near the supervisor.
- A drawing showing the underwater hazards and down lines must be displayed.
- Some clients require that a copy of the company's insurance certificate is displayed.
- There must be a system to display the dive permit and the work permit on the wall.
- Virgin accident reporting forms must be available.
- Virgin work permit (hot and cold) and dive permit forms.

11.6 - Vessel

The conformity of the vessel is the responsibility of the master and the vessel owner.

The vessel must have been audited according to IMCA M 149 by a recognised marine specialist. The following certificates are indicated to be on board and updated:

- International Tonnage Certificate (1969)
- International Load Line Certificate
- International Load Line Certificate Exemption
- Cargo Ship Safety Construction Certificate
- Intact stability booklet
- Cargo Ship Safety Equipment Certificate
- Cargo Ship Safety Radio Certificate
- Cargo Ship Safety Radio Exemption Certificate
- Damage control booklets
- Minimum Safe Manning Document
- Cargo securing manual
- International Oil Pollution Prevention Certificate
- Offshore support vessel Certificate of Fitness (for hazardous and noxious liquids); or International Pollution Prevention Certificate for the Carriage of Noxious Liquid Substances in Bulk (INLS Certificate)
- Document of Compliance with the special requirements for ships carrying Dangerous Goods
- Dangerous Goods Manifest or Stowage plan
- Garbage management plan and garbage record book
- Diving Systems Safety Certificate (this document is the resolution A.536 from the International Maritime Organisation.)
- Dynamically Supported Craft Construction and Equipment Certificate
- Oil Record Book
- Shipboard Oil Pollution Emergency Plan
- Shipboard Marine Pollution Emergency Plan
- International Air Pollution Prevention Certificate
- Safety Management Certificate
- Document of Compliance (copy)
- Noise Survey Report
- Continuous Synopsis Record
- International Ship Security Certificate (copy)
- Ship Security Plan (not for examination – content secure to vessel)
- Cabotage – if applicable
- Anti-fouling/TBT Free – if applicable
- MARPOL IV/V/VI – if applicable
- Ship Sanitation Certificate – Derat
- Ballast Water Management Plan
- P&I *(Protection and indemnity insurance, commonly known as P&I insurance, is a form of marine insurance provided by a P&I club, that provides cover for its members.)*
- H&M Insurance certificate *(Marine insurance covers the loss or damage of ships, cargo, terminals, and any transport or cargo by which property is transferred, acquired, or held between the points of origin and final destination.)*
- Employer liability insurance
- Locally applicable additional certificates

In addition:

- If the vessel is a DP vessel, it must conform to the guidance IMCA M 103 “the design and Operation of dynamically positioned vessels”, and the vessel crew must be trained according to the guidance IMCA M 117 “the training and experience of key DP personnel” and the circular International Maritime Organisation (IMO) 738/rev 1 “guidelines for dynamic positioning system (DP) operator training”.
- The certificate of class of the boat is usually required.
- Some clients request the vessel to be recorded in the Offshore Vessel Inspection Database (OVID) from the Oil Companies International Forum (OCIMF)
- Documents regulations/standards of the country of operation

11.7 - Check list & Logs

- Pre-dive diving system check lists.
- Dive logs updated.
- Virgin diving log sheets.
- Operational log book (reporting).
- Virgin reporting forms.
- Virgin accident reporting forms.
- Virgin forms from the client if required.

11.8 - Project working procedures

- Task plans:

The task plans are normally built in 7 parts:
1) Presentation
2) Description of the task
3) Risk assessment
4) Preparation of the task
5) Dive plan
6) Management of changes
7) Post dive / next task

- Virgin Risk assessment and management of change forms

11.9 - Diving team personnel certificates

It is the duty of the person representing the company to make sure that all the certificates are valid originals before the beginning of the diving operations. (Passports and ID cards are everyone's documents and not indicated). Depending on whether the contractor is affiliated to IMCA, ADCI, or not affiliated to a professional association, the certificates accepted may change. As an example IMCA accepts several national diving certificates ADCI does not and vice versa.

Important note:
The client representative usually requests the certificates at mobilization and any crew change. These documents must be restituted to the proprietors immediately after the examination.

11.9.1 - Teams following IMCA & IOGP guidelines

- Offshore manager & project engineer:
  - Letter of appointment
  - Basic Offshore survival approved OPITO with HUET modules
  - Basic H2S training
  - Offshore medical certificate
  - Proof of qualification / log book
- Diving superintendent:
  - Letter of appointment
  - Log book
  - Diving supervisor certificate agreed by IMCA:
    - IMCA Air Diving Supervisor
    - ADAS offshore air diving supervisor issued after the 01/07/07 (Australia and NZ)
    - DCBC air diving supervisor issued after the 10/04/07 (Canada)
  - Basic Offshore survival approved OPITO with HUET modules
  - Basic H2S training
  - Offshore medical certificate / or better, diving medical certificate
- Air diving supervisors (rescue team):
  - Letter of appointment
  - Log book
  - Air supervisor certificate agreed by IMCA:
    - IMCA Air Diving Supervisor
    - ADAS offshore air diving supervisor issued after the 01/07/07 (Australia and NZ)
    - DCBC air diving supervisor issued after the 10/04/07 (Canada)

- Basic Offshore survival approved OPITO with HUET modules
- Basic H2S training
- Offshore medical certificate / or better, diving medical certificate

- Trainee air diving supervisors: *(Note that trainee supervisors may also work as divers)*
  - Letter of appointment
  - Log book
  - Trainee air or bell diving supervisor course certificate agreed by IMCA:
    - IMCA bell or air diving supervisor certification scheme
    - ADAS (Australia and NZ) offshore air or bell diving supervisor certification scheme.
    - DCBC (Canada) air or bell diving supervisor certification scheme.

  Important: *The trainee supervisors are allowed to act only under the supervision of an appointed diving supervisor.*
  - Basic Offshore survival approved OPITO with HUET modules
  - Basic H2S training
  - Offshore medical certificate / or better, diving medical certificate

- Air divers: (employed in the rescue team)
  - Log book
  - Air diving certificate agreed by IMCA :
    - Australian Diver Accreditation Scheme Part 3
    - Brazilian Curso de Especialização em Mergulho para Praças
    - Brazilian Curso Especial de Escafandria para Officiais
    - Brazilian Curso Básico de Mergulho Raso Profissional (Brazilian certificates to be supported by a Brazilian Navy stamped divers logbook)
    - Canadian Category 1 Diver
    - Canadian Surface Supplied Mixed Gas Diver to 70 m
    - Canadian Unrestricted Surface Supplied Diver to 50 m
    - French Class 2 Mention A
    - India - Commercial Surface Supply Course, Kochi (post September 2002)
    - Netherlands Part 1 - Surface Dependent Diver (issued up to 2002)
    - Netherlands Certificaat Duikarbeid Categorie B
    - New Zealand Construction Diver Part 3
    - Norwegian NPD surface diver
    - South African Class II
    - TSA or MSC Basic Air Diving
    - UK HSE Surface Supplied Diving Top-Up
    - UK HSE Part I
    - UK Transitional Part I (issued 01/07-31/12/1981)
    - ADCI Surface-Supplied Air Diver - International endorsement (since 01/08/18)
    - ADCI Surface-Supplied Mixed Gas Diver (HeO2) - International endorsement (since 01/08/18)
  - Basic Offshore survival approved OPITO with HUET modules + Basic H2S training
  - First aid training certificate

- Diver medics:
  In addition to the diver’s certificates, the diver medics must hold:
  - A valid IMCA diver medic certificate
  - A letter of appointment

- Inspection divers (NDT):
  In addition to the diver’s certificates , the inspection divers must hold:
  - Cswip certificates 3.1 or 3.2 are commonly required. However, the required certificates depends on the client and the rules in force in the country where the project is planned to take place. As a result, technicians from other systems like ASTM International (American Society for Testing and Materials) or the members of the European Federation for Non-Destructive Testing (EFNDT) can be imposed..
  - Log book inspection diver.

- Lead divers:
  - A letter of appointment is requested with most of the clients.

- Senior dive technician:
  - Letter of appointment
  - Diving technician logbook

- Valid training/competence certificate, or documentary proof of qualification(s) or military service qualification (ref IMCA C 03) . Notice that most of the clients request a technician holding a valid training/competence certificate.
- Hat technician certificate is requested by most of the OGP members
- Basic Offshore survival approved OPITO with HUET modules
- Basic H2S training
- Offshore medical certificate

- Dive technician:
  - Diving technician logbook
  - Valid training/competence certificate (NHC; KB ass or other recognised establishment) or Documentary proof of qualification(s) or Military service qualification (ref IMCA C 03) . Notice that most of the clients request a technician holding a valid training/competence certificate.
  - Hat technician certificate is requested by most of the OGP members
  - Basic Offshore survival approved OPITO with HUET modules
  - Basic H2S training
  - Offshore medical certificate
- Tender:
  - Basic Offshore survival approved OPITO with HUET modules
  - Basic H2S training
  - A tender is considered as an apprentice diver and must hold a diving medical certificate (refer to “divers”)
  - Offshore medical certificate
  - A Proof of competency / log book or ADCI Entry Level Diver/Tender - “International endorsement” (since 08/2018)
- ROV superintendent:
  - Basic Offshore survival approved OPITO with HUET modules
  - Basic H2S training
  - Offshore medical certificate
  - ROV Supervisor or ROV Tooling Supervisor competence
  - Log book (180 days’ offshore experience as ROV Supervisor)
- ROV supervisor:
  - Basic Offshore survival approved OPITO with HUET modules
  - Basic H2S training
  - Offshore medical certificate
  - ROV Supervisor competence
  - Log book
- ROV tooling supervisor:
  - Basic Offshore survival approved OPITO with HUET modules
  - Basic H2S training
  - Offshore medical certificate
  - ROV tooling Supervisor competence
  - Log book
- ROV senior pilot/technician:
  - Basic Offshore survival approved OPITO with HUET modules
  - Basic H2S training
  - Offshore medical certificate
  - ROV senior pilot/technician competence
  - Log book
- ROV senior tooling technician:
  - Basic Offshore survival approved OPITO with HUET modules
  - Basic H2S training
  - Offshore medical certificate
  - ROV senior tooling technician competence
  - Log book
- ROV pilot/technician grade 1:
  - Basic Offshore survival approved OPITO with HUET modules

- Basic H2S training
- Offshore medical certificate
- ROV pilot/technician grade 1 competence
- Log book

- ROV tooling technician grade 1:
  - Basic Offshore survival approved OPITO with HUET modules
  - Basic H2S training
  - Offshore medical certificate
  - ROV tooling technician grade 1 competence
  - Log book
- ROV pilot/technician grade 2:
  - Basic Offshore survival approved OPITO with HUET modules
  - Basic H2S training
  - Offshore medical certificate
  - ROV pilot/technician grade 2 competence
  - Log book
- ROV tooling technician grade 2:
  - Basic Offshore survival approved OPITO with HUET modules
  - Basic H2S training
  - Offshore medical certificate
  - ROV tooling technician grade 2 competence
  - Log book

11.9.2 - New IMCA supervisor certification scheme *(source: IMCA D 07/19)*

IMCA information note D 07/19 says: *"Nowadays, industries operating in high risk environments (including the offshore marine sector) require their safety critical personnel to undertake some form of Continuing Professional Development (CPD) in order to prevent skill-fade and keep staff up-to-date with current recognised good practice. The time has now come for IMCA to provide its certified diving supervisors with a user-friendly but effective CPD scheme intended to renew and revalidate their knowledge and skills".*

11.9.2.1 - Description

- Delivery:
  The IMCA diving supervisor Continuing Professional Development (CPD) scheme is delivered on an annual rolling programme through the use of a dedicated application. The app will be accessible either through IOS or Android mobile phone platforms or through standard laptop or desktop PCs. Participants will be able to work through the app at home, on the move or while offshore.
- Content:
  Each year of CPD material is made up of 4 Units that are issued quarterly, and each unit will consists of 6 Modules:
  - 1 Core Module aimed at both air diving and bell diving supervisors. The module contains details of new IMCA Safety Flashes and recent relevant IMCA Diving Information Notes;
  - 4 Modules focused on refreshing and updating supervisors' knowledge of the IMCA Diving Division's current information and guidelines;
  - 1 Saturation Module; differentiated from the other Modules to apply to Bell Diving supervisors only.
- Assessment Requirements:
  Questions will be included in each Unit to test the understanding of participants, and users are unable to progress to the next module until they have successfully completed the previous one by answering all the assessment questions correctly.
- Certificate of Currency
  Candidates are required to complete all four units within the year, upon which they receive a certificate of currency containing a QR code that can be used for verification purposes. This certificate demonstrates they have completed the annual CPD programme and it remains valid for the following calendar year.
  The scheme currently is only open to qualified IMCA diving supervisors and to qualified diving supervisors from the Australian Diver Accreditation Scheme (ADAS) and the Diver Certification Board of Canada (DCBC).
  Persons joining the scheme part way through the year will be required to complete ALL the Units for that year to receive the certificate of currency valid for the following calendar year.

11.9.2.2 - Benefits of the IMCA Diving Supervisor Continuing Professional Development (CPD) Programme (according to IMCA…)

IMCA says that Diving Supervisors are able to demonstrate that they participate in a credible and effective Continuing Professional Development (CPD) programme that refreshes their knowledge and skills and keeps them up-to-date with industry events and current guidelines.
The IMCA Diving Supervisor CPD programme is delivered in a straightforward user-friendly but effective format.
In addition, IMCA will be able to identify all its currently active diving supervisors and be able to contact them, should the need arise, on issues of importance.
The programme should help reinforce the standing of IMCA Diving Supervisor qualifications throughout the industry.

11.9.3 - Teams following ADCI guidelines

Clients will have the same requirements as with IMCA members with ADCI members regarding:

- Letters of appointment
- Log books
- Basic Offshore survival approved OPITO with HUET modules
- Basic H2S training
- Offshore medical certificate or diving medical certificate for the divers

Regarding diving certificates, ADCI does not publish the schemes they recognize, but they do recognize the same certifications schemes that IMCA recognizes. As a result, IMCA recognized certificates are accepted for surface orientated diving but not for saturation. For this reason, a saturation project made with an ADCI contractor, should employ diving teams with the following certificates:

- Saturation diving team
    - Bell saturation supervisor ADCI
    - Life Support Technician ADCI
    - Assistant Life Support Technician
    - Saturation technician ADCI
    - Bell/sat diver ADCI
- Surface diving rescue team
  Note that the selection of the team depends on the depth of intervention.
    - Air supervisor ADCI
    - Nitrox supervisor
    - Mixed gas supervisor ADCI
    - Air diver ADCI
    - Air diver agreed IMCA
    - Mixed gas diver ADCI
    - Tender ADCI
- The ROV Team should be in the procession of recognized proof of competence.

11.10 - Important point - Diving and offshore fitness medical certificates

11.10.1 - Topside personnel

Offshore topside personnel must be in possession of a valid "certificate of medical fitness for work offshore", which should be carried out in accordance with requirements identical than those issued by Oil & Gas U.K (OGUK). These requirements can be found at the address http://www.oilandgasuk.co.uk.
The validity of a topside medical certificate is two years regardless of age with most of the clients. However, some clients request this certificate to be renewed every year and limit the operations offshore to a maximum age. These clients may also request some medical tests not asked by others.

11.10.2 - Diving personnel

To allow a diver to dive, IMCA and clients request valid certificates of "medical fitness to dive" issued by suitable doctors. These certificates are valid for one year. The guideline IMCA D 061 *"Health, Fitness and Medical Issues in Diving Operations"* addresses certain problematic diver health, fitness and medical issues. In complement to this guidance, the information note IMCA D 20/01 gives information of how the practitioner should be selected, the organizations providing courses in diving medicine, and how the medical examination should be performed. The diving superintendent must ensure that all the certificates of medical fitness to dive are valid and conform with IMCA D 20/01.

ADCI (Association of Diving Contractors International) also provide guidelines for "Diving personnel medical and training requirements" page 23 of the document "International consensus standards for commercial diving and underwater operations" that can be downloaded for free on the website of this association

Depending on the country where the diver is based, finding a recognized diving medical specialist is not always easy. The following documents or Internet links can be used to solve this problem.

- List published by IMCA:
  Several initiatives have been made by IMCA diving contractors of several regions to mutually recognize some doctors able to perform suitable medical examination of divers. These lists have been published as information notes by IMCA as follows:
  - IMCA D 07/09 Asia-Pacific initiative has been withdrawn from IMCA website. However the list updated in 2017 is available through the link above. This list indicates doctors in the following countries.
    - Australia and New Zealand
    - Indonesia
    - Malaysia
    - Philippines
    - Singapore
    - Thailand
  - IMCA D 11/09 Italy initiative, gives the list of doctors in Italy.
  - IMCA D 05/12 Middle East and India initiative, gives the list of doctors in the following countries:
    - Azerbaijan
    - Egypt
    - Georgia
    - India
    - Oman
    - Qatar
    - Saudi Arabia
    - United Arab Emirates
- Doctors agreed by HSE UK:
  The list can be found at this address: https://www.hse.gov.uk/diving/amedsapproval.htm
- Doctors in Canada :
  The list is available at this address: http://www.divercertification.com/English/PhysiciansList.html
- Doctors in USA:
  UHMS (undersea & hyperbaric medical society): Note that the 2012 "NOAA/UHMS Physicians' Training in Diving Medicine" course has been formally approved for 5 years by the Diving Medical Advisory Committee (DMAC) and the European Diving Technology Committee (EDTC) as a DMAC/EDTC med Level IId course. A list of doctors is available at: http://membership.uhms.org/
- Doctors in Australia:
  The south Pacific Underwater Medicine Society (SPUMS) provides a list of diving doctors and contacts forms.
- Doctors in France:
  Navy - Hopital d'instruction des armees Sainte Anne 83800 Toulon - . Tel 04 83 16 20 14 / Mail: chefferie@sainteanne.org. & Centre hospitalier universitaire la Cavale Blanche Brest
- Doctors in Norway:
  Helse Bergen Haukeland universitetssjukehus (Department of diving medicine) in Bergen.
- Doctors in Sweden:
  Navy and Department of Hyperbaric Medicine, Sahlgrenska University Hospital Gothenburg. Mail: ylva.karlsson@ltblekinge.se.
- Doctors in Denmark:
  Medical examinations for divers:
  https://www.dma.dk/SikkerhedTilSoes/Erhvervsdykning/Laegeundersoegelse/Sider/default.aspx.
- Netherlands:
  Royal Netherlands Navy's Diving Medical Centre (DMC)
- South Africa:
  Diving medicine: http://www.airseamed.co.za/Diving-Medicine
  Southern African Undersea and Hyperbaric Medical Association (SAUHMA). http://www.sauhma.org/
- Doctors in other countries:
  - Most Navies use divers that are usually followed by competent doctors. For this reason Navy hospitals can be be consulted.
  - OXYNET is a website of information resources on hyperbaric oxygen therapy and diving medicine for medical professionals, scientist and healthcare providers. This website published a list of hyperbaric medical facilities managed by competent diving medical specialists at this address: http://www.oxynet.org/03HBOCenters/centres.php
  - The Asia Hyperbaric and Diving Medical Association (AHDMA) groups more than 120 diving medical specialists from Asia Pacific. This association can be contacted through its website: https://ahdma.org
  - http://www.midlandsdivingchamber.co.uk/index.php?id=contact&page=11&region=9 This website groups chambers in Argentina, Brazil, Chile, Equator, Peru.

11.10.3 - Important points

In case of suspicious certificate of "medical fitness", the person should not be authorized to work and a new medical examination should be organised with a recognized practitioner.

Some clients have their own medical system, and do not consider the medical certificates provided by the contractors as valid. They may require a medical examination of fitness to work to be performed through their systems. Nevertheless, it must be remembered that the certificates of medical fitness issued by these clients authorize the personnel to work on the premises and offshore facilities of these clients only. These certificates will not be considered valid to work with other clients. For example, Total does not recognise the diving medical certificates issued by other petroleum companies, but the certificates issued by competent practitioners indicated in the lists above.